Acknowledgments

Having worked on all four editions of Amgen’s Core Curriculum for the Dialysis Technician since 1992, I know what a tremendous team effort goes into writing, editing, illustrating, referencing, and reviewing each module, and my gratitude toward all of the stellar individuals who contributed their time and dedication to this vital project is boundless. Our mutual goal, as always, is to help dialysis centers across the nation train patient care technicians to do the best possible job of caring for people on dialysis. This much-awaited fourth edition incorporates 2006 KDOQI Guidelines, USRDS figures, AA MI Standards, the national Fistula First breakthrough initiative, Life Options research, and much more.

The American Nephrology Nurses Association (ANNA) and the National Association of Nephrology Technicians/Technologists (NANT) contributed their tremendous expertise and focus on professionalism, and the Core Curriculum is better for it. Both organizations have a long tradition of initiatives to improve dialysis technician training, and their efforts are very much appreciated.

We were extremely fortunate to have an outstanding group of expert authors who worked together tirelessly via conference call and email to divide and conquer the material; update the module content, posttests, and illustrations; verify each other’s suggestions; and reference each key point.

Our Advisory/Review Board contributed decades of clinical knowledge and practical experience, validating and expanding on the work of our authors, and adding an additional layer of verification so that the Core Curriculum will, in fact, be the resource we all intend it to be.

In addition, several members of the Medical Education Institute’s team made contributions so numerous and important that I’d like to acknowledge them here:

- Susan Hossli, MSN, RN, who coordinated the entire author revision and review process, wrote and edited modules, tracked down references, contributed illustration ideas, and helped us pull everything together.
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Core Curriculum for the Dialysis Technician
The mission of the non-profit Medical Education Institute is to help people with chronic disease learn to manage and improve their health. Thus, the Core Curriculum for the Dialysis Technician is a project that has always been close to my heart, because of its potential to help improve patients’ day-to-day lives by enhancing the preparation and professionalism of patient care staff. Technicians who treat patients with respect, courtesy, and dignity and who encourage patients’ efforts to learn and self-manage their kidney disease have the opportunity to influence countless lives for the better.

Dori Schatell, MS
Executive Director, Medical Education Institute, Inc.
September, 2008

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Foreword
Each year, the number of ESRD patients rises by 5% to 7%. And, patients are getting older and have more health problems, which complicates their care. The dialysis care team must cope with fixed payment levels, more regulations, and a nursing shortage. Yet, they have the vital job of delivering optimal care. Technicians, the largest number of caregivers in dialysis, need skill, professionalism, and knowledge to meet the ever-changing challenges of dialysis. Your role as a technician is central to the delivery of safe, high-quality care.

Better technology has made dialysis safer and more efficient. But, technology alone can never replace the commitment and dedication of committed patient care staff. Other members of the care team—nurses, doctors, social workers, dietitians—complete a formal course of study to learn their jobs. Their years of learning and respect for their chosen field leads to professionalism. Plus, the history of their profession garners respect from their peers and the patients they serve. However, there are very few formal dialysis technician training programs in the United States. As of this writing, most states do not require technicians to become certified. Each dialysis provider takes on the task of training technicians, and how that training is done varies from clinic to clinic. You can obtain voluntary certification and enhance your own knowledge and professionalism. I’ve been a witness to more than 30 years of challenges and changes in dialysis. I became a dialysis technician straight out of the military, and at the time, had no concept of what the job would entail. My training back then was entirely done on the job. The pace, patient load, and focus was quite different then than it is now. Typical treatment times were 5 to 6 hours. The shift turnover time wasn’t such a stress. Nursing shortages were not an issue, and staff-to-patient ratios were not yet a concern. We didn’t focus on kinetic modeling and had no concept of sodium profiling. Our goal was to have the patient feeling well. My educator had my undivided attention to her teaching, and she, in turn, was able to dedicate her time to me.

Today, a typical treatment time is 3 hours. A Kt/V goal must be met. A 4:1 patient/staff ratio is not unusual. Training can be with a preceptor. Learning how to do dialysis becomes the focus, and the rationale for why things are done may become secondary. I’ve always approached dialysis as a life sustaining treatment, a life threatening procedure. In the fast pace of today’s dialysis clinics, the severity and incidence of errors can be exaggerated. You, as a dialysis technician, are in the forefront of ensuring each patient’s safe and efficient treatment. How well you understand the treatment and the consequences of improperly applied procedures is critical to keeping your patients safe and healthy. As technicians, we hold our patients’ lives in our hands by virtue of our
skill and knowledge
of dialysis.
Core Curriculum for the Dialysis Technician
IV
The Core Curriculum for the Dialysis Technician is a tool that has been widely used and accepted for educating new patient care technicians about the history, principles, theory, application, and practices of dialysis care. The Core Curriculum can improve the consistency of training content between clinics and across the nation. With the Core Curriculum in hand, you can learn to care for your patients safely and efficiently.

Danilo B. Concepcion, CCHT, CHT
President, National Association of Nephrology Technicians/Technologists (NANT)
February, 2006

Providing quality dialysis in today’s healthcare environment presents many challenges. Skilled technicians, with the help and supervision of the nephrology nurses who work alongside them, play a critical role. As Danilo Concepcion points out, the need for comprehensive dialysis technician training is as great—or greater—than it was when the first edition of the Core Curriculum for the Dialysis Technician was published in 1992.

The newly-revised 4th edition of the Core Curriculum will help to fill that need. Like previous editions, it will serve as a single, comprehensive source of information on every aspect of dialysis, including scientific principles, devices, reprocessing, water treatment, and more. Producing this edition was a collaborative effort. Many dialysis nurses and other professionals spent hours of their own time updating the contents, illustrations, and references to reflect current dialysis practices. Speaking for the ANNA members involved in the process, I can assure you that we take pride in our contributions. Our work on the Core Curriculum is a reflection of our long-standing commitment to improve the training and educational opportunities available to dialysis technicians.

Nephrology nurses and skilled dialysis technicians share a common goal: providing safe, effective dialysis care that enables our patients to live long and live well. We must come to our task as well-prepared as possible, using all the resources available to enhance our skills and knowledge. The newly-revised Core Curriculum will be a welcome addition.

Suzann VanBuskirk, BSN, RN, CNN
President, American Nephrology Nurses’ Association (ANNA)
September, 2008

V X
Core Curriculum for the Dialysis Technician

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About this Core Curriculum
This Core Curriculum for the Dialysis Technician is offered as a general educational guide for dialysis technicians and other medical professionals. When using these materials, the reader must be aware of certain limitations.
This Core Curriculum is not to be used as a substitute for professional training, or as a substitute for practice guidelines and protocols of the particular hospital or clinic providing dialysis treatment. It is important, since certain hospital or clinical protocols may differ from those discussed in this Core Curriculum. There may also be local, state, and federal regulations imposed on the technicians, hospital, or clinic which require different practices from those outlined in this guide. It is important to consult product labeling for any pharmaceutical or medical device referenced in this Core Curriculum.

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The reader must recognize that dialysis involves certain risks, including the risk of death, which cannot be completely eliminated, even when the dialysis procedure is undertaken under expert supervision.
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XVI
Objectives
After completing this module, the learner will be able to:
1. Discuss how dialysis therapy is reimbursed in the United States.
3. List the steps of the continuous quality improvement (CQI) process.
4. Describe ways that dialysis technicians can demonstrate professional behavior when working with patients.
5. Explain the certification process for dialysis technicians.

Today’s Dialysis Environment: An Overview

Module 1 cover photo credit:
Introduction
As a patient care technician, your job is to help patients with chronic kidney disease (CKD) receive safe and effective dialysis. To do this well, it will help you to learn what dialysis is, how it was developed, how to ensure high-quality care for patients, and how to perform and carry out your duties in a professional manner. We cover all of these topics in this module.

While there are many treatment goals for patients with CKD, the main goal is to help each patient reach the highest level of wellness possible. Helping patients to reach this goal is one of the most rewarding parts of caring for patients with CKD. Dialysis is provided by a team that includes technicians, nurses, dietitians, social workers, doctors—and, most important of all, patients. Some patients choose to take a very active role in their care and know a lot about their treatment and how it affects them. The team should support this interest and knowledge: research shows that patients who self-manage their care and know more about it stay healthier and live longer. It takes a team to make sure that patients’ needs for treatment, nutrition, medications, and social services are met. Other specialists, such as physical therapists, pharmacists, exercise physiologists, and clergy, may be called on as well.

With good dialysis, many people with CKD can lead full and active lives. For others, having a good quality of life is harder. A person’s health depends on a number of factors. These can include age, former activity level, proper treatment, other illnesses (such as diabetes or high blood pressure), and support from loved ones. With training and experience, a dialysis technician can help patients feel their best, and at the same time, have a rewarding career.

Overview of Dialysis
When the kidneys fail, patients need treatment to live. Dialysis is the main treatment for end-stage renal disease (ESRD). It replaces three main kidney tasks: removing wastes from the blood, removing excess fluid from the blood, and keeping electrolytes (electrically charged particles) in balance. There are two main types of dialysis: hemodialysis (HD), and peritoneal dialysis (PD). HD is most common (see Figure 1).

To do HD, an entry into the patient’s bloodstream is needed. This is called a vascular access. During a treatment, needles are placed into the access. Blood flows out of the patient, through an artificial kidney (dialyzer) where...
the blood is cleaned, and back to the patient. The dialyzer contains a semipermeable membrane which allows some substances, such as wastes and excess water out, but keeps others, such as blood cells, in. Wastes and water pass through the membrane into a fluid called dialysate and some substances pass from the dialysate into the blood. The dialysis machine, or delivery system, controls the flow of blood to the dialyzer, includes safety alarms to monitor the machine during a treatment, and mixes and delivers dialysate. HD is most often done in a center 3 times a week, for about 4 hours per treatment. Some patients do HD at home, and may do short treatments 5 or 6 days a week. Or they may do longer treatments at night while they sleep for 3-7 nights per week. Access for PD is through a catheter (tube) placed in the abdomen. The blood never leaves the body; instead, the lining of the abdomen, which has many tiny blood vessels, acts as a filter in the same way as a dialyzer. In the most common type of PD,1 patients use a cycler machine at home at night, while they sleep, to cycle sterile dialysate in and out of the abdomen. PD can also be done by hand, usually with four exchanges of fresh dialysate for used dialysate each day. PD goes on 7 days per week. Manual PD can be done at home, at work, or while traveling. HISTORY OF DIALYSIS Dialysis as a treatment for kidney failure was not always the sleek, high-tech process it is today. The first hemodialysis treatment in a patient, using cellulose membrane, was done in 1943 using a rotating drum artificial kidney (see Figure 2) developed by a Dutch doctor named Willem Kolff.2 Before that time, patients with kidney failure had no effective treatment; the disease was always fatal. Kolff’s rotating drum device featured a large wooden wheel dialyzer made of slats wrapped with 30-40 meters of sausage casing (the cellophane membrane). To gain access to the blood, a fresh artery and vein had to be used for every treatment.
each treatment and tied off after. Because a patient had limited blood vessels, dialysis could only be used to treat patients whose kidneys were expected to recover.

The science and technology of dialysis made great strides during the Korean War (1950–1953). Dialysis was used to treat soldiers with acute renal failure, improving their chances of survival.3

Vascular Access
In 1960, Dr. Belding Scribner and his colleagues came up with a way to reenter and use blood vessels multiple times for dialysis. They linked a patient’s artery and vein using a plastic tube outside the skin. Called a shunt (see Figure 3), this first vascular access made it possible to treat patients with chronic kidney failure, who would need dialysis for the rest of their lives. But shunts often became infected or clotted.4

In 1966, Dr. James Cimino and colleagues found a way to connect an artery and a vein together inside the arm. The arteriovenous (AV) fistula caused fewer infections and blood clots than the shunt. Even today, the AV fistula, or native fistula, lasts longest and is the best access for HD.4

Dialyzers
Kiil dialyzers used in the 1960s were 70-pound flat plates (see Figure 4). Their large surface areas were covered by sheets of cellophane. After each treatment, the membranes were cleaned and stored in a chemical bath or the plates were taken apart and the membranes replaced. Each corner of the dialyzer had to be uniform and torqued down, a lengthy task called building a dialyzer. Treatments took up to 14 hours, 3 times a week.

The first dialyzer to be mass-produced was the coil dialyzer, a membrane supported by a mesh screen coiled around a central core. It was primed with a large amount of blood, set in a holding container called a canister, and bathed with dialysate. Coil dialyzers were sterile and disposable, which made them very costly. With the advent of technology in the mid 1960s came a new membrane material called cuprophane. This launched another type of

Figure 3:
Scribner shunt in the forearm position
Silastic tubing
Connection broken here for dialysis

Figure 4:
Kiil dialyzer
Latches Inside the Kiil, two pairs of membrane sheets (4 sheets) were separated by three grooved, polypropylene boards.
dialyzer: the Gambro flat plate (see Figure 5).
Considered small at the time, early flat plate dialyzers were more than 30 inches long, with many layers of membranes in pairs. Each pair of membranes formed an envelope. During a treatment, blood flowed between the pairs of membranes, and dialysate flowed around the outside.
In the late 1960s, researchers made a small, lightweight, hollow fiber dialyzer (see Figure 6). Blood flowed through the insides of the fibers—thousands of tiny hollow tubes the size of hairs. Dialysate flowed around the outside of the fibers. The hollow fiber dialyzer, much improved over the years, is the only type on the market today.
Since the 1960s, many advances have made dialysis more safe and reliable. Better membranes that are more compatible with the tissues of the human body (biocompatible), increase treatment comfort for patients.
Machine alarms and automated functions in the machine help protect patients from harm.

MEDICARE PAYMENT FOR ESRD PATIENTS
What if we knew how to save the lives of patients with kidney failure, but we didn’t have enough machines to treat them all? Who would decide which patients would live and which would die? Before 1973, this really happened all across the country. Hospitals had Life and Death committees made up of lay people and clergy. They chose patients for treatment based on age, maturity, education, whether they had children to support, could afford the care, and how much they might give back to society if they could live. For patients who were chosen, the costs of treatment were very high. Some chose death rather than impose this burden on their loved ones.
To make sure that people could get treatment for kidney failure that could help them live full lives, Congress passed Public Law 92-603, the Medicare End-Stage Renal Disease (ESRD) Program, in 1972. This program gives Medicare to patients who are entitled to Social Security based on their work record (93%) of all patients. It covers both dialysis and kidney transplants. Medicare pays 80% of allowable costs; insurance, Medicaid, state programs, or patients pay the other 20%.6 Once the law

Life and Death committees

Committees made up of lay people and clergy.

Today’s Dialysis Environment: An Overview

Figure 6:
Hollow fiber dialyzer
Figure 5:
Flat plate dialyzer
Blood out Blood in
Dialysate out
Dialysate
Support structure
Blood flows between pairs of semipermeable
membranes
Pair of
semipermeable
membranes
Dialysate flows between the
support structure and the
outsides of the membranes
Dialysate in
Dialysate out
Blood
from
patient
Blood
back to
the patient
Dialysate in
Fibers
passed and more machines were built, shortages were no longer a life-or-death problem. Today, kidney failure is still the only disease with its own Medicare program.

Government funding changed dialysis. Before 1972, many patients did their treatments at home with a helper. Most centers were based in hospitals. After the Medicare ESRD Program began, more centers began to open. Today, most centers are free-standing and about 2/3 of them are part of a large dialysis organization (LDO), a company that owns many centers all over the country. Each year, there are fewer and larger LDOs, as they buy more centers.

Centers today are paid a composite rate by Medicare for each treatment. This rate is based on the patient’s age, weight, and height, and is different for each patient. The amount must cover overhead, staff wages and training, equipment, rehabilitation, and some drugs. The composite rate is not raised each year for inflation the way hospitals and nursing home rates are. Instead, Congress must pass a law to raise the rate. In 1974, the average rate per treatment was $138. In 2002 it was $130.50 which was worth only $34 in constant dollars. At this point, centers may lose $5 to $10 per treatment on patients who have Medicare only. This has forced centers to become ever more efficient without reducing the quality of the care they provide.

There is a second source of income for centers: insurance. During the first 30 months of treatment, if patients have an employer group health plan (EGHP) through a job or a spouse’s job, that plan is primary; it pays first. On average, EGHPs pay $126,000 per patient, per year, while Medicare itself pays about $63,000. So, centers that offer work-friendly treatments and/or schedules can help patients keep their jobs and insurance and improve their own bottom line at the same time.

In 1978, ESRD Networks were set up to oversee the quality of dialysis care across the country. There are 18 ESRD Networks; most are non-profit, and all are under contract with Medicare to cover a region of 1-6 states (see Figure 7). Networks are charged to promote rehabilitation, collect and report data, and do quality improvement projects. Networks also offer a patient grievance process and provide resources to staff and patients.

What is quality care? In 1990, the Institute of Medicine (IOM) defined quality as: The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.
Figure 7:
ESRD Network map
Drawing adapted with permission from the
Forum of ESRD Networks
aspects of the care and treatment of Medicare patients, and found that changes were needed to improve care.9 The IOM still assesses our healthcare system; in 2001, it put out a report that found ongoing problems. The IOM set a strategy and action plan to improve care, with six Aims for Improvement.10 Providers and users of the healthcare system must commit to the six aims to foster innovation and improve the delivery of high quality care. The aims are to provide care that is:

1. Safe: avoid harm to patients from care that should help them.
2. Effective: provide care based on science to all who could benefit.
3. Patient-centered: provide care that respects and responds to patient wishes, needs, and values, and ensure that patient values guide clinical decisions.
4. Timely: reduce waits and sometimes harmful delays for those who receive and give care.
5. Efficient: avoid waste of equipment, supplies, ideas, and energy.
6. Equitable: provide care that does not vary in quality due to gender, ethnicity, geography, education level, and income.

The quality of dialysis care has been a focus since the Medicare ESRD Program was passed in 1972. The original purpose of dialysis was not just to keep patients alive, but to help them stay active, work, and pay taxes. Once there were enough machines to treat all patients, we were able to focus on whether dialysis was meeting this goal. Because of the cost, Congress needs to be assured that the Medicare ESRD Program is worth the money. This is done, in part, by showing that centers and staff are providing good quality care. There is pressure throughout healthcare to look at how well patients are doing, so we can keep costs down while still having high quality.

DIALYSIS QUALITY STANDARDS

Since the 1970s, quality in dialysis has been checked by comparing centers to preset standards. This is called quality assurance. Centers that do not meet these standards risk losing their Medicare certification to provide ESRD services and the payments they receive for these services.

For example, the Centers for Medicare and Medicaid Services (CMS) is the federal body that oversees Medicare. CMS inspects dialysis centers through contracts with state Departments of Health. State surveyors have checklists of standards and conditions that centers must meet to keep their certification. Centers that do not meet these can lose their Medicare funding. With so many centers and
nursing homes to inspect, years may go by between surveys, but a center should always be ready for a survey and work each day as if it will be inspected.

Many other dialysis standards exist:
- ESRD Networks have Medical Review Boards that collect patient and center data to measure outcomes.
- The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) has standards for hospital-based dialysis centers.

Today’s Dialysis Environment: An Overview
n The Association for the Advancement of Medical Instrumentation (AAMI) has standards for dialysis water treatment, dialysis solution preparation, and dialyzer reprocessing. The Food and Drug Administration (FDA) oversees the safety and effectiveness of all medical devices. In 1991, the FDA put out Quality Assurance Guidelines for Hemodialysis Devices. These guidelines, still in effect, cover dialyzers and blood tubing, monitoring devices and alarms, dialysis machines, dialyzer reprocessing equipment, water treatment, and all other dialysis devices. The FDA requires healthcare providers to fill out special reports to tell manufacturers and the FDA about problems with devices and equipment, as well as adverse events. National dialysis data can serve as standards. The United States Renal Data System (USRDS) puts out a report each year that compares data from all the dialysis centers in the United States. Data in the USRDS include annual mortality (death) rate, number of patients, cost of treatment, and much more. The results may be used to find out if outcomes for all patients are getting better or worse. Centers can use the data to compare their outcomes with national averages. Another source of national data is the ESRD Clinical Performance Measures (CPMs) project. This is a team effort of CMS, the ESRD Networks, and dialysis centers. The CPMs compare the quality of Medicare dialysis. Data are gathered each year from a random sample of patients from each center. The CPMs are based on the National Kidney Foundation (NKF) Kidney Disease Outcomes Quality Initiative (KDOQI) Clinical Practice Guidelines. The hemodialysis CPMs are adequacy of dialysis, vascular access, anemia, and albumin. A report is put out each year. Dialysis centers can compare the CPM results with their own outcomes.

GUIDELINES FOR DIALYSIS CARE
To measure the quality of care in a center, outcomes (results of care) must be used. These outcomes must be agreed upon by providers and patients and based on the most current knowledge. They are then measured for each patient, for groups of patients, or for centers, and are tracked over time. Today, patients whose kidneys fail can live longer than ever before. Some patients live for decades. But, too many patients still die early or suffer ill effects from kidney disease. Even with standards, patient outcomes like morbidity (sickness) and mortality (death) vary from center to center. This may be due, in part, to differences in care at centers or in approach...
to care and treatment among nephrologists (doctors who specialize in kidney disease). How can we improve outcomes for all patients? By finding the best way to provide dialysis care and sharing these ideas with all centers. Clinical practice guidelines are efforts to do just that.

Renal Physicians Association

The first clinical practice guideline for kidney failure was written in 1993 by Renal Physicians Association (RPA) nephrologists.
Today’s Dialysis Environment: An Overview

The guideline, Adequacy of Hemodialysis, covered the dose of treatment a patient should receive. Healthy kidneys work 24 hours a day, 7 days a week. Dialysis done three times a week provides only about 15% of the function of healthy kidneys. Patients who do not get enough treatment feel ill and are at risk of dying sooner. So, the RPA guideline suggested a minimum dose of hemodialysis for all patients. The RPA has written other guidelines, which include: Appropriate Patient Preparation (care of patients with advanced CKD who are not on dialysis); ESRD Workgroup (care of ESRD patients); and Shared Decision Making (starting and ending dialysis).

National Kidney Foundation-KDOQI

In 1995, the NKF’s Dialysis Outcomes Quality Initiative (NKF-DOQI) was formed, supported by a grant from Amgen. Teams wrote guidelines in four key areas: anemia, hemodialysis adequacy, peritoneal dialysis adequacy, and vascular access. The hemodialysis adequacy guidelines built on the 1993 RPA guideline. Since 1999, the NKF has increased the scope of DOQI to include all phases of kidney disease, and updated the first set of guidelines. Now it is called the Kidney Disease Outcomes Quality Initiative (KDOQI). Its goal is to improve the care and outcomes of all people with CKD.

In 2003, a new NKF program called Kidney Disease: Improving Global Outcomes (KDIGO) was launched. Its mission is to improve the care and outcomes of kidney patients around the world. KDIGO is an effort to write and implement global clinical practice guidelines. To work, the KDOQI guidelines must be put into daily practice. The guidelines change the way some centers provide care. As a technician, you will be a key member of a healthcare team that uses these guidelines and helps patients understand their purpose.

For example, anemia is a shortage of oxygen-carrying red blood cells. It causes fatigue, heart disease, and many other problems. The KDOQI anemia guidelines help centers identify and treat anemia so patients stay healthier. You may be able to help reduce anemia by making sure patients get more of their blood back after a treatment, keeping dialyzers from clotting, and stopping excess blood loss when you put in or take out the needles.

Patients sometimes get less than the minimum dose of dialysis. The KDOQI adequacy guidelines suggest that the doctor prescribe a higher dose, so patients will at least reach the minimum amount of treatment or more. You
can help ensure that patients get adequate dialysis. You can correctly draw blood for testing, and check that the entire prescription is given. For example, you could make sure the correct blood flow rate is used, and explain why patients should stay on for the prescribed time. The vascular access guidelines give ways to check and preserve a patient's access. You can help protect patients' accesses when you use good technique to put in needles, help patients put the right pressure on needle sites after a treatment, and report problems with the access to a nurse or doctor right away. KDOQI guidelines have also been written for heart disease, CKD, nutrition, high blood pressure, bone disease, and lipid disorders.
Updates and new guidelines are in process. You need to be aware of these changes and how they may affect your practices and those of your center.

DOPPS
The Dialysis Outcomes and Practice Patterns Study (DOPPS) is a long-term study of patients in 12 countries (Australia, Belgium, Canada, France, Germany, Japan, Italy, New Zealand, Spain, Sweden, the United Kingdom, and the United States). The goal of DOPPS is to help patients live longer by looking at practice patterns in centers. The data are used to help find treatment factors that can be changed to improve patient outcomes.

CONTINUOUS QUALITY IMPROVEMENT IN DIALYSIS
Improving patient outcomes by giving high-quality, efficient care has become a goal of the dialysis industry. There are efforts by CMS and insurance companies to control costs and improve quality. One way to meet these goals is the use of continuous quality improvement (CQI). Like quality assurance, CQI is a way to improve care. The focus of quality assurance is on audits and reviews to look for problems. The focus of CQI is to see how things are working, take steps to make them better, and prevent future problems.

CQI can be both top-down and bottom-up. Top-down means management commits to a CQI culture and uses resources to help CQI projects succeed. Bottom-up means workers find best practices and barriers to better care, and make changes to improve care. CQI projects can be:
- Clinical (e.g., anemia, adequacy, access problems)
- Technical (e.g., water treatment, dialyzer reuse)
- Organizational (e.g., staff schedules, patient safety)

CQI Process
Different CQI models exist, but their goals are the same. All dialysis centers should use a model of CQI. The large dialysis organizations have developed CQI programs that are used in all of their centers.

Below is an example of a four-step CQI process. Steps one through three are where the CQI models may differ.

I. Identify Improvement Needs
The goal of this step is to find an area that needs to be improved. There are four substeps to finding improvement needs:
1. Collect data.
2. Analyze the data.
3. Identify the problem/need for improvement.
4. Prioritize activities.

II. Analyze the Process
This step has four substeps:
1. Choose a team. CQI teams should include
different members of the care team based on the problem: doctors, nurses, dietitians, technicians, social workers, and patients.
2. Review the data The CQI team should review the data collected in the first step.
3. Study the process/problem Review the literature on the problem to see if there are standards or guidelines for it. Find reasons why the problem may have occurred.
4. Identify patterns/trends | Review all of the possible reasons for the problem, using the data.

III. Identify Root Causes
From research, discussion, and data, decide the exact causes of the problem.

IV. Implement the Plan, Do, Check, Act Cycle
The last step is to use the plan, do, check, act (PDCA) cycle (see Figure 8). The four steps to the PDCA cycle are:
1. Plan | Make a plan to address the problem. Include outcomes, solutions to the problem, a task list for each team member, and a time frame.
2. Do | Implement the action plan.
3. Check | Monitor the results of the plan, assess results after the plan is done, and assess the plan for any needed changes.
4. Act | Adopt the plan in the center on a formal basis and continue to monitor progress.

The PDCA cycle is an ongoing process. Once a solution to the problem is started in the center, you can’t assume that the problem is solved. The new process needs to be checked to ensure that it is being used in day-to-day practice.

Today’s Dialysis Environment: An Overview

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Identify Improvement Needs
- Collect data
- Analyze data
- Identify problem statement
- Prioritize activities

1

Analyze the Process
- Select a team
- Review the data
- Study the process/problem
- Identify partners/trends

2
- Identify probable root causes
- Define/refine the problem

Identify Root Causes

3

4

Implement the solution, change or modify facility-wide tests, revise standards and specifications, incorporate revisions into day-to-day practices.

Obtain judgments of improvement achieved (performance, process measurements, outcomes); determine if solution, change, or medication has been successful
Deliver care, perform policy or procedure in limited trial run.
Design or redesign policies, procedures, services, or products.
Specify objectives or degree of improvement desired.
Figure 8:
CQI process
PROFESSIONALISM

When you became a hemodialysis patient care technician, you became a member of the healthcare team that cares for patients at your center. As a technician, you will have more direct patient contact than any other staff member. So, you need to understand what it means to perform and behave in a professional manner, and build that into your daily practice.

One of the key skills to learn is how to behave in a professional way. The Merriam-Webster dictionary defines professionalism as a way of exhibiting a courteous, conscientious, and generally businesslike manner in the workplace.

What are some ways you can be courteous to your patients while being both caring and professional?

- Address patients by their titles (i.e., Mrs. Smith).
- Don’t use a first name without permission.
- Don’t use nicknames, especially ones that could make a patient feel dependent (i.e., baby or sweetie).
- Use “please” and “thank you” when talking to patients, families, and other staff members.
- Treat everyone with respect and pride. Maintain the patient’s dignity. Always introduce yourself and other members of the team to new patients, so they feel more comfortable with the center.

What are some ways you can show you are conscientious?

- Get to work on time.
- Be ready to work when you arrive.
- Don’t talk about your personal life to patients or other staff members when in the patient care area.
- Never discuss or burden patients with your personal problems.
- Don’t talk around or over patients, as though they weren’t there.
- Never talk about one patient in front of another patient.
- Protect everyone’s privacy and confidential information.

What are some ways you can show a businesslike manner?

- Wear appropriate clothes that are clean and well kept.
- Groom yourself well:
  - Trim your fingernails and keep them free of inappropriate decorations.
  - Keep makeup tasteful and minimal.
  - Brush or comb your hair neatly.
  - Don’t wear too much perfume, cologne, or aftershave.
- Keep things peaceful and the level of noise to a minimum:
  - Don’t shout across the treatment area.
  - Don’t rush or run around the treatment area.
  - Don’t always appear to be too busy or
indifferent patients may feel unsafe.

- Take the appropriate amount of time with every patient.
- Make certain all equipment is ready and working when the patient arrives.
- Keep the patient care area clean, swept, and free of blood.

Knowing how to maintain boundaries is a key part of professionalism. Boundaries keep the relationship...
between you and your patients appropriate and safe. They also protect everyone from misunderstandings. What are some examples of boundaries?

- Never date patients.
- Never ask for or borrow money from patients.
- Never invite patients to your home or to activities that are not related to the center.
- Never discuss your personal problems with patients.
- Never accept tips, money, or gifts from patients.
- Never touch patients in an inappropriate manner.
- Never invade a patient’s personal space.
- It can make the patient afraid and be dangerous for the staff.

Another key issue is confidentiality and maintaining patient privacy. Your center will give you required training on privacy and the Health Insurance Portability and Accountability Act (HIPAA) privacy rule.

DIALYSIS TECHNICIAN ASSOCIATIONS

Remember that knowledge is power, and power is confidence. It takes time and discipline to learn all you will need to know, but you will reap the rewards in many ways. Knowledge can be seen in the positive outcomes of patients, and felt as the result of your discipline and commitment. The dialysis technician organizations below can help you learn more about dialysis.

National Association of Nephrology Technicians/Technologists (NANT)
The National Association of Nephrology Technicians/Technologists (NANT) is a national, non-profit, professional organization. NANT was founded in 1983 to improve dialysis care; promote education, certification, and licensing; aid job security; and help technicians find jobs. NANT is the only group in the country just for dialysis technicians; it has an elected Board of Directors and 1,300 active members.

For more information on NANT, write to: P.O. Box 2307, Dayton, OH, 45401, call (877) 607-6268, or visit their website at www.dialysistech.org.

Council of Nephrology Nurses and Technicians (CNNT)
The Council of Nephrology Nurses and Technicians (CNNT) is a professional membership council of the NKF. Its focus is on making health policies that aid professional practices and patient care. CNNT advocates for, and contributes to, the professional development of its members through education, networking, and the sharing of information. The CNNT supports the mission of the NKF to bring help and hope to those who suffer from kidney disease through research, patient services, a national organ donor program, professional education, and public education.
For more information on CNNT, write to: NKF, 30 E. 33rd Street, New York, NY, 10016, call (800) 622-9010, or visit their website at www.kidney.org.

TECHNICIAN CERTIFICATION
You may want to take an exam to become certified. Three exams are offered, one is for entry-level technicians with about 6 months experience, and the other two require one or more years of experience.

Today's Dialysis Environment: An Overview
Certified Clinical Hemodialysis Technician (CCHT) Exam

The Nephrology Nursing Certification Commission (NNCC) offers the Certified Clinical Hemodialysis Technician (CCHT) exam, a competency-level exam. The certification is good for 2 years. A joint task force of NANT and the American Nephrology Nurses Association (ANNA) wrote this exam. To take the CCHT exam, you will need:

- At least a high school diploma or a General Education Development (GED).
- Successful completion of a training program for hemodialysis patient care technicians with both classroom instruction and supervised clinical work.
- The signature of a preceptor/supervisor to prove training and clinical experience.
- Suggested (not required) 6 months full-time or equivalent (1,000 hours) experience, including training.
- Compliance with state regulations for hemodialysis patient care technicians, if they apply. Applicants must meet the experience requirement (for certification) of the state in which they practice.

The CCHT content comes from four hemodialysis practice areas: clinical (50%), technical (23%), environmental (15%), and role (12%). NANT recognizes the CCHT exam as a valid measure of basic competency for hemodialysis patient care technicians.

NNCC was founded in 1987 to promote the highest standards of nephrology nursing practice through the development, implementation, and evaluation of all aspects of certification and recertification. To learn more about the exam, check at your dialysis center or see the exam website at www.nncc-exam.org.

Certified Hemodialysis Technician (CHT) Exam

The Board of Nephrology Examiners (BONENT) offers an exam to become a Certified Hemodialysis Technician (CHT). BONENT is an international organization that has been providing certification of dialysis nurses and technicians for more than 30 years. You can take the CHT exam if you have worked for at least 12 months in a dialysis center or have completed an accredited dialysis course. You must also have a high school diploma or a GED.

The BONENT CHT exam measures technical proficiency in five major areas of practice and tasks: patient care (65%), machine technology (10%), water treatment (5%), dialyzer reprocessing (5%), and education/personal development (15%). NANT recognizes the CHT exam as a
valid measure of technical proficiency for all hemodialysis technicians. The CHT exam has 150 multiple-choice questions, and a 3-hour time limit. An on-line practice exam is also available. BONENT certification is designed to:
1. Provide and measure a standard of knowledge for nephrology practitioners
2. Encourage professional growth and individual study
3. Formally recognize individuals who meet the requirement for certification

15 15
To learn more about the exam, ask at your dialysis center or check the BONENT website at www.goamp.com/bonent/.

Certified in Clinical Nephrology Technology (CCNT) and Certified in Biomedical Nephrology Technology (CBNT) Exams

The National Nephrology Certification Organization, Inc. (NNCO) offers two exams. One is in Clinical Nephrology Technology, for a Certified in Clinical Nephrology Technology (CCNT) designation. The second is in Biomedical Nephrology Technology, leading to the Certified in Biomedical Nephrology Technology (CBNT) designation. You must have at least 12 months of work experience to take the CCNT and CBNT exams.

The CCNT exam measures knowledge in four major areas: principles of dialysis (25%), machine preparation and operation (20%), patient assessment (20%), and treatment (35%). NANT recognizes the CCNT exam as a valid measure of current competence for patient care hemodialysis technicians.

The CBNT exam measures knowledge in six major areas: principles of dialysis (25%), scientific concepts (15%), electronic applications (10%), water treatment (20%), equipment functions (20%), and environmental/regulatory issues (10%). NANT recognizes the CBNT exam as a measure of current competence for biomedical hemodialysis technicians.

The mission of the NNCO is promotion of safe and effective care in nephrology technology by credentialing qualified clinical and biomedical technicians. Both the CCNT and CBNT exams are given by the Professional Testing Corporation. To learn more about the exams and schedules for the exams, see the NNCO website at www.ptcny.com/clients/NNCO.

Conclusion

The history of dialysis and the current system of care are the context for your job as a patient care technician. Efforts to improve quality and professionalism are the processes that will help you and your team provide the best care to patients.

Today’s Dialysis Environment: An Overview
References
Today’s Dialysis Environment: An Overview

Objectives

After completing this module, the learner will be able to:
1. Identify the structures and functions of the normal kidney.
2. Describe acute vs. chronic kidney disease.
3. List five symptoms of uremia.
4. Describe at least four conditions that often occur due to kidney failure.
5. Discuss the treatment options for kidney failure.
6. Identify members of the care team.
7. Discuss the communication skills dialysis technicians use while working with patients.
8. Describe the goal of rehabilitation and the technician’s role in it.

The Person with Kidney Failure

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Introduction

People whose kidneys fail need dialysis or a kidney transplant to live. Kidney failure creates a complex cascade of problems that can affect every aspect of life. People on dialysis must cope with changes in how they eat, drink, work, plan their daily lives, and have normal family time. Some manage to view dialysis as a small part of their lives. They consider themselves cell biologists, homemakers, lawyers, teachers, bus drivers, real estate agents, tool and die makers, retired professionals, students, and parents—not just patients.

The patient is the focus of care. He or she is the one whose life can be improved by good dialysis—or who can be harmed by poor treatment or error. Some patients are able to take an active role in their care and learn all they can. Respect this interest and encourage it. Others may not be as active. They need your support and encouragement as well.

The goal of caring for people with kidney failure is to help each one reach the highest level of health possible. As you go about your work, keep in mind that your patients have one thing in common—kidneys that don’t work. Aside from that, each one is an individual with his or her own knowledge level, interests, and preferred ways to do things. Having respect for each person will help you provide the best care for all of your patients.

As a technician, you are the eyes and ears of the care team, the person in the closest contact with each patient. This means you are in a unique position to learn about patients and share vital insights with the team that can help improve care. Patients will also ask you questions and expect you to know the answers or refer them to a staff person who can help. To take on this role, you need to understand kidney disease, its causes and consequences, treatment options, and much more.

This module covers normal kidney function, acute and chronic kidney disease, conditions caused by kidney failure, treatment for kidney failure, the care team, renal (related to the kidneys) nutrition, coping with kidney disease, communication skills, and rehabilitation. This information will help you learn what happens to the person with kidney failure.

Renal Anatomy & Physiology

HOW HEALTHY KIDNEYS WORK

Perhaps more than any other body system, kidneys help maintain the constant chemical and fluid balance that we call homeostasis. Kidneys are amazing organs, made up of many types of cells arranged in a complex network of structures and functions. Most people have two kidneys (see Figure 1). Each one is about the size of a fist and weighs...
Figure 1:
Location of the kidneys
Rib cage
Kidney(s)
Ureter
Bladder
Urethra
about five ounces. The kidneys are in the back of the body, just above the waist. Pads of fat and the bones of the rib cage protect them. A tough, fibrous outer capsule holds each kidney together (see Figure 2). Just under the capsule is the cortex. If you cut a kidney in half, you’d find that beneath the cortex, the kidney is in sections. The inner part, or medulla, is made up of pie-shaped wedges called pyramids. Points of the pie are called papillae. Each papilla points into a cup-shaped opening called a calyx. Each calyx sends drops of urine into the renal pelvis. The renal pelvis of each kidney links to a ureter (a tube that sends the urine to the bladder). Both ureters empty into the bladder, where urine is stored until it leaves the body through a tube called the urethra. Structure of the Kidneys

Nephrons
Nephrons are the working units of the kidneys (see Figure 3). They are found in the renal cortex and extend into the medulla. Each nephron is a tiny filter and purifier. The heart pumps blood, which contains wastes, into the kidneys. Nephrons filter and clean the blood, discard excess water and wastes, and keep what the body needs for homeostasis. Each kidney has about one million nephrons, which can be seen only with a microscope. Tiny blood vessels called capillaries carry blood to each nephron, where wastes are filtered out and needed substances are reabsorbed. A nephron is made up of a glomerulus and a tubule.

Glomerulus
A glomerulus is a tangled ball of capillaries held together by a membrane called a Bowman’s capsule. Capillary walls are semipermeable membranes; they have pores that let small substances pass through, but keep in blood cells and larger molecules, like proteins.

The Person with Kidney Failure

Figure 2: Cross section of the kidney

2–3 inches
Renal vein
Fibrous capsule
Renal artery
Renal pelvis
Small blood vessels
Calyx
Papillae
Cortex
Ureter
Medulla
(pyramid)
4.5
inches
Figure 3:
Nephron
Waste and
water move
from capillary
into urinary
space to
Tubules form filtrate
conduct
urine
out of
nephron
Filtrate is
modified
to form
urine in
tubule
Tubule
Urine
Glomerulus
Blood moves
into glomerulus
Blood leaves
nephron
Kidney
24
Blood enters each glomerulus from an afferent (toward the organ) arteriole (small artery). Blood pressure forces water to filter out of the blood through tiny slits and into the urinary space of a glomerulus. Small wastes pass through the pores along with the water to form a liquid called glomerular filtrate. If there is damage to the nephrons, larger substances, like proteins, can also pass through.

Your coffee maker works like this, too. Water pumps into a tank, where it mixes with the coffee grounds. A filter keeps the large grounds in, but lets the coffee liquid pass through. If the filter is torn, grounds will leak through and foul your coffee.

A normal adult makes about 125 mL of glomerular filtrate per minute; about 180 liters per day. Nearly all of the filtrate water is reabsorbed in the tubules. Blood goes back to the bloodstream through the efferent (away from the organ) arteriole.

Tubular System
Each glomerulus sends filtrate into a tubule that has four parts: the proximal (near) convoluted tubule, the loop of Henle, the distal (far) convoluted tubule, and the collecting tubule. In the tubules, chemicals and water the body needs are reabsorbed into the blood; the rest empties into the calyces and then flows into the ureter to be excreted as urine.

The Functions of the Kidney
Kidneys do a number of key tasks: they remove wastes, keep fluids and electrolytes in balance, control blood pressure, maintain acid-base balance, and make hormones. Kidney disease occurs when something like disease, birth defect, or injury keeps the kidneys from working correctly.

Removal of wastes
One of the main tasks of the kidney is to rid the body of wastes and excess fluids. These are excretory functions. The most obvious of these is making urine. Urine is excess body water with a high level of waste products. The wastes come from foods that are digested and metabolized (broken down into simpler substances) and from the breakdown of tissue due to normal muscle use. Other wastes include drugs, toxins, and acids.

In the kidneys, only about 1% of the water contained in the glomerular filtrate is excreted in urine; almost 99% is reabsorbed into the bloodstream. Each day, 180 liters of filtrate (a liter is about a quart) become one to two liters of urine.

Most of the glucose, protein, and electrolytes that pass through the kidneys go back into the blood or are metabolized. This process helps the body keep precise levels of these substances in the blood at all times.
Figure 4:
Capillary
Oncotic
pressure
Hydrostatic
pressure
Capillary
Arteriole Venule
Drawing adapted with permission from Dialyrn®
By controlling the amounts of water and electrolytes like sodium that are reabsorbed into the bloodstream, kidneys maintain body water balance and help control blood pressure.

Endocrine functions
Making hormones (chemical signals from one part of the body that act on other parts) is an endocrine function (see Figure 5). The kidneys make hormones that include:
- Erythropoietin, which triggers the bone marrow to make red blood cells
- Calcitriol (active vitamin D), which controls the balance of calcium and phosphorus that is key to bone metabolism

Types of Kidney Disease
ACUTE KIDNEY FAILURE
Acute kidney failure is a sudden loss of kidney function. It is most often caused by an illness, injury, or toxin that stresses the kidneys. Acute kidney failure is called prerenal, intrarenal, or postrenal, based on where the problem starts.
- Prerenal failure occurs if the kidneys don't get enough blood flow. This can be due to the shock of trauma, severe dehydration (loss of body fluid), or heart disease. An acute blockage of the renal arteries caused by blood clots can also cause acute kidney failure.
- Intrarenal failure occurs due to an injury to the kidneys. The injury can be due to glomerulonephritis, a physical blow, or a toxin, like a drug or poison.
- Postrenal failure occurs when a blockage causes urine to back up and harm the kidneys. The blockage might be due to an enlarged prostate gland, kidney stones, or a kinked ureter.

Some cases of acute kidney failure can be treated. Acute kidney failure may last for days, weeks, or months. Some patients with acute kidney failure die, some go on to chronic kidney failure, and some recover their kidney function. Treatment (intense medical care and dialysis) supports the person until the cause can be treated, and/or normal kidney function comes back.

The Person with Kidney Failure

Figure 5:
Hormones produced by the kidneys
Erythropoietin acts on cells in the bone marrow to stimulate red blood cell production
The kidney converts vitamin D into its...
active form,
calcitriol
CKD is most often a slow process of nephron loss. Kidneys have so many nephrons that people can stay healthy with fewer than half of the normal number. People may not notice early symptoms of CKD. Routine medical check-ups with a urine test and blood pressure check are good screening tools. A blood test for creatinine (a waste product of muscle use that healthy kidneys remove) may find CKD in the early stages, when treatment to slow its progress will work best. It can take CKD months or years to reach kidney failure; most patients die of other causes before their kidneys fail. Treatment of CKD depends on the cause. The progress may be slowed with blood pressure control, diet, blood sugar control for people with diabetes, and reducing risk factors like smoking and high cholesterol. In time, CKD may reach kidney failure, where dialysis or a transplant is needed. The National Kidney Foundation (NKF) lists five stages of CKD based on the glomerular filtration rate (GFR), or the amount of filtration going on in the kidneys (see Table 1). Stage 5 CKD is kidney failure. Physicians can easily estimate GFR using a formula, based on blood test results.4

Causes of CKD
CKD has a number of causes. Diabetes, high blood pressure, or glomerular diseases caused kidney disease in 80.4% of new patients who started dialysis in 2003.5

Diabetes
Diabetic kidney disease, or diabetic nephropathy, is the number one cause of stage 5 CKD in the United States. Nearly 45% of patients with kidney failure at the end of 2003 lost their kidney function due to diabetes.40.5% lost their kidney function due to type 2 diabetes.5 Two main types of diabetes cause most kidney disease.5 In type 1 diabetes, the immune system destroys the pancreas cells that make insulin. In type 2 diabetes, the body does not make enough insulin or can’t use what it does make.2 More than 90% of people with diabetes have type 2.6 Diabetes affects the blood vessels, and causes heart disease and nerve damage. It is the leading cause of blindness and limb loss, as well

<table>
<thead>
<tr>
<th>Stage</th>
<th>Glomerular Filtration Rate (GFR) (mL/min/1.73m²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kidney damage with normal or increased GFR. The patient usually has no symptoms.</td>
<td></td>
</tr>
</tbody>
</table>
2 60
Kidney damage with mild
decrease in GFR. Usually no
symptoms, although may be
anemic and have disturbances in
blood pressure and calcium and
phosphorus metabolism.
3 30
Moderately decreased GFR.
Symptoms may become noticeable
at GFR <60 mL/min/1.73m².
May have fatigue, anemia,
disorders of calcium and
phosphate balance, swelling, high
blood pressure.
4 15
Severe decrease in GFR. Usually
symptomatic. Preparation for
dialysis and/or transplant should
begin at this stage.
5 <15
Severely symptomatic. Dialysis
is usually begun when GFR is
<15 mL/min/1.73m².
Table 1: Stages of CKD4
90
as kidney disease (see Figure 6). Certain ethnic groups, African Americans, Hispanics, and Native Americans, are at a higher risk for type 2 diabetes. In the Diabetes Prevention Program, a large study of people at high risk for diabetes, lifestyle changes such as losing 5% of body weight and getting 30 minutes of exercise at least 5 days a week, reduced the development of diabetes over 3 years.

Hypertension

The second most common cause of kidney disease in the U.S. is hypertension: high blood pressure. Most often, the cause of high blood pressure is not known. This is called primary hypertension. In some people, high blood pressure can be caused by a kidney problem, a birth defect in the aorta (large artery leaving the heart), and renal artery stenosis (narrowing). These types of problems can be fixed with surgery. Primary hypertension can be treated with medications, exercise, sodium limits, and diet. Since high blood pressure often has no symptoms, many people don’t know they have it, or don’t take their blood pressure pills. At the end of 2003, 27.1% of patients on dialysis had kidney failure due to hypertension.

Glomerular diseases

Glomerulopathies (diseases of the glomeruli) include illnesses like glomerulonephritis (inflammation of the glomeruli) and glomerulosclerosis (hardening of the glomeruli). These illnesses may have a slow or a rapid onset. About 8.5% of all patients with kidney failure at the end of 2003 had glomerular diseases.

Cystic disorders

or polycystic kidneys

Polycystic kidney disease (PKD) is a genetic disease that causes large, fluid-filled cysts to grow in the kidneys, spleen, pancreas, and liver. The cysts can become so large and numerous that they crowd out the healthy kidney tissue, causing kidney failure. If PKD affects the brain, it can cause aneurysms (bulging of arteries that can rupture). Of all patients who had kidney failure at the end of 2003, 3.2% had cystic disorders.

Other causes of CKD

There are many other causes of kidney failure, too. Birth defects, frequent or large kidney stones, a disease called systemic lupus erythematosus (SLE), use of street drugs, cancer, kidney infections, AIDS, and sickle cell disease are a few of the rarer causes of CKD.
Gastrointestinal System
Kidneys
Circulatory System
Nervous System
Skin
Muscular System
Heart
Eyes
Neuropathy (nerve damage)
Pruritus (itching)
Abnormal energy metabolism
Atherosclerosis plaque build-up in blood vessels can cause heart disease, hypertension, peripheral vascular disease, and reduced cardiac output
Cerebrovascular Vision problems
disease
Digestive disorders
Renal failure
Circulation in lower limbs can be affected
In many cases, the cause of CKD is not known.5 No matter what caused the problem, once the kidneys fail, treatment options, or renal replacement therapies, are the same.

Conditions Caused by Chronic Kidney Failure
As you have learned, the kidneys have a number of complex jobs in the body and as they begin to fail, they stop doing these vital tasks (see Figure 7). Kidney failure affects most body systems, as you will see.

UREMIA
Patients whose kidneys are failing have uremia (a build-up of wastes in the blood). Both a history and a physical exam are needed to diagnose kidney disease and uremia.12 Symptoms come on slowly or patients may not know what to look for.13 These symptoms may include:13,14

- Fatigue; weakness; dizziness; feeling cold all the time; mental confusion; pale skin, gums, and fingernail beds (due to anemia, a shortage of red blood cells)
- Edema (swelling) in the feet, hands, and face due to fluid retention
- More or less urine than usual, foamy or bubbly urine (due to protein), getting up at night to urinate (nocturia)
- Itching
- Flu-like symptoms; muscle aches, nausea, and vomiting, poor appetite
- Ammonia breath, metallic taste in the mouth
- Pain in the back or flank
- Dyspnea (trouble breathing) due to fluid in the lungs
- Yellow skin complexion
- Sleep problems
- Sexual problems
- Joint swelling and bone pain

Dialysis will help many of these symptoms, but in-center hemodialysis replaces only about 15% of normal kidney function. So, patients may have uremic symptoms if they are not getting enough treatment. For your job, you will need to:

- Learn the symptoms of uremia
- Ask your patients if they have these symptoms (they may not know what to look for)

Figure 7: Complications of CKD
Patient may experience:
- Loss of visual acuity
- Numbness, burning, or tingling in hands or feet
- Muscle weakness and pain
- Impotence
- Constipation or diarrhea
- Fatigue

Medical complications:
Atherosclerosis
Skin changes
Eye changes
Kidney damage
Peripheral vascular disease
Report symptoms to the nurse so the patient’s treatment can be adjusted as needed.

ANEMIA

Healthy kidneys make a hormone called erythropoietin (EPO), which triggers the bone marrow to make red blood cells. As the kidneys fail, they make less EPO, so anemia occurs (see Figure 8). Red blood cells contain a protein called hemoglobin (Hgb) that carries oxygen to all the cells in the body. With fewer red blood cells, patients with anemia don’t get enough oxygen to their tissues. Anemia in CKD is associated with a heart problem called left ventricular hypertrophy (LVH), which is one of the leading causes of death in people with kidney disease.

Before other treatments for anemia became available, most people on dialysis had severe anemia. They needed frequent blood transfusions to have Hgb levels that were often still below 10 g/dL (grams per deciliter; a normal Hgb is 14–18 g/dL in a healthy man and 12–16 g/dL in a healthy woman). Transfusions led to a high risk of hepatitis, were costly, and reduced patients’ chances of getting a transplant. Good anemia management is a team effort.

Your center may have an Anemia Management Protocol. A nurse or dietitian may be the Anemia Manager to oversee the protocol. He or she coordinates anemia management tasks, follows the protocol, looks at trends in Hgb levels, and works with the patient’s doctor. Ask who the Anemia Manager is in your center. As a technician, you can work with that person and help ensure that your patients have good anemia outcomes.

Figure 8: Anemia

Red blood cells
A normal red blood cell count
Kidney failure can cause anemia

Your Role in Anemia Management

- Rinse back as much of the patient’s blood as you can at each treatment.
- Use pediatric blood tubes for blood tests, if the lab will accept them.
- If your center reuses dialyzers, report poor reuse numbers to the nurse.
- Ask your patients about their symptoms and tell the nurse. These include unusual bleeding; signs of infection such as redness, tenderness, or swelling; shortness of breath; chest pain; and any others.
- Urge your patients to come for each treatment and stay on for the full time.
SECONDARY
HYPERPARATHYROIDISM
Secondary hyperparathyroidism is
overproduction of parathyroid hormone (PTH)
by the parathyroid glands in the neck (see
Figure 9). Healthy kidneys make a hormone
called calcitriol, the active form of vitamin D.
Calcitriol helps the body absorb calcium from
food. When the kidneys fail, they make less
calcitriol, so less calcium can be absorbed. At
the same time, failing kidneys remove less
phosphorus, which builds up in the blood.
Having less calcium triggers the parathyroid
glands to release PTH. PTH controls calcium
and phosphorus levels in the blood. Low serum
calcium, high phosphorus, and low calcitriol
levels contribute to increases in PTH levels. In
time, the parathyroid glands grow so large that
they can’t shut off. This is the cycle of
secondary hyperparathyroidism.17-20
High PTH levels cause bone disease, called
renal osteodystrophy,21 and other problems.22
Patients with renal osteodystrophy may not
have symptoms or may complain of joint
pain, bone pain, muscle pain, and/or weakness
that causes major disability.23 Experts have
found that secondary hyperparathyroidism is
related to calcium deposits on the heart and
blood vessels.24,25 This raises the risk that a
patient will have a stroke or heart attack.
People on dialysis take drugs to treat secondary
hyperparathyroidism.
PRURITUS (ITCHING)
Severe and constant itching, or pruritus, is
common in CKD patients. Causes include high
phosphorus and serum calcium levels,
secondary hyperparathyroidism, changes in
calcium metabolism, dry skin, and uremic
toxins (substances retained in the body as the
kidneys fail).26 Since itching sometimes improves
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Your Role in Secondary Hyperparathyroidism
Management
Listen well and report symptoms that patients tell you they have.
Reinforce what the doctor, nurses, and dietitian teach patients.
Urge patients to take medications as prescribed and to follow
their diets.
Figure 9:
Parathyroid Glands
Thyroid Gland
Parathyroid
Glands
when the parathyroid gland is taken out, vigorous treatment of secondary hyperparathyroidism with medication may also help itching.

Itching with hives (raised welts) that occurs only during dialysis may be due to an allergy. Contact dermatitis—an allergy to a substance that touches the skin—like a laundry detergent or bleach used to clean dialysis chairs—can cause hives. Drug allergies (e.g., pork or beef heparin) or reactions to chemicals used to sterilize a new dialyzer can also cause hives during a treatment.

**PERICARDITIS**

Patients who have kidney failure may develop pericarditis, inflammation of the membrane or sac around the heart. Pericarditis may be caused by poor dialysis, infection, surgery, or other acute illness. It causes constant pain in the center of the chest, fever, low blood pressure, irregular heartbeat, and other symptoms. There is a typical heart sound, called a pericardial friction rub that the doctors and nurses will hear through a stethoscope. The treatment includes good dialysis, getting enough fluids, anti-inflammatory drugs, antibiotics, and maybe surgery to relieve pressure in the sac that surrounds the heart.

**AMYLOIDOSIS**

Amyloidosis is a condition where a waxy protein is deposited in the soft tissues, bones, and joints. This protein, beta-2-microglobulin (ß2m) is normally found on the surfaces of cells and in body fluids. Healthy kidneys remove its excess. When the kidneys fail, ß2m serum levels increase, it enters the tissues, and is converted to amyloid. Deposits of amyloid can cause carpal tunnel syndrome (painful compression of a key nerve in the wrist), joint pain, bone cysts, and compression fractures. On x-ray, amyloid is found in about 20% of patients after 10 years of hemodialysis, 30%—50% after 15 years, and 80%—100% after 20 years or more. Synthetic dialyzer membranes remove more ß2m than membranes made of cellulose. Longer and/or more frequent treatments also remove more ß2m.

**NEUROPATHY**

(NERVE DAMAGE)

Over time, some patients—especially those with diabetes—may develop nerve damage called peripheral neuropathy. Symptoms include burning of the hands and feet, a pins and needles feeling, and restlessness in the legs. Peripheral neuropathy can make it hard for patients to walk. The cause is not known, though secondary hyperparathyroidism, sodium imbalance, and high serum calcium levels have been considered. Retention of some other toxins, which are not efficiently removed by dialysis, can also be responsible for neuropathy.
Your Role in Pruritus Management
- Work with the nurse to find out if oatmeal baths (Aveeno® soap) can be advised.
- Work with the nurse and dietitian to see if advising the patient to be sure they take their phosphate binders is appropriate.
- Encourage patients to come for each treatment and stay the whole time.

Your Role in Pericarditis Management
- Report any and all complaints of chest pain to the nurse right away.
- If a patient has chest pain before dialysis, do not start the treatment until the nurse has seen the patient.
- If a patient develops chest pain during a treatment, tell the nurse right away.
- Be sure that patients receive their full dialysis prescription.
SLEEPING PROBLEMS
Restlessness and trouble sleeping (insomnia) are common in people with kidney failure. The causes of sleeping problems are unclear. The problem may be worse if a patient sleeps during dialysis. Sleep problems are improved with more intensive dialysis (e.g., nocturnal dialysis). Further research into dialysis sleep problems is needed. Patients with CKD may respond poorly to sleep medications.

BLEEDING PROBLEMS
Bleeding problems in people with CKD are due to complex blood factor changes. Signs include easy bruising, gastrointestinal (GI) bleeding, blood in the stool, and nosebleeds.

ELECTROLYTE IMBALANCES
Electrolytes are compounds that break apart into ions when they dissolve in a fluid. Electrolytes are found in body fluids and cells, and play a role in many basic cell functions, like sending nerve signals to muscles. Healthy kidneys keep electrolytes in balance, but this balance is disturbed in CKD. When the level of an electrolyte in the blood is too high (hyper) or too low (hypo), the effects can be harmful or even fatal.

Sodium (Na+)
Sodium helps maintain the body’s water content and fluid balance. It also plays a role in keeping acids and alkaline substances in balance in the body and helps transmit nerve signals.

- Hypernatremia is too much sodium in the blood. Symptoms can include intense thirst, flushed skin, fever, seizures, and death.
- Hyponatremia, low blood sodium levels, can also occur in CKD, most often if the dialysate does not have enough sodium. Signs and symptoms can include low blood pressure, muscle cramping, restlessness, anxiety, pain in the access site, headache, and nausea.

Potassium (K+)
Potassium helps control the nerves and muscles including the heart. It also helps keep the body’s water balance and aids glucose metabolism.

- Hyperkalemia is a higher-than-normal level of potassium in the blood. In people on dialysis, a common cause is eating too many high-potassium foods, since the kidneys can no longer remove potassium. Other causes include bleeding, trauma, hemolysis (breakdown of red blood cells), and missed treatments. Hyperkalemia can cause serious, even deadly, changes in the heart rhythm. Symptoms may include muscle weakness, abdominal cramps, and abnormal heart rhythms. Or, there may be sudden cardiac arrest with no early warning symptoms.
- Hypokalemia is a lower-than-normal blood potassium level. This is not common in people on dialysis. Hypokalemia can occur if the patient is vomiting and has diarrhea, has a diet that does...
not include enough potassium, or has too much potassium removed by dialysis. Hypokalemia can be very dangerous, causing fatigue, muscle weakness, and abnormal heart rhythms.

Your Role in Bleeding Problem Management

- Question patients about any bleeding between dialysis treatments.
- Report excessive postdialysis bleeding to the nurse.
- If you are allowed to give heparin, be sure that the dose is correct.
- If bleeding occurs, get advice from the nurse about how the heparin dose should be changed.
- Report excessive dialyzer clotting to the nurse.
Calcium (Ca++)
Calcium is mainly found in the bones and teeth. The body needs small, constant levels of calcium in the blood and fluids at all times to control blood clotting, enzyme regulation, hormone action, and nerve and muscle function.\(^{33}\)

Hypercalcemia is a high blood calcium level, most often due to high doses of vitamin D or calcium. Symptoms include vomiting, weakness, confusion, and coma.\(^{33}\)

Hypocalcemia is a low calcium level, most often due to problems with the metabolism and absorption of calcium. It also occurs with hyperphosphatemia. Patients with hypocalcemia may have numbness, seizures, and tetany (tremors, muscle spasms, and muscle pain).\(^{33}\)

Phosphorus (P)
Like calcium, phosphorus is mainly found in the bones and teeth. It also plays a vital role in the body’s use of energy.

Hyperphosphatemia is a high phosphorus level. People whose kidneys don’t work can’t excrete phosphorus, so it builds up in their blood. This problem is quite common.\(^{17}\)
In the short term, hyperphosphatemia can cause severe itching. In the long term, it contributes to bone disease. Patients who use in-center hemodialysis must take binders to remove some phosphorus from the blood, and follow a diet that limits phosphorus.

The most important problems related to hyperphosphatemia are hypocalcemia and metastatic calcification (calcium phosphate deposits that are found in the skin, eyes, lungs, heart, joints, and blood vessels).\(^{17}\)

Hypophosphatemia is a low phosphorus level. In CKD patients, this is most often due to a poor diet or taking too many phosphate binders. Mild or moderate hypophosphatemia usually does not have symptoms. Symptoms are usually not seen until phosphorus is <1 mg/dL, and include muscle weakness, paralysis, and problems with the function of red blood cells.\(^{17}\)

COMMON DIALYSIS BLOOD TESTS
Laboratory testing is done to monitor patients’ health, identify problems, and check patients’ treatment adequacy. Routine blood tests are done each week, month, and quarter, or as ordered by the doctor. Table 2 lists common dialysis blood tests. It is helpful for you to know why these tests are done and what the normal values are so you can support the care team’s patient teaching and answer patients’ questions (see Module 6: Hemodialysis Procedures and Complications for a section on how to draw and process blood tests).

Treatment Options
Once CKD reaches stage 5 (kidney failure),
patients need dialysis or a kidney transplant to
The Person with Kidney Failure
Your Role in Electrolyte Management
- Water system checks are critical. Patients should not start dialysis each day until the water system QA/QC has been completed.
- Double check that the correct dialysate is delivered.
- If you mix dialysate, double check, with another staff person, that you have mixed the solution correctly.
- Encourage patients to follow their prescribed diet and fluid limits. Reinforce what patients are told about diet and fluids.
- Report all symptoms to the nurse.
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Blood Test Usual
Frequency
Target Value
(varies with lab) Significance of Test
Albumin Monthly
General: 3.6\textsuperscript{[5.0]} g/dL
Dialysis:
Should be \textbf{>4.0} g/dL
Albumin is a protein that helps keep fluid balance inside the blood vessels. Low serum albumin levels are used to diagnose malnutrition, which raises the risk of death in people on dialysis.
Blood cultures
When needed Negative, or no growth Many types of bacteria cause infections. Sepsis is a blood infection, often fatal, illness. A blood culture identifies the bacteria so the doctor can choose the right antibiotic.
Blood urea nitrogen (BUN) Monthly
Predialysis and postdialysis
General: 5\textsuperscript{[25]} mg/dL Urea is an easy-to-measure waste product used to indicate levels of other wastes in the blood. BUN levels are drawn before and after a treatment to measure the dialysis dose.
Calcium (Ca++) Monthly
General: 8.5\textsuperscript{[10.5]} mg/dL
KDOQI target for dialysis: 8.4\textsuperscript{[9.5]} mg/dL
Ca++ is an electrolyte needed for muscle action and bone structure. Precise levels must be in the blood at all times. Calcium levels are drawn to see if levels are too high or too low. If so, the patient’s diet or dialysate may need to change.
Calcium-Phosphorus Product (Ca x P) Monthly
KDOQI target for dialysis: \textless 55 mg2/dL2
If the Ca x P product is high, the patient is at risk for calcium deposits on the blood vessels and soft tissues, such as skin, muscles, joints, and eyes. These can be painful and can reduce blood flow to the heart or limbs.
Complete blood count (CBC) Monthly
Depends on cell measured CBC is a basic screening test, which includes white and red blood cell counts, differential white cell count, hematocrit, hemoglobin, and platelets. It shows immune cell function, anemia, infection or inflammation, and more.
Creatinine Monthly
General male:
0.5\textsuperscript{[1.5]} mg/dL
General female:
0.5\textsuperscript{[1.3]} mg/dL
Dialysis: 10\textsuperscript{[18]} mg/dL
Creatinine is a waste product of muscle metabolism that is removed
by healthy kidneys or dialysis. A large, muscular patient will have a higher creatinine than a small, frail one. Changing levels mean a change in muscle mass over time or in dialysis therapy.

Serum ferritin
Monthly while monitoring EPO dose to reach target Hgb range.
At least every 3 months in patients with stable EPO dose or patients not on EPO.
Dialysis target: >200 ng/mL

Ferritin is the chief iron-storage protein in the body. Levels of ferritin are low when patients have iron deficiency anemia. High serum ferritin levels may be caused by a genetic illness called hemochromatosis (a genetic disorder that causes iron build-up in the body), high iron intake, blood transfusions, chronic inflammation, certain anemias, or malignancies.

Table 2: Common Blood Tests Performed on People with CKD
The Person with Kidney Failure

Blood Test Usual Frequency Target Value (varies with lab) Significance of Test
Glucose Monthly General: 65-110 mg/dL (fasting)
Glucose is blood sugar; it is measured to check the status of diabetes and other conditions.
Hypoglycemia is low blood sugar. This most often occurs with too much insulin. Other causes include a pancreas tumor, cancer, a poorly working liver, Addison’s disease, and other problems.
Hyperglycemia is high blood sugar. This is mainly found in people with diabetes.
Hemoglobin (Hgb) 37
Every 1-2 weeks
Every 2-4 weeks
when a stable Hgb/Hct level is achieved
General male:
14-18 g/dL
General female:
12-16 g/dL
KDOQI target for dialysis: =11 g/dL
Hgb is the oxygen-carrying red pigment of the red blood cell. Low levels occur in anemia, bleeding, and destruction of red blood cells. High levels occur in hemoconcentration (decrease of the fluid content of blood, for example dehydration) and chronic obstructive pulmonary disease.
Hepatitis B
1. Hepatitis B core antibody (HBcAb)
2. Hepatitis B surface antibody (HBsAb)
3. Hepatitis B surface antigen (HBsAg)
Twice a year
Twice a year
Monthly (unless antibody positive)
General: Negative
General: Negative
Immunized: Positive
General: Negative
HBcAb is a test for exposure to hepatitis B. If it is positive, it means the person was exposed in the past.
HBsAb is a test for exposure or immunization in the past, and immunity to hepatitis B.
HBsAg is a test for exposure to viral hepatitis (hepatitis B) that shows...
if someone has been infected; it is the earliest sign of an acute infection. Positive patients are contagious and must be isolated.

Hepatitis C
Virus HCV
Antibody (anti-HCV)

Once a year General: Negative Anti-HCV is a test that shows infection with the hepatitis C virus. Someone who tests positive may be able to spread the virus.

Table 2: Common Blood Tests Performed on People with CKD (continued)
Blood Test Usual
Frequency
Target Value
(varies with lab) Significance of Test

Magnesium
(Mg++)
Monthly General adult:
1.7[2.5 mg/dL
Mg++ is an electrolyte found in tissues, muscles, and bones that helps break down carbohydrates and protein. Mg++ is found in some foods and medicines.
Low magnesium levels may occur in malnourished dialysis patients.
High magnesium levels may occur due to the use of magnesium-containing antacids or laxatives.

Plasma intact parathyroid hormone
(PTH)36
Every 3 months General: 10[65 pg/mL
Dialysis: 90[200 pg/mL
KDOQI target for dialysis: 150[300 pg/mL
PTH regulates serum calcium, calcitriol, and serum phosphorus levels. PTH levels rise as calcitriol and serum calcium levels fall.

Phosphorus
(PO4)36
Monthly General population adult: 2.5[4.5 mg/dL
KDOQI target for dialysis: 3.5[5.5 mg/dL
PO4 is needed for energy transfer and to form bone.

Potassium
(K+)
Monthly General population:
3.5[5.5 mEq/L
K+ is an electrolyte that plays a vital role in nerve and muscle function. High or low levels can cause heart rhythm problems (arrhythmias), heart failure, and death.

Sodium
(Na+)
Monthly General population:
135[146 mEq/L
Na+ is an electrolyte; it helps maintain fluid balance and send nerve signals. Most patients can keep normal levels if they follow their sodium and water limits.

Transferrin saturation
(TSAT)37
Monthly General population
male: 20%[55%
KDOQI target for dialysis: >20%
TSAT shows how much iron is in the body to form red blood cells.
Low TSAT levels suggest an iron deficiency (often due to blood loss) or problems releasing iron from body stores.
High TSAT levels may suggest hemochromatosis, a genetic disorder that causes iron build-up in the body.38

Table 2: Common Blood Tests Performed on People with CKD (continued)
stay alive. The key factor in choosing a treatment option is the fit with the patient’s lifestyle, which may include work if he or she is of working age as half of all new patients are. The schedule, site, and convenience of treatment can also affect the patient’s choice. In acute kidney failure, hemodialysis (HD) is most often the treatment of choice until the kidneys recover. In chronic kidney failure, there are a number of choices, based on the person’s lifestyle and health status. Of course, old age, severe illness, homelessness, and other problems may limit a patient’s options. Advising patients on which treatment option to choose is not part of your job. However, patients may ask you about the different options, and the more you know, the better you can address their questions. Refer a patient who wants to change treatments to his or her doctor.

In most of the modules of this Core Curriculum, we discuss only in-center hemodialysis, because you are most likely to work with these patients. Below, we have a brief discussion of all of the treatment options. To learn more about other treatments, please check the references at the end of this module.

TRANSPLANT
A kidney transplant gives a patient one healthy kidney from a donor (see Figure 10), and a lifestyle that is closest to normal. People of all ages with kidney failure can get a transplant. Patients who would like to have a kidney transplant need to be tested to make sure they are healthy enough to have the surgery. Some patients choose not to have a transplant. Patients who do want to think about this option should talk with their doctors about it. There are three options for a kidney transplant:

1. A kidney from a blood relative (living related donor)
2. A kidney from a non-blood relative, spouse, or friend (living nonrelated donor)
3. A deceased donor kidney (from someone who has died) from the national transplant list.

Getting on the list is not automatic. A patient who wants a deceased donor kidney must talk to his or her doctor about how to get on the list. The United Network for Organ Sharing (UNOS) keeps the national transplant list. Close family members and friends in good health can volunteer to donate a kidney. People can live with just one kidney if they are in good health. They must be tested to see if their blood and tissue type match the patient’s and if they...
Location of patient's kidney
Iliac artery
Location of transplanted kidney
Ureter
Bladder
are suited physically and emotionally to donate a kidney.
A transplant is not a cure for kidney disease; it is another form of treatment. A transplant may last 5, 10, 20, or more years or it may not work at all. On average, between 89 and 95% of transplanted kidneys work one year after surgery. The most common problem after transplant is rejection; the body's immune system sees the transplant as foreign and attacks it. To lower the chance of rejection, transplant patients take immunosuppressant drugs to keep the immune system from attacking. These drugs have side effects that may include weight gain; high blood pressure; and an increased risk of infection, diabetes, and certain kinds of cancer. All of these side effects can be managed. Transplant patients will still have to follow a special diet, but with many fewer limits than for patients on in-center hemodialysis. Each year in the United States, more than 100,000 people reach kidney failure and more than 15,000 kidney transplants are done. A severe shortage of deceased donor organs for transplant means that people who want one may have to wait a long time. Waits of a few years are common. Patients go on dialysis while they wait, and if the transplant doesn't work, they can go on dialysis again.

DIALYSIS
Dialysis is the process of cleaning the blood by removing wastes and fluid that build up when the kidneys fail. Dialysis is a way to replace some, but not all, kidney functions. Table 3 compares dialysis to normal kidney function. The goal of dialysis is to help keep people with kidney failure as healthy as possible. Dialysis can't fully clean the blood. A person on dialysis will have abnormal blood findings and some symptoms but the human body can adjust to some degree of abnormality. A well-dialyzed patient will have good fluid balance he or she won't be overloaded or dehydrated. Blood pressure will be near normal with few medications. Anemia will be controlled, the rate of bone disease will be slow, and blood tests will be in the target range. Patients' treatments should be comfortable and leave them feeling well. They should not have severe muscle cramps or low blood pressure. Dialysis patients should have few, if any, complications, and no treatment-related accidents. People who are well-dialyzed should have enough energy to carry out their activities of daily living, do their usual work, pursue hobbies, and 39 19

Kidney Dialysis
Removes all excess fluid each day
Removes waste products each day
Removes some wastes on treatment days
Controls electrolyte and acid/base balance
Helps restore electrolyte and acid/base balance
Controls blood pressure by fluid removal, sodium balance, and hormonal action
Helps control blood pressure by removing fluid and balancing sodium on treatment days
Makes erythropoietin, a hormone that triggers the bone marrow to make red blood cells
Can’t make erythropoietin
Controls calcium/phosphorus balance each day
Can change serum calcium levels somewhat by adjusting calcium in dialysate; can remove some phosphorus, but not as well as healthy kidneys
Plays a role in hormonal balance Has little, if any, effect on hormones
Activates vitamin D Cannot activate vitamin D

Table 3: Normal Kidney Function Compared to Dialysis
enjoy life. They should sleep well and have a good appetite. It is normal to be discouraged at times, but well-dialyzed people can have good coping skills and can be as happy as anyone else.

Peritoneal Dialysis
Dialysis filters out wastes and excess fluid that damaged kidneys can no longer remove. Peritoneal dialysis (PD) uses part of the patient’s own body as a filter—the membrane that lines the inside of the abdomen, called the peritoneum. This lining is full of capillary blood vessels, each of which acts as a tiny filter. People who choose PD have a plastic catheter placed into their abdomen (see Figure 11) or in a more round-about way via the chest wall (presternal catheter). Catheter placement is a minor surgical procedure. In some patients, PD is not an option due to body type, scarring, or adhesions from other surgery. PD is a daily self-care treatment that patients can do alone, at home or at work, after a week or two of training. It lets patients fit their treatments into their lives, instead of fitting their lives around the center’s schedule. PD is work-friendly; it makes it more possible for working-age patients to keep their jobs. It also allows fewer fluid and diet limits than in-center HD. People who do PD often don’t see other patients, and may not view themselves as sick.

The most common complication for patients on PD is a painful infection called peritonitis. Peritonitis can scar the peritoneum, which may make PD impossible. The most important way to prevent peritonitis is to follow the steps exactly as they were taught, including handwashing and masking. Infections of the peritoneal dialysis catheter can also occur. Patients who want to do PD must have space in their homes to store a month’s supply of fluid bags.

Most people on PD have some remaining kidney function. Over time, this function may decline or even end. Also, over time, the peritoneum may lose some ability to filter. Patients who use PD must have tests done to ensure that they are getting enough dialysis. There are two ways of doing PD: CAPD and CCPD. We’ll describe them below.

CAPD
To do continuous ambulatory PD (CAPD), the patient fills the abdomen with sterile dialysate fluid (solution of chemicals that removes wastes) through the catheter. Wastes and excess water flow into the fluid, and the patient drains it out after a few hours (see Figure 12). Draining out the used fluid and putting in fresh fluid is called an exchange. Most patients do four exchanges per day at home or at work; each takes about 30 minutes. The patient must wash his or her hands carefully, control airflow to the room, wear a mask, and use aseptic technique. Pets must be kept out of the room during an exchange.
The Person with Kidney Failure
Figure 11:
Peritoneal catheter
Peritoneal catheter
40
Because the abdomen is always full of fluid, the treatment goes on all the time, even while the person is ambulatory (walking around). According to the latest figures from the United States Renal Data System, about 2.5% of people with kidney failure in the United States were using CAPD. Nearly anyone can learn how. Dialysis centers train patients and monitor their care.

CCPD
The other form of PD is called continuous cycling PD (CCPD) or automated PD (APD). Instead of going on all the time, APD is done for 9-10 hours once a day. The patient uses a cycler machine (see Figure 13) to do many PD exchanges while he or she sleeps. This kind of peritoneal dialysis, done at night, is also called nightly PD (NPD). Some patients do one exchange or two exchanges during the day and APD at night to get more treatment. A combination of NPD on a cycler and daytime ambulatory exchanges is called CCPD. Per the USRDS, about 3.2% of U.S. dialysis patients were using CCPD and this number has been growing. USRDS calls CCPD any treatment which uses a machine regardless whether daytime exchanges are done. APD or NPD leaves patients days free for other tasks, like work.

Hemodialysis
Hemodialysis (HD) done in homes, centers, and hospitals all over the world is used to

Figure 12:
Patient doing CAPD exchange
The peritoneal cavity is filled with dialysate, using gravity.
At the end of the exchange, the dialysate is drained into the bag, again using gravity.

Figure 13:
CCPD cyclers
Drawings adapted with permission from Fresenius Medical Care North America and Baxter Healthcare, respectively
treat most people with kidney failure. In HD, blood is pumped out of the patient’s body, through an artificial kidney, or dialyzer, then back into the patient (see Figure 14). Blood and dialysate fluids are pumped through different parts of the dialyzer at the same time. A semipermeable membrane keeps the blood and dialysate from mixing. Excess water and wastes pass out of the blood through pores in the membrane, into the dialysate. The used dialysate is sent down a drain. Only a small amount of blood is out of the body at one time.

In-center HD

Most HD in the United States today is done in a center (in-center) with 3- to 4-hour long treatments. Prescribed treatment time depends on the size of the patient, diet, and how much kidney function remains. Some patients feel safer getting treatment in a center with nurses and technicians there to help. They like the chance to meet other people who need dialysis and may make friends at the center. Doing treatments in the center means the home is free of medical supplies. The patient also has days off between treatments to not think about dialysis.

When a patient starts in-center HD, the center may not have a shift time that fits his or her lifestyle. In time, a patient may be able to switch to a time slot that is a better fit, but this may happen too late to keep a job or stay in school. Some in-center patients may need to find a ride to and from the center three times a week. Parents of young children may have childcare issues, especially during school breaks.

Conventional HHD

When dialysis first started in the United States, 40% of patients were on home hemodialysis (HHD). A small number of patients still do HHD today on a (conventional) (three times a week) schedule, or sometimes every other day. Conventional HHD is an option offered by 343 centers across the country, as of 2005. These HHD patients and their partners are trained for a few weeks like you in how to put in needles, order supplies, run the machine, take blood samples, report problems, and respond to emergencies. In effect, they become their own technicians. Most home patients do very well with this self-care treatment. They are in charge of their day-to-day care and can choose what time they want to do treatments, so dialysis fits better into their lives.
Because HHD patients can do their treatments on their own schedules, they may be more likely to keep their jobs or stay in school. The treatment is work-friendly. Patients may do longer treatments so they feel better and have fewer symptoms. Most centers that offer HHD want patients to have a partner who will train with them and be on hand for treatments. They also need space in their homes to store the machine and supplies. Some machines require plumbing or wiring changes to the home.

Nocturnal

Nocturnal home hemodialysis (NHHD) is an option offered by 98 centers across the country, as of 2006. Patients are trained to do their treatments from 3 to 7 nights each week, for about 8 hours, while they sleep. Special connectors keep the needles from coming out in case patients toss or turn. Bedwetting alarms, placed beneath the needle insertion area, may be used to detect moisture and wake the patient up if even a drop of blood is lost. In some programs, the machine is linked by a modem to the hospital so a nurse or technician can follow each treatment.

Reports on NHHD in the United States and other countries have been quite positive. Patients who received 48 hours of treatment each week ate a normal diet and had normal blood pressure without drugs. They did not need phosphate binders. Most had no fluid limits. They also had fewer symptoms including less fatigue, cramping, dizziness, shortness of breath, or feeling cold. They felt more in control, and had better physical functioning. Patients who received 48 hours of treatment each week ate a normal diet and had normal blood pressure without drugs. They did not need phosphate binders. Most had no fluid limits. They also had fewer symptoms including less fatigue, cramping, dizziness, shortness of breath, or feeling cold. They felt more in control, and had better physical functioning. They had less heart damage than patients on conventional in-center hemodialysis. Longer treatments also remove much more β2m, the protein that causes amyloidosis. Patients who live far from a center or who want to keep their days free for other things like working or caring for small children may want to think about doing NHHD.

In some areas, in-center nocturnal HD is offered three nights a week (or every other day). Patients sleep in the center while getting their treatment. This is a good option for people who don’t have a partner or a home that is suited for dialysis. They get about 24 hours of treatment a week instead of the 9 to 12 they would normally get in-center, their days are free, and they can have a more normal meal plan and fluids. Your center may offer this treatment.

Short Daily HHD

Short daily home hemodialysis (SDHHD) is 2 to 3 hour treatments done 5 to 7 days a week. Healthy kidneys work every day, and this is what the body is used to. And because the first 2 hours of each treatment are the most efficient, the short treatments can work very well.
SDHHD is the newest type of home hemodialysis in the United States; 92 centers offer it as of 2006. New dialysis machines designed for patient use are fast and easy to set up and clean up, and make SDHHD more practical. Shorter treatments are easy to fit into family and work life; they can be done early in the morning before work or during a couple of hours of TV shows at night. Patients using SDHHD have reported fewer symptoms, including headaches; feeling tired, dizzy, or cold; shortness of breath; and thirst.

Without dialysis or transplant, people with kidney failure will die. Death is sometimes a reasonable
choice, if the patient’s health is very poor even with proper treatment. People who are very old and have other illnesses may opt not to have dialysis or a transplant, or to stop treatment if they are not getting better or have a poor quality of life. In these cases, the care team uses all of its resources to make sure the patient and family have reached a comfortable decision, and to support them as the patient passes away. This is one of the hardest parts of working with people with kidney disease. However, as hard as it may be, helping a person to have a peaceful death can be rewarding.

In many centers, the doctor, nurse, or social worker talks with patients about what treatments they would want if they were not able to decide for themselves. The talks include discussing advance directives, documents that outline what to do if the patient becomes too ill to speak for him or herself. These talks can be difficult, but most patients value the chance to talk about these issues and to have a way to ensure that their wishes will be respected.

HD Care Team
Members of the care team for people who choose in-center HD include the patient, nephrologist, nurse, social worker, technician, and dietitian. Good outcomes for patients require that all members of the team work together. Medicare requires each dialysis center to have a nephrologist, registered nurse (RN), registered dietitian (RD), and a social worker with a master’s degree (MSW).

PATIENT
As the person who has a chronic disease, the patient’s job is to:
- Learn about kidney failure and its treatment
- Have input into the care plan, then follow it (diet and fluid limits, drugs, dialysis)
- Tell the care team about symptoms or problems
- Know his or her rights and responsibilities

Patients know themselves best. They are also outside of the center for more of their lives than they are in it. People with any chronic disease do best if they become active partners in their own care. The rest of the team can help them get up to speed and should respect the knowledge they gain. In some cases, family members will speak for patients who can’t speak for themselves.

NEPHROLOGIST
A nephrologist is a licensed physician who specializes in kidney disease. He or she establishes the plan of care with the other care team members, prescribes the patient’s treatment and medications, orders blood tests, and makes changes as needed based on a patient assessment.

NURSE
The nephrology nurse works to coordinate each patient’s care with the other members of the care team. His or her responsibilities include implementing the plan of care, designing and
implementing the patient education plan,
assessing each patient before and after the
dialysis treatment, providing direct patient care
during a treatment, and training other staff.
A nurse may also be the manager of the center.
SOCIAL WORKER
Nephrology social workers help patients and
family members adjust to dialysis and rebuild
their lives. The social worker counsels patients
The Person with Kidney Failure
44
and family members to help with the emotional and financial issues that are a part of dialysis. Some areas social workers address are healthcare coverage, rehabilitation, patient resources, and community services.

**DIALYSIS TECHNICIAN**

In some centers, there are three types of dialysis technicians. Patient care technicians provide care for patients on dialysis, working under a registered nurse. Biomedical equipment technicians maintain and repair the equipment. Reuse technicians reprocess dialyzers.

**RENAL DIETITIAN**

The renal dietitian’s role is to incorporate patient’s nutritional needs, dietary restrictions, and food preferences into a meal plan that will maintain health and that the person can follow and enjoy. The renal dietitian also teaches the patient, family members, and other caregivers how to best meet nutrition needs.

**Nutrition for People on In-center HD**

Healthy kidneys work 24 hours a day to remove wastes from the blood that build up mainly from the food we eat. These wastes include urea, creatinine, potassium, sodium, phosphorus, and fluid. Dialysis can replace only some of the function of healthy kidneys. Most people in the United States do in-center HD three times per week for 3–4 hours per treatment. So, they need a diet to reduce the levels of wastes in the body. The main goal of the diet is to help the patient have good nutrition while keeping the build-up of wastes between treatments to a minimum. Most patients on peritoneal, nocturnal, or daily dialysis have fewer diet and fluid limits.

The diet is planned for each patient. Levels of protein, calories, fluid, sodium, potassium, calcium, phosphorus, and vitamins may change based on the patient’s needs. Balancing these components in the diet can help improve a patient’s sense of well-being during and between treatments.

The in-center HD diet is based on these food groups (see Figure 15):

- Meat and meat substitutes (e.g., beef, pork, chicken, eggs, fish, cheese, peanut butter, tofu, and vegetarian meat products)
- Dairy (including milk, ice cream, yogurt, and pudding)
- Bread and starches
- Vegetables and fruits
- Fats (includes butter and oils)
- Calorie boosters (e.g., hard candy or jelly beans)
- Miscellaneous (such as spices and condiments)

45 25

**Figure 15:**

Major food groups

Meat and
Fruits

Vegetables

meat substitutes

Dairy products

Starches

Miscellaneous

(mild spices)

Fats (often high

in desserts)
PROTEIN

All foods contain large or small amounts of protein. There are two types of protein. High biological value (HBV) or animal protein (e.g., meat, fish, poultry, eggs, tofu, soy milk, and dairy products). Low biological value (LBV) or plant protein includes breads, grains, vegetables, dried beans and peas, and fruits. A balanced diet has both types. In the body, proteins:

- Aid growth and maintain body tissues
- Provide energy
- Keep fluid balance in the blood
- Form parts of enzymes, hormones, and growth factors
- Form parts of antibodies

Many people on dialysis are malnourished which is a risk factor for death. There are guidelines for how much protein they should eat. People on HD should eat 1.2 grams per kilogram (kg) of body weight per day; half of this should be animal protein. A patient who weighs 65 kg (about 143 lbs) will need to eat about 78 grams of protein each day. After protein is eaten, nitrogenous wastes, such as urea and creatinine, are left over. Healthy kidneys remove these wastes, but diseased kidneys cannot. Blood urea nitrogen (BUN) levels will vary with the amount of dialysis and level of protein intake (see Table 4). Creatinine is a normal byproduct of muscle metabolism that healthy kidneys remove.

Creatinine levels are tested in people on dialysis. Changing creatinine levels may mean changes in the patient’s muscle mass. The patient’s progress should be followed over time by repeating the creatinine test. Like BUN, high creatinine levels may suggest poor dialysis, but low levels alone don’t mean the patient is getting adequate dialysis. Low creatinine levels may occur in patients with poor muscle mass.

CALORIES

Calories in food provide energy to run the body. People on dialysis must eat enough calories to meet their energy needs. If they don’t eat enough of the right foods, they will become malnourished. Patients who don’t eat enough calories will burn protein for fuel. They won’t have enough protein left for other key body functions.

Patients who are uremic often lose their appetites. Food may taste strange or metallic, and patients may have flu-like symptoms, such as vomiting. Watch your patients closely for weight loss and ask them how well they are eating especially new patients, since appetite is poor even before the kidneys fail. Tell the dietitian if you suspect a patient is not eating well. It is vital to note loss of lean body mass and not mistake it for fluid removal from
treatment. If a patient loses body mass, it may not be noticed right away. Signs that a patient has lost body weight, even if postdialysis weight has been recorded.

The Person with Kidney Failure

46 Causes Symptoms

High BUN

- Not enough dialysis
- Increased tissue breakdown (catabolism)
- High protein intake
- Gastrointestinal bleeding
- Nausea and vomiting
- Confusion

Low BUN

- Nausea and vomiting
- Diarrhea
- Poor protein calorie intake
- Weakness
- Weight loss

Table 4: Causes and Symptoms of High and Low BUN56,57
is unchanged, include: fluid build-up in the ankles and fingers, shortness of breath, or the patient saying he or she can't lay flat in bed.

MALNUTRITION
Studies have found that many HD patients are malnourished.34,58,59 Patients whose serum albumin (protein) levels are less than 4.0 g/dL are more likely to die.60 The risk of death also rises as cholesterol levels fall, because low cholesterol also indicates poor nutrition.34,61 Other factors that raise the chances of malnutrition in people on dialysis include:56,58,61-64
n Metabolic acidosis (a shift of the body's acid-base balance toward acid)

n Illnesses besides kidney failure
n Too many diet limits
n Loss of nutrients during dialysis
n Not enough dialysis
n Hospitalizations and surgeries
n Chronic inflammation and infection
Close monitoring of changes in dry weight can help dialysis staff learn if a patient is eating enough calories. Pay special attention to any patient comments about eating and drinking. If a patient is not eating well or has had a change in his or her normal eating habits, ask the dietitian to assess the patient's food intake and determine what is needed.

Malnutrition can be treated in a number of ways. Often, the first step is to try to get the patient to eat more. If this does not work, oral supplements (e.g., nutritional drinks, protein powders, and bars) are used. Many supplements are on the market, even some for people on dialysis. These products provide calories and protein, with less sodium, potassium, and phosphorus. It is important to choose products that the patient will drink.65,66 If supplements don't work, tube feedings are a next step. If tube feeding fails, intradialytic parenteral nutrition (IDPN) or total parenteral nutrition (TPN) intravenous feeding of a

How You Can Help Your Patients
Achieve Better Nutrition Status
At each treatment, ask your patients how they are eating. Tell the dietitian and nurse about any changes in appetite, taste, GI problems (feeling full after very little food, constipation, diarrhea, bloating and heartburn, nausea or vomiting), or trouble keeping blood sugar levels in control.

Tell the dietitian and social worker if a patient is missing meals due to dialysis treatment times or can't afford to buy food.

Tell the dietitian and nurse when a patient consistently arrives below dry weight. Any unplanned weight loss or low energy level may mean there are nutrition concerns.

For diabetic patients, tell the dietitian if a patient tells you that he/she is having trouble eating or keeping blood sugar under control.

Encourage patients to follow their fluid and sodium limits. Tell the nurse or dietitian if a patient gains a lot of fluid between treatments.
Encourage patients to eat as much as they can, but follow the prescribed meal plan.
Remind patients to take their binders with meals and/or snacks, and other drugs and nutritional supplements as prescribed.
Encourage patients to come for their treatments and stay for the whole time. Tell the nurse and the dietitian if a patient is having problems with treatments that may affect adequacy, like not getting the prescribed blood flow or problems with needle sticks.
Get involved with patient education.
special solution that may have carbohydrates, protein, fat, sugars, and amino acids may be used. Malnourished patients can be helped with a team approach. As a technician, you are a communication link between patients and the rest of the team. Be sure to share what you learn with the team. Finding and treating malnutrition early can help your patients stay healthier.

**FLUID**

Once the kidneys fail, they make little or no urine. So, almost all of the excess fluid patients drink or eat must be removed by dialysis (see Figure 16). There are also less obvious forms of fluid loss. For example, breathing, stool, perspiration, etc. use up about 600 milliliters (mL) of fluid each day. People on in-center hemodialysis have fluid limits. Most often, the fluid limit is the volume of the patient’s urine output plus 1 liter (4 cups) per day. So, it may be as low as just 4 cups per day for patients who make no urine (see Figure 17).

Part of the predialysis assessment is figuring out how much water to remove at each treatment. Ideally, each treatment will remove the amount of fluid the patient gained between treatments. As you will learn, knowing just how much to remove is a fine art.

Dry weight is the postdialysis weight at which all or most excess fluid has been removed. Weight is often measured in kilograms (kg). Each kg is 2.2 lbs. People at their true dry weight should feel well, have no excess fluid or trouble breathing, and need few, if any, blood pressure pills. People on dialysis tend to lose real weight (muscle mass) and replace it with fluid weight. Each patient’s dry weight must be adjusted often.

Patients need to learn what will happen if they have fluid overload. In the short term, if a treatment removes too much fluid, or removes it too quickly, the patient will have hypotension (low blood pressure), painful muscle cramps, dizziness, nausea and vomiting, and may pass out. If this occurs, the patient may feel washed out and ill for a few hours after the treatment as well. And, if not enough fluid is removed by The Person with Kidney Failure

**Helpful Hints for Patients About Thirst and Fluid**

- Avoid salty or sugary foods that make you thirsty.
- Ask your doctor or pharmacist if any of your drugs have thirst or dry mouth as a side effect. If so, ask your doctor if there is a substitute that doesn’t have this problem.
- Know your fluids (all foods that are liquid at room temperature like popsicles and ice cream are fluids).
- Use small cups or glasses instead of large ones. Know how much fluid your favorite glass holds. Use a small cup size, such as an 8 ounce cup.
- Quench thirst with hard candies. (Use sugar-free candies if you have diabetes).
Brush your teeth or rinse your mouth with mouthwash.
Rinse your mouth with cold water or cold mouthwash, then spit it out.
Suck on frozen grapes or ice cubes.
Use lemon wedges to help stimulate saliva.
Make your own popsicles out of a low potassium juice (e.g., grape).
Ask the wait staff not to refill your glass when you eat out. Ask for a cup of ice and a bit of fluid and take small sips (limit to 1 cup).
Take pills with pudding or applesauce instead of fluid.
Measure your fluids. Fill a quart jug of water each morning with your daily fluid limit. Use water from this jug all day. If you drink other fluid, pour that amount out of the jug (see Table 5 on page 50).
a treatment, the patient must try to be even stricter with fluid intake—a discouraging task! In the long term, fluid overload can cause congestive heart failure (CHF; the heart cannot pump out all the blood it receives). Signs of CHF include edema and shortness of breath. Keeping a good fluid balance may be the greatest challenge for people on in-center HD and the staff who care for them. How much fluid weight each patient can gain between treatments will vary. But blood pressure checks and watching out for signs of edema or swelling in the feet, face, and hands are the same for all dialysis patients. Encourage your patients to follow their fluid limits. You can teach patients how their fluid intake relates to their treatment complications (i.e., shortness of breath, edema, and cramps).

Figure 16:
Fluids
Milkshakes
Soda Coffee, tea
Water, milk, juice Ice cubes, popsicles
Ice cream, sherbet, frozen yogurt, gelatin
Alcoholic Soups beverages
Milk
32 oz
8 oz
8 oz
12 oz
8 oz
4 oz
8 oz
12 oz
12 oz
8 oz
8 oz
8 oz

Figure 17:
Examples of fluid limit of
4 cups (32 ounces)
SODIUM

Sodium is found naturally in foods and is the major part of table salt. Just 1/2 teaspoon of salt has more than 1 gram, or 1,000 mg, of sodium. Because all foods have small amounts of sodium, it can’t be eliminated from the diet. But people on hemodialysis should not use table salt or most salt substitutes (which have potassium), or eat most foods that are processed with added salt.

Sodium causes thirst and plays a role in high blood pressure and fluid weight gain. Sodium that is retained in the body attracts fluid, which causes swelling. Unhealthy kidneys cannot remove excess sodium. Patients must reduce their intake of both sodium and fluids if they develop edema in the face, hands, or feet; if their blood pressure rises; or if they gain weight rapidly. Patients who limit sodium in their diet are usually less thirsty. This makes it easier to control their fluid intake.

The recommended sodium limit for in-center HD is most often 2.4 grams (87.174 mEq) per day. In most cases, this level can be reached by reducing fluid intake and limiting foods high in sodium.

The Person with Kidney Failure

Food/Drink Ounces mL Household Measure

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<tr>
<th>Quart</th>
<th>32 960</th>
<th>4 cups</th>
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<tbody>
<tr>
<td>Soda pop (1 can)</td>
<td>12 360</td>
<td>1 and 1/2 cups</td>
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<td>Coffee, tea</td>
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<td>1 cup</td>
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<tr>
<td>Milk (1 small carton)</td>
<td>8 240</td>
<td>1 cup</td>
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<tr>
<td>Milkshake</td>
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<td>Ice cream</td>
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<td>Sherbet</td>
<td>4 120</td>
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<tr>
<td>Soup</td>
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<td>1 cup</td>
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<tr>
<td>Wine</td>
<td>4 120</td>
<td>1/2 cup</td>
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</table>
Beer (1 can or bottle)  12  360  1 and 1/2 cups
Popsicle
  - Single popsicle
  - Fudgsicle
  - Creamsicle or
double popsicle
  1.5
  3
  2.5
  45
  90
  75
3 tablespoons
1/3 cup
1/2 cup
Ice cube
(household, 8 pieces)  4  120  1/2 cup
Ice chips  4  120  1/2 cup
Table 5: Measurement Conversions
50
avoiding table and cooking salt, canned foods, packaged [helper] foods, pickled foods, and preserved meats, such as cold cuts, sausages, and hot dogs. Encourage patients to read food labels and try no-salt-added herbs and spices (e.g., basil, lemon pepper, and Mrs. Dash®).

POTASSIUM

A well-dialyzed patient should be able to maintain a normal range of serum potassium \[3.5-5.5 \text{ mEq/L}\] with a diet that includes 2\(\frac{3}{4}\) grams (51-77 mEq) of potassium or 1 mEq/gm protein.

Patients can learn to limit the obvious high-potassium foods (see Figure 18), such as espresso/cappuccino, avocados, mangos, bananas, orange juice, dried fruit, cantaloupe, dried peas and beans, tomato sauce, and potatoes but it is a challenge for most.

Patients who are in the habit of drinking orange juice at breakfast, for example, can switch to a juice that is lower in potassium, perhaps apple or cranberry. Pasta and rice can replace potatoes in the meal.

Besides avoiding high-potassium foods, patients should also learn proper portion sizes.

Apples may be allowed but eating three or four of them at a time without reducing potassium elsewhere in the diet could cause hyperkalemia (high serum potassium).

CALCIUM AND PHOSPHORUS

In CKD, the kidneys are less able to convert vitamin D to its active form and to maintain calcium and phosphorus balance. Low serum calcium, elevations in phosphorus, and vitamin D deficiency result in secondary hyperparathyroidism. KDOQITM Clinical Practice guidelines recommend keeping the serum calcium levels of people with stage 5 CKD at the lower end of the normal range (8.4-9.5 mg/dL).

Total intake of elemental calcium (diet and binders) should not exceed 2,000 mg per day. Serum phosphorus levels should be maintained between 3.5-5.5 mg/dL. Symptoms of high phosphorus include itching, bone and joint pain, muscle weakness, and bone fractures. Dialysis removes some phosphorus. But for most people on hemodialysis, phosphorus must

Figure 18:

Examples of high potassium foods

Facts About Potassium that Patients Need to Know

- Potassium overload can cause sudden death.
- Symptoms of hyperkalemia include muscle weakness, abnormal heart rhythms, and cardiac arrest.
- Most salt substitutes have potassium.
- Hyperkalemia may occur most often after a weekend or the longest period between in-center HD treatments. Some salt substitutes Oranges and
some juices
Cantaloupe Potatoes and sweet potatoes
Nuts and beans Chocolate Dried fruit
Avocado
Tomatoes
Bananas
Fresh-cooked spinach
51 31
also be controlled with phosphate binders and diet, and by avoiding some foods like dairy products (see Figure 19). Patients often find it very hard to control phosphorus. High blood phosphorus levels, or hyperphosphatemia, is related to secondary hyperparathyroidism and bone damage which may have no symptoms until significant damage has been done. High serum phosphorus is linked with an increased risk of death.36 A typical phosphorus diet limit is 800-1,000 mg/day adjusted for dietary protein needs.36 Foods high in phosphorus include dairy, meats, nuts, peanuts and other dried beans and peas, whole grains, chocolate, and colas. Many foods that are high in phosphorus are also good sources of protein. Dietitians work with each patient to develop a healthy meal pattern that meets their needs. Patients find it a challenge to control phosphorus, as it is found in so many foods and requires many extra daily medications. Phosphate binders are a group of medications used to control the amount of phosphorus absorbed from food. They should be taken with meals and snacks. Patients who take binders often complain of constipation. In these cases, the doctor may prescribe a stool softener, since most patients on hemodialysis have limited fluid and fiber intake. VITAMINS Dialysis removes some water-soluble vitamins, so patients need supplements. But megadoses of water-soluble vitamins (biotin, folacin, niacin, pantothenic acid, riboflavin, thiamin, and vitamins B12, B6, and C) or any fat-soluble vitamins (vitamins A, D, E, and K) are not recommended for them. Patients should take 60-100 mg of vitamin C, 0.8-1.0 mg (800-1,000 mcg) of folic acid, and the recommended Dietary References Intakes (DRI) for the B-complex vitamins (see page 31 for information on active vitamin D). Patients should talk to their doctor, dietitian, or pharmacist before they take any over-the-counter product including vitamins, herbs, or home remedies. Many products are removed from the body by healthy kidneys. Dialysis patients may build up toxic levels of these substances in the blood. Helping Patients Cope Stage 5 chronic kidney disease (CKD) can cause many problems for patients. Eighty-nine

Suggestions for Patients on Managing Phosphorus Levels
- Do not skip or shorten treatment time; dialysis removes some phosphorus, so it helps to get every minute of treatment the doctor prescribes.
- Follow a low phosphorus diet.
- Take phosphate binders with meals and snacks.

Figure 19:
Examples of high phosphorus foods
Chocolate Dairy products Colas Nuts and dried beans
Pizza
percent of patients have said that they have major life changes because of it. Working, eating, sleeping—even planning a daily schedule around dialysis—can be a huge challenge for patients and their families. Patients who are diagnosed with kidney failure often have many serious questions, such as:

- Will I die?
- Will my life be worth living?
- Can I still work and take care of my family?
- Will I be able to pay for my treatment?
- What about my relationship; will my partner leave me?
- Will I ever feel better?
- Why me?

It is common for patients to move back and forth from anger, depression, fear, and denial to adjustment and acceptance of the illness and treatments. How each patient adjusts depends on many factors, including personality, support from family and friends, and other health problems. All center staff will see patients who are under emotional stress at some point in their coping with dialysis.

Patients who are just starting treatment may be very fearful and depressed. When they start to feel better physically, they may feel more hopeful again, and grateful that dialysis can keep them alive. This is sometimes called the "honeymoon period." During this time, a person may resume some previous activities and start to plan again for the future.

But, when the chronic nature of kidney failure and the ongoing demands of treatment sink in, a patient may feel angry and depressed again. This may also happen if a patient has medical setbacks or problems during a treatment. Patients react not only to their real losses but also to potential losses—what they imagine their future would have been like if they had not become ill. They may resent having to depend on machines, the care team, and their families.

FINANCIAL CONCERNS

Many people on dialysis have money problems— their bills don’t stop just because their kidneys did, and disability or retirement pays most people much less than work did. Yet, they may need to buy special foods, costly drugs, and transportation to and from the center three times a week if they choose in-center HD.

TRAVEL

Many patients are able to travel, even though they must arrange dialysis treatments away from home. Most dialysis companies have a system for matching patients with a center away from home. Your social worker and/or charge nurse can help patients arrange treatments in just about any location world-wide. There are some barriers to overcome. Not all centers have room or staff to care for visiting
patients. Some private insurers won't pay for out-of-network care. Insurance regulations may require that the patient pay for part or all of the treatment they receive while traveling. However, many patients travel, and it can be arranged. The best way to assure space in a dialysis center away from home is to plan in advance.

BODY IMAGE/SEXUALITY

Body image concerns occur often. Patients may think their vascular accesses or peritoneal catheters
are ugly, or may worry about loss of muscle mass, scars, and hair loss (usually temporary if caused by dialysis). Patients of all ages have issues related to sexuality and reproduction. People on in-center hemodialysis and peritoneal dialysis may report problems with sexual function due to their illness or drugs they take, and this is a vital issue for them.71 Female patients are also less likely to get pregnant; if they do, they may have problems. About half of babies born to women on dialysis survive. Baby survival is better with more intensive dialysis (e.g., daily or nocturnal treatment).72

PAIN
Both hemodialysis and peritoneal dialysis patients report having pain.73 Pain can result from surgeries, cramping, needle sticks, neuropathy, and bone disease. Iacono found that 60% of people on dialysis had chronic pain, and that 66% of these patients were on prescription pain pills.74,75

LIFE CHANGES
In many cultures, where events center on food and drink, people on in-center HD may feel isolated. They may not be able to eat pizza and french fries when out with their friends, or eat the ethnic meals they used to share with their families. Having to limit food and fluids and learn new ways to eat and cook is a huge day-to-day burden. Most of us would have a very hard time dealing with the significant lifestyle changes that come with kidney failure. Patients may react to the changes in their lives by withdrawing; missing treatments; leaving early; or acting hostile, very dependent, or demanding. Beneath these behaviors is a grieving process for the loss of the way things used to be. Try to keep this in mind when you work with patients who may be rude or mean to you. Patients’ families also have problems coping with the illness and its treatments.76 MacDonald found, for example, that mothers of children with ESRD have a hard time adjusting to the impact of the illness on their lives.77 Anxiety and depression often occur in people with kidney failure. One study found that 52% of ESRD patients had significant anxiety;78 another found that 49% were depressed.79 Members of the care team must understand that anger, depression, and/or denial are normal reactions to a chronic illness, such as CKD. If the patient can talk and problem-solve with a caring, sensitive staff member, this can help the patient adjust. You can play a pivotal role in helping patients adjust by talking to them and by referring them to the social worker, who is specially trained to help people cope with their feelings and behaviors, and to help ease grief.

COMMUNICATION
The way you interact with your patients is very
important in their care. Everything you do and say, along with your body language, are part of the care you provide and the messages you give patients. Keep good communication in mind at all times.

Patient Confidentiality

Medical records and talks with patients are confidential. Patients need to feel safe in the center, and this extends to keeping their confidences in the team and in the treatment setting. We can do enormous harm with idle lunchroom or elevator gossip. Patients see and hear everything in a dialysis center. Patients need to feel that all of their information is taken

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seriously and not shared inappropriately with others. You should never discuss a patient’s condition when anyone can overhear. The main rule of patient/caregiver interaction is confidentiality. Anything patients share with their team must be held in strict confidence.

The Health Insurance Portability and Accountability Act (HIPAA)

In 1996, The Health Insurance Portability and Accountability Act (HIPAA) became law and created national rules about the security and privacy of health data, that took effect in 2003. Since then, there have been major changes in how patient information can be stored. There are also serious limits now on sharing patient information, and guarding patient confidentiality and privacy. Your center will have its own rules to meet the HIPAA standards. Ask your manager or administrator how to follow HIPAA rules in your center to be sure you are keeping your written and electronic patient records private.

Active Listening

Active listening is a skill used to give patients undivided attention and to be sure you understand them. Active listening involves a close focus on the patient’s words and asking questions to be clear on the key points. Some things you can do to be a good, active listener are talk very little; use short, open-ended questions to draw out what the patient means; and make eye contact. Focus on both the words and the non-verbal clues, asking questions like:

- Can you describe the pain in your feet?
- Do I understand you to mean that you...?
- Can you tell me more about what you ate yesterday?
- How did you feel when you learned you had to have another access surgery?
- Tell me more about the pain you describe.

Watch body language, facial expressions, and tone of voice. Caregivers use these clues to help patients share their feelings and to find more information. Open-ended questions followed by silence can help patients tell you what is really going on. These questions also can help patients get out bottled-up emotions, and send the message that you care and will accept and support them. Don’t ask yes-no questions. Instead, use phrases that need longer answers, such as:

- This must be hard for you
- You seem sad when you talk about having to take early retirement. Can you tell me about it?
- You’ve been through a lot
- You seem angry today
- Mr. Jones, you are very quiet today. Can you tell me what’s bothering you?
Active listening is a skill that takes time to learn. One sign that you are not doing active listening is that you find yourself preoccupied with what you want to tell the patient, rather than listening to what he or she is telling you. You can learn to be a good listener by paying close attention and learning to draw patients out. You will be the team member who spends the most time with the patient, and your skills will help you report key information to the other team members. What you observe will help the whole team better care for each patient.

Boundaries

Psychological boundaries are the rules people use to create appropriate relationships with each other. In the healthcare setting, good boundaries are vital to good communication. In a dialysis center, you may spend 40 hours a week in direct contact with patients, and you may see the same patients for years. Staff become very close to patients and to each other. We need this closeness for a good therapeutic relationship, but there is a danger that staff will become too attached to patients, and vice versa. It is also not appropriate to see your patients on a social basis outside the center.

You need to be a professional and not blur the boundaries between a therapeutic and a personal relationship. Patients are not your friends and family, though they may seem close enough to be. You can’t solve everyone’s problems. Most of the time you can only be there to encourage and offer support. Patients may express their feelings to you, and you will need to stay calm and professional no matter what they say. It is not appropriate to give gifts to or accept gifts from patients, or to buy things for or sell things (e.g., candy) to patients; most centers have rules about this.

Focus all talks on the patient, not your own life. This is one way to keep talks professional. Patients do care very much about the staff, but you need to limit the personal details you share with them. People on dialysis have many strong emotions. At times, the center may be the only safe place for them to share sadness or anger. Or, patients may hide their sadness or fear under anger or hostility. Keep in mind that anger though it seems to be aimed at you is most often about other things in their lives. Don’t show anger yourself; you can’t control how you feel, but you can control how you act. As a caregiver, always act in a calm, professional, accepting way. Don’t argue with a patient. If a patient confronts you, seek help from the charge nurse, social worker or other staff. Keeping professional boundaries will help you deal with confrontations calmly and professionally. You will find that most people, when treated with respect, will act with respect. Treat your patients
and fellow staff as you would like to be treated. To help you keep your perspective, remind yourself that patients must cope with many difficult things. Resist the urge to give advice, take on patients' problems, and become emotionally embroiled in their lives. You go home to another life at the end of the shift. Patients must take kidney failure, and the limits of their illness, home with them.

Patient Education
Other team members teach patients. But you, as the person who spends the most time with the patient, must be able to reinforce what has
been taught. So, you need to have a thorough knowledge of CKD and its treatments. Patients will ask you questions. Be sure not to give answers or advice that are beyond your scope of practice. If you don’t know an answer, refer the patient to the right member of the care team. However, you are integral in supporting your team’s learning plan for each patient. Below, we cover some key points about how adults learn.

**READINESS**

Adults learn only when they are ready. Pain and fear can make it impossible to learn. For example, you will notice the dietitian does not try to talk to patients about their diets while you are putting in needles. Don’t try to teach a patient to hold needle sites if they are afraid to touch the access at all. Wait for signs of readiness, such as when a patient asks questions or shows less fear. At first, patients are often too ill or scared to learn much, even though we want them to know as much as possible. This is why it is so vital to repeat information as patients become more ready to learn over time. This is also why it is vital to give patients hope that they can have a good life after kidney failure. If patients are afraid that they will die or have a poor quality of life, they won’t be able to learn. Or, they’ll assume that what you tell them doesn’t matter, since they’re just going to die anyway. Some people live 20 or 30 years or more on dialysis—a fact you can share with your patients. (Read the Rehabilitation section on page 58 about the need for hope.)

**NEED**

Adults learn only what they feel they need to know—what is relevant to their lives. The nurses will assess what the patient wants and needs to know to cope right now, and then develop a teaching plan. The nurse or doctor would not start a detailed talk about transplant drugs at a patient’s first dialysis. Rather, they would be more likely to focus on the machine, the needles, the need for frequent vital sign checks, and how to report symptoms.

**APPROPRIATE LEVEL**

All learning must be tailored to the learner. If Ms. Brown has a PhD in a science field, staff will explain how the dialyzer works quite differently than they would for Ms. Green, who didn’t finish high school. The only way for staff to know patients’ educational background is to ask them—never assume. Appropriate level includes the patient’s ability to see, read, hear, and understand the language. Healthcare professionals have written volumes of patient education materials. Sometimes we are so anxious to get our message across that we forget about things like language level and readability. It does an 86-year-old woman who speaks only Polish little good to receive a detailed pamphlet in English.
As the staff person who talks most to patients, you can help ensure that they receive appropriate information. Pay attention to the questions patients ask, and to their answers to your questions. If you can tell that a language, hearing, vision, or reading barrier is present, alert the nurse. Once aware of the problem, the team can work on a solution.

REINFORCEMENT
Patients get so much information from all of the team members that it is hard to remember it all. Researchers have found that most people need to
see a concept 5-8 times before they learn it. It is not enough to teach something once; teaching must be repeated many times to be learned.

BELIEF
People must believe that the concept the staff is trying to teach them is true, that it will benefit them, and that learning it will have the desired effect on their lives. This is even more vital when you deal with patients who come from other cultures. Often they have very different truths about the effects of some remedies. Dialysis staff must be sensitive to the cultural healthcare beliefs of others. If you think a patient’s religious or cultural beliefs are affecting dialysis care, alert the nurse. The dialysis team, family, and clergy can be called upon to help find answers. The nurses, dietitians, and social workers will assess the patient’s readiness and ability to learn and make a plan to help them learn what they need. Make sure you share any clues or tips you learn from working with the patient with the other team members.

Rehabilitation
When someone has an acute illness, like strep throat, the goal of healthcare is to cure the problem. But a chronic disease like kidney disease will never go away. So, the goal of treatment is not cure—it is rehabilitation: living as normal a life as possible. The purpose of dialysis is to let patients feel their best so they can keep doing things that mean something to them, like caring for children or grandkids, staying active in their towns or churches, golfing, playing music, or keeping a job. When patients are in the center, on the machine, it may seem as if they can’t do much. But when they are outside the center, they are living their lives and you are helping to make that possible.

IMPROVING PATIENT OUTCOMES
In healthcare, we often talk about patient outcomes—the end result of the care we give. Some of the outcomes we look at are morbidity (number and length of hospital stays), mortality (death), quality of life, and a working vascular access. In 1993, the Life Options Rehabilitation Program was formed, with an unrestricted educational grant from Amgen Inc., to look at how to improve outcomes in people with kidney disease. Part of the Life Options model is on the next page (see Figure 20). In it, you can see that the care you and your teammates deliver is vital. And you can also see that the patient has a key role: you can give the best care in the world, and it won’t matter if the patient doesn’t do his or her part to follow the care plan.
So, what is the patient’s part? Self-management. Self-management means that patients learn to become their own experts who can:

- Follow their treatment plans while working with their care teams
- Keep themselves safe by knowing how the treatment should be done
- Recognize and report symptoms to avoid serious problems

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It is self-management that makes rehabilitation possible.

PATIENT
SELF-MANAGEMENT
In a dialysis center, a team takes care of patients. But, as you can see from Figure 21 on page 60, most of the time patients are outside of the center. And, they are caring for themselves self-managing with every bite of food they eat, every sip of fluid they drink, each pill they take or forget, each symptom they report or keep to themselves, and each treatment they go to (or miss).

Life Options studies have found that long-term HD patients (15+ years) self-manage, and that in-center patients who do this may live longer. A recent, large study found that patients who took the lead in choosing their treatment option for kidney failure had a 39% lower risk of death than patients who did not. They were also more likely to get a transplant. The authors say that greater efforts to empower patients with chronic kidney disease may improve clinical outcomes.

You may notice that we have not said that patients must comply or adhere. These terms mean that the patient needs to take orders and do what he or she is told. But patients with a chronic disease are part of their own care teams. They need to have input into the plan of care that they must live with day in and day out for months or years. So, the phrase follow the treatment plan is a better fit for a chronic disease. In the center, it is vital to help patients become their own experts and feel more in control.

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Figure 20:
Life Options model
Care
Delivered
by Providers
Followthrough
by Patients
+ Input
Health
Longevity
Quality of Life
Vascular
Access
Input Input Outcomes
Your center staff can urge patients to do as much as they can, for example:
  - Tracking their blood test results in a notebook
  - Choosing the right foods
  - Learning to put in their own needles
  - Weighing themselves and writing down the number
  - Calculating how much fluid to remove at each treatment
  - Checking their dialyzer with a staff member
  - Checking their machine settings and dialysate
  - Telling the staff about any symptoms they are having
  - Knowing what each of their pills is for and how to take them the right way

This is where you come in. Research shows that attitudes of family members and staff have a profound effect on patients. When patients believe their families and caregivers think they can do well, they believe it, too—and they are even more likely to keep their jobs.83

As someone who talks to patients often, the messages you give are very important.

THE IMPORTANCE OF HOPE

For patients to self-manage, they must first believe that they can have a good life on dialysis. Hope for a good life can motivate patients to learn. Then, patients must know that they need to take an active role in their care. This idea is new to many patients (and staff, too). They need to ask questions and seek information so they can understand their disease and its treatment. Finally, they need to take action to feel their best. This includes doing some type of exercise as well as staying active in work, hobbies, and community life. All of this can be summed up in three words:

1. Attitude — looking on the bright side, being grateful to be alive
2. Answers — learning what they need to know to care for themselves
3. Action — staying involved in the world and keeping physically fit

Attitude

While social workers and nurses play a major role in helping to orient new patients and address their fears, you, too, are a key staff person who can help give patients hope.

How? Here are several ways:

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Figure 21:
Patient time in-center vs. time on own in a typical week

Time on own
92%

Time at in-center dialysis
n Have a positive attitude yourself. As the saying goes, "Attitudes are contagious. Is yours worth catching?" Be excited when patients tell you they have done something new. Praise their efforts.
n Expect patients to keep up with their favorite activities. Some patients assume that because they are "sick" they can no longer sing in the choir, mow the lawn, or do other things they enjoy. Since this illness will not go away, we need to challenge these ideas. Ask, "Why not?" when patients tell you they can't do something.
n Share success stories. Give patients some examples (with no names) of what others with kidney failure have done, whether it is travel to visit grandchildren, plan a family reunion, or start a business. (A center newsletter or a patient bulletin board can highlight patient achievements and inspire other patients to try new things.)
n Ask patients to help with their treatments. Self-care is a very powerful tool to foster hope. Chronic illness can make patients feel as if they have lost all control of their lives. Regaining some control by taking part in treatment, even if at first their role is very small, can build self-esteem. Small successes build confidence so patients feel they can take on bigger challenges.
n Talk to patients and find out what they value most. Use this to help motivate them to work harder toward rehabilitation.
n Act as a holder of hope. Patients can't see the light at the end of the tunnel. They have never walked this path before. Staff can hold out the hope that the patient will begin to feel better in a month or two.

Answers
Think about how much you must learn to become a technician. Patients also need to know a lot to live well with kidney failure. Knowledge reduces fear and improves coping skills. All staff can help patients learn. As a technician, you can help in these ways:
n Talk about what you're doing as you do it. Even if patients do not ask questions, you can explain how the machine works, how the alarms protect them, what the dialyzer does, and other steps.
n Be askable. Take a moment to answer patients' questions or tell them when you can talk to them in more detail. If you don't know an answer, never guess. Refer the question to another staff person or learn the right answer.
n Ask patients simple quiz questions. If you have been telling a patient about the machine, for example, ask what the dialyzer does, or ask them other basic questions, like, "What is anemia?" Explain things in simple
language.

Report patient questions or misconceptions to the nurse or social worker. By pooling information about what patients are asking and what they do and do not know, the entire team will be better able to help patients learn more.

Action

Staying active in life includes things like keeping a job, volunteering, or exercise. Work is a source of income, health insurance, identity, and self-esteem. Patients who are just starting dialysis may suffer from uremic symptoms and not know that they will feel better in a few weeks.
weeks. They may be told to quit their jobs and go on disability, which can make it very hard to return to work later.

Keeping a job
Only about 1 in 4 working-age in-center HD patients keeps a job, but another 21% have said that they are willing and able to work.83 Helping patients keep their jobs is much easier than helping them to find new ones. Sometimes center barriers, like scheduling problems, force patients to quit their jobs. Centers can remove these barriers by adding evening or early morning shifts, offering home dialysis, or letting working patients bump non-working patients off the shift they need.

Urge patients who are working or in school to stay there. Patients who are willing and able to work but don’t have jobs will need help from the social worker and a vocational rehabilitation agency. Other patients who are too old, too ill, or unable to work may still be able to pursue hobbies, travel, or exercise.

Staying fit
Research shows that people on dialysis who say they have good physical functioning live longer than patients who don’t.84 One large study found the highest survival rates among patients who exercised from 2.5 to 5 times per week.85 Exercise for people on dialysis may be, literally, a matter of life and death.

Some patients can keep doing exercise they did before dialysis or can start an exercise program. Patients with heart disease may need a cardiac rehabilitation program. Others who are very weak or have other illnesses may need physical therapy to be able to exercise. Some centers offer exercise during treatment, which can improve heart health; reduce blood pressure and muscle weakness; relieve anxiety, depression, and fatigue; and increase the level of wastes and phosphorus removed in a treatment.86 The biggest barrier to exercise is a patient’s lack of motivation87—something you can help with.

How you can help
You can help patients stay active in life by doing the following:

n Suggest that patients with employment concerns talk with the social worker. The social worker has resources and ideas that can help patients keep their jobs. For example, a leave of absence may help a patient avoid disability.

n Work with the nurse and other team members to help patients understand their disease and its treatment. Once they know what to expect, they can explain it to an employer.

n Talk to patients about what they enjoy doing. Help them brainstorm work or volunteer
tasks that can help keep them involved in life.

- Talk with retired patients to help them plan activities they will enjoy.
- Share success stories (without violating patient confidentiality).
- Ask patients what they do for regular exercise. Sometimes just asking the question is enough to make patients realize they do not have to stop exercising because of their illness.
- Urge patients to take part in your center’s exercise program, if you have one.

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Patients who hear the same message about exercise from all of their care team may be more likely to believe it. Encourage people to walk as much as they can. Ask the nurse if the patient’s ability to walk would be helped by a visit to a podiatrist or a physical therapist.

Allow patients to do as much as they can, physically. It may be faster to offer wheelchairs to frail elderly patients when they come for treatment. But patients who stop using their physical abilities will lose them and, in this case, may also lose the ability to live independently.

Share success stories. Again, while keeping patient confidentiality, you can talk about other patients you know who play golf or tennis, belong to a walking club, or lift weights.

Patient Resources

Many patient resources are available, and as a dialysis technician, you should know them in case a patient asks you for information. In fact, you may want to join these groups or visit their websites to learn more about kidney disease. Besides these national programs, there may also be local groups in your area.

AMERICAN ASSOCIATION OF KIDNEY PATIENTS (AAKP)

The AAKP is a support and advocacy group for people with kidney failure and others who want to help them. AAKP chapters are located in many states. Membership includes a quarterly magazine and materials on topics like treatment options, adequate dialysis, the Americans with Disabilities Act, diet guides, and blood test values. The AAKP also holds an annual meeting each year for members. The AAKP can be contacted by calling (800) 749-AAKP, or visiting the AAKP website at www.aakp.org.

AMERICAN DIABETES ASSOCIATION (ADA)

The ADA is a large non-profit organization that provides diabetes information, research, and patient advocacy. The mission of the ADA is to prevent and cure diabetes, and to improve the lives of all people who have the disease. Many publications are offered for both patients and healthcare professionals. You can call the Diabetes Information and Action Line (DIAL) at (800) DIABETES. The ADA website is www.diabetes.org.

AMERICAN KIDNEY FUND (AKF)

The AKF is an organization dedicated to improving the lives of people with kidney disease. Programs include small direct grants to patients; publications on topics like diabetes, diet, organ donation, treatment options, and kidney disease in African Americans; and a tollfree Helpline to answer questions at (800) 638-8299. The AKF website is www.kidneyfund.org.
DIALYSIS FACILITY
COMPARE (DFC)
Medicare maintains a website that compares all of the dialysis centers in the United States. Patients and staff can look up a center to find out its address, phone number, hours, treatments offered, owner, etc. Certain quality information is also compared, including adequacy, anemia treatment, and survival rates. You can find DFC on the www.medicare.gov website.
END-STAGE RENAL DISEASE NETWORKS
The 18 regional ESRD Networks are private, non-profit, federally-mandated agencies that exist to improve the quality of healthcare and quality of life for ESRD patients, and to gather and report data on ESRD. Among other activities, Networks handle grievances for patients that cannot be solved by the center. You can find your local Network on the Forum of ESRD Networks website at www.esrdnetworks.org.

HOME DIALYSIS CENTRAL
The non-profit Medical Education Institute (which also administers the Life Options program and developed Kidney School and this Core Curriculum) has created a resource website to raise awareness and use of peritoneal dialysis and home hemodialysis. The site has a database of every center in the United States that offers home treatments, coverage maps, descriptions of each type of home treatment, active patient and staff message boards, patient stories, slide kits, an equipment catalog, links, and more. You can visit Home Dialysis Central at www.homedialysis.org.

KIDNEY SCHOOL
Life Options offers a free, on-line kidney learning center in sixteen 30-minute modules that can also be downloaded. Each module has a pretest and posttest, photos and graphics, a lesson, a completion certificate, and a Personal Action Plan. Topics include kidneys and how they work, treatment options, anemia, coping, vascular access, sexuality and fertility, nutrition, staying active, and more. Kidney School was designed to help patients learn how to self-manage their kidney disease, and it is also useful background for new dialysis staff. Visit Kidney School at www.kidneyschool.org.

LIFE OPTIONS REHABILITATION PROGRAM
Life Options, supported by Amgen Inc., conducts research and offers free, research-based booklets, fact sheets, posters, videotapes, and audiotapes for patients, families, and renal professionals to support rehabilitation. Information is available on topics including exercise, employment, adjusting to kidney disease, and much more. For publications or answers to rehabilitation questions, call (800)468-7777, e-mail lifeoptions@meiresearch.org, or visit the Life Options website at www.lifeoptions.org.

NATIONAL KIDNEY FOUNDATION (NKF)
The goal of the NKF is to eradicate kidney and urologic diseases. The NKF promotes patient and public education, patient service projects, professional education, research, advocacy for legislation affecting patients with renal failure,
and professional issues. Membership is open to anyone with an interest in kidney and urologic diseases. There is also a large Patient and Family Council. Many brochures are offered on topics like coping with renal failure, dining out, emergency meal planning, anemia, fitness, sexuality, transplant, and others. NKF chapters are available around the country; members receive a quarterly magazine. The NKF can be reached at (800) 622-9010, or visit the NKF website at www.kidney.org.

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PKD FOUNDATION
The PKD Foundation is the only organization worldwide that is devoted to promoting research to find a cure for polycystic kidney disease (PKD). PKD affects 600,000 Americans and 12.5 million people worldwide—more than cystic fibrosis, muscular dystrophy, Down's syndrome, hemophilia, and sickle cell anemia combined. To obtain educational information on PKD, call (800) PKD-CURE or visit www.pkdcure.org.

RENAL SUPPORT NETWORK (RSN)
Started by Lori Hartwell, a long-time kidney patient herself, the RSN helps people with kidney disease become self-sufficient through education, advocacy, and employment. The group helps train patient advocates all over the country to speak up for kidney patient issues to local and national lawmakers. The RSN holds a national meeting each year, and offers a prom in Southern California that is open to teens with kidney failure from across the nation. Find the RSN at www.renalnetwork.org.

Conclusion
A team approach to care that involves the patient, doctor, nurse, dietitian, social worker, and technician can give people with kidney failure the best possible care. With good care, patients can live long and live well on dialysis. You have chosen a demanding but rewarding career. Your contribution to the care of your patients can make a difference in their lives.
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Objectives
After completing this module, the learner will be able to:
1. Define the basic principles of diffusion, filtration, ultrafiltration, convection, and osmosis.
2. Explain how diffusion, filtration, ultrafiltration, convection, and osmosis relate to solute transport and fluid movement during dialysis.
3. Describe the principles of fluid dynamics and how they relate to dialysis.
Introduction
Hemodialysis may seem complex, but it is based on simple scientific principles. This module will help you understand these principles and how they are used in dialysis. Dialysis replaces three main kidney functions:
1. Removing wastes from the blood
2. Removing excess fluid from the blood
3. Keeping electrolytes (electrically charged particles) in balance
You will learn how these three functions are replaced by the dialyzer.

Scientific Principles Used in Dialysis

SOLUTIONS
A solution is a mixture of a solvent and a solute. The solvent is a fluid. The solute is any substance that can be dissolved into the solvent. In salt water, water is the solvent and salt is the solute.

Dialysate is the solution that is used during dialysis. Water is the solvent. The solutes are electrolytes (e.g., potassium, calcium, sodium, magnesium, and chloride ions) and glucose (sugar). Electrolyte levels in dialysate closely match the levels in human blood. This reduces the loss of these electrolytes out of the blood and into the dialysate during dialysis.
The patient’s blood electrolyte levels can be controlled by changing the dialysate. Adding an electrolyte to the dialysate at a level higher than in the blood will allow the electrolyte to enter the patient’s blood during a treatment.

SEMIPERMEABLE MEMBRANE
A semipermeable membrane is a type of thin, flexible filter—a barrier that allows only particles smaller than a certain size to pass through it. Think of the membrane as a strainer you might use to drain noodles. The water drains out, but the noodles are too big to pass through the holes.
In dialysis, the semipermeable membrane’s holes allow small molecules, such as water and urea, to pass through easily. Middle molecules can also pass through, but more slowly. The small size of the pores keeps larger molecules and blood cells from passing through the membrane.

DIFFUSION
Diffusion is the process by which atoms, molecules, and/or other particles move from an area where they are in high concentration to an area where they are in low concentration. For example, when a tea bag is placed in hot water, molecules from the tea leaves diffuse into the water and flavor it (see Figure 1 on page 78). Diffusion can occur in solids, gases, or liquids, such as blood. Energy for the movement comes from the molecules themselves, and does not depend on outside forces.
In the body, substances move into and out of cells by diffusion through the cell membranes. In dialysis, diffusion occurs across an artificial semipermeable membrane. This is how wastes and fluid are removed from the patient’s blood, and electrolytes are balanced. The following factors affect all diffusion from tea bags to hemodialysis.
Factors Affecting Diffusion: the Nature of the Solution
1. Concentration gradients: How concentrated is the fluid on each side of the membrane? Solute movement through a semipermeable membrane from an area of greater concentration to an area of lesser concentration. Solutes can move through a membrane in either direction, but always toward the area of lesser concentration. A gradient is a difference. As the concentration gradient—the difference in solute concentration—increases, solute movement increases, too. Diffusion stops when the concentrations on both sides of the membrane are equal. Concentration gradients allow dialysate to remove wastes from a patient’s blood and to balance electrolytes in the blood with electrolytes in the dialysate.
2. Molecular weight of the solutes: How large are the dissolved particles? Smaller molecules diffuse more easily and quickly than larger ones. Large blood components, such as red blood cells, white blood cells, albumin, and platelets, as well as viruses and bacteria, diffuse more slowly because they are bigger. Small molecules, such as urea and salts, diffuse faster. Middle molecules may pass through, but more slowly.
3. Temperature: How warm is the fluid? Molecules move faster at higher temperatures, so warmer fluids allow faster diffusion. This is why you’ll get tea sooner if you put your tea bag in hot water instead of cold water. Dialysate temperature is controlled during dialysis for patient safety, comfort, and faster diffusion.

Factors Affecting Diffusion: the Nature of the Membrane
1. Membrane permeability: How plentiful and large are the pores? A membrane with more pores allows faster diffusion. Larger pores allow larger molecules to pass through. The membrane’s thickness and design also affect the diffusion rate (see Figure 2).
2. Surface area of the membrane: How big is the membrane? Surface area is the amount of membrane in direct contact with the blood and dialysate. Larger surface areas allow more diffusion.
3. Flow geometry: How do the fluids flow? In dialysis, blood flows one way while dialysate flows the opposite way (see Figure 3). This countercurrent flow of blood to dialysate speeds up diffusion, because with this...
Diffusion through a semipermeable membrane

Tea particles diffuse into the water.

An ordinary tea bag is made of porous paper—a semipermeable membrane. Tiny holes allow the tea particles to come out into the water, but keep the tea leaves in the bag.
arrangement, a high concentration gradient between the blood and dialysate can be maintained throughout the length of the dialyzer. (A concurrent flow would occur if blood and dialysate moved in the same direction).

OSMOSIS

In diffusion, solutes move. In osmosis, the solvent moves across the membrane. Osmosis is movement of a solvent through a semipermeable membrane from an area of lower solute concentration toward an area of higher solute concentration. The difference in concentration is called an osmotic pressure gradient. In both diffusion and osmosis, movement goes on until the concentration of molecules equilibrates (becomes equal) on both sides of the membrane.

Imagine a jar divided in two by a membrane that allows water but not glucose molecules to pass through. If you fill one side of the jar with water, half of the water will slowly pass through the membrane, until the water level on both sides of the jar is the same. You could then dissolve sugar on one side of the jar, to create a difference in glucose concentration between the two sides. Osmotic pressure created by the sugar would draw water across the membrane to dilute the sugar water. In time, the level of sugar water would rise above the level of pure water. The more sugar you added, the higher the osmotic pressure would build, and the higher the sugar water level would rise. Osmotic pressure can be overcome by hydraulic pressure using a pump, gravity, or other means. The total pressure on a fluid will include both.

Figure 2:
Membrane and fiber characteristics
Figure 3:
Blood and dialysate flow:
Countercurrent directions
Wall thickness
Internal diameter
190 to 240µ
Surface area
Number and size of pores
Blood
Drawing adapted with permission from Althin Academy, Miami Lakes, Florida
Blood out
Blood in
Used dialysate and excess fluid from the patient’s body out to drain
Each blood-filled fiber is surrounded by dialysate
Dialysate in
Direction of blood flow
Direction of dialysate flow
Single, hollow fiber
osmotic and mechanical forces. In our jar, hydraulic (mechanical) pressure was applied by gravity. Water would be pulled into the sugar water until the osmotic pressure is equal to the pressure created by the weight of the water. The osmotic pressure drops as the sugar water is diluted. Hydraulic pressure can reduce or overcome osmotic pressure. If you raised the hydraulic pressure on the sugar water in the jar, you could overcome the osmotic pressure. This would cause water to move from the sugar water back into the pure water. This principle is the basis for reverse osmosis water treatment devices.

FILTRATION AND ULTRAFILTRATION
Filtration is movement of fluid through a filter as the result of hydraulic pressure. Fluid will always move from a higher pressure to a lower pressure. The filter traps any matter that is too large to pass through it.

In dialysis, ultrafiltration (UF) is used to remove excess water that has built up. The filter used in UF is a semipermeable membrane.

Convection is the transfer of heat and solutes by physical circulation or movement of the parts of a liquid or gas. In dialysis, convective transport leads to solvent drag.

As a solvent crosses a semipermeable membrane, it drags along smaller solutes.

FLUID DYNAMICS
A fluid is a liquid or gas that changes shape at a steady rate when acted upon by a force. The field of dynamics addresses the motion and equilibrium of systems. Fluid dynamics applies to dialysis, because it describes how two fluids are pumped through tubing. Within the dialyzer, blood and dialysate are kept apart by the semipermeable membrane.

Figure 4: Diffusion, osmosis, and ultrafiltration

Semipermeable membrane Pressure
Diffusion is the movement of solutes from an area of higher concentration to an area of lower concentration.
Osmosis is the movement of a solvent across a semipermeable membrane from a lower concentration of solutes to a higher concentration of solutes.
Ultrafiltration is the removal of extra fluid through the membrane using additional
pressure.
Several forces affect the movement, or flow, of fluid through tubing. Flow rate is the amount of fluid that flows through the tubing in a given period of time (e.g., 10 milliliters per minute, or mL/min). Flow velocity is the speed at which the fluid moves through a given length of tubing. Velocity is based on the rate of flow and the area of a cross section of the tube. So, if the flow rate is held constant but the cross section of the tube is reduced by half, the flow velocity will double.

Imagine that one gallon of water must move through a tube with a one-square-inch cross section in one minute. If you reduce the cross section of the tube by half, to 1/2 square inch, the fluid will have to go twice as fast to move a gallon of water in one minute; flow velocity would need to double. Adding a piece of tubing with a 1/2-square-inch cross section to the end of a tube with a one-square-inch cross section will have the same effect: doubling flow velocity. Because all the water must pass through the narrowest part of the tube, the narrowest part of any tubing limits the maximum flow velocity. Adding a second, narrower, piece of tubing also increases resistance to the flow—another force that affects the movement of fluid in a tube. In any tubing, simple friction creates some resistance to the flow of fluid. But a restriction, such as a narrowing of the tube, will greatly increase resistance and so will increase the pressure of the fluid in the tube.

If, for example, the end of a soaker hose is open, water will flow through it freely (see Figure 5). Because there is little resistance, there will be little pressure and the water will dribble out of the holes slowly. But if you raise the pressure, increasing the resistance, the water will squirt out of the holes forcefully.

The pressure in any fluid system is always related to the flow and the resistance; the greater the flow and the greater the resistance, the greater the pressure.

Applying Scientific Principles to Dialysis

Dialysis patients' kidneys don't work. So, they come to dialysis with wastes in their blood, extra fluid between their cells and in their blood vessels, and often with electrolyte imbalances. The main tasks of dialysis are to remove wastes and excess fluid, and balance electrolytes. Blood itself is a solution. Water is the solvent, and electrolytes, glucose, and many other substances are the solutes. Blood also has many particles, such as red and white blood cells. The principles of fluid dynamics, diffusion, UF, and osmosis apply to each dialysis treatment. To use the principles, we expose the patient's blood (a solution) to
Positive pressure in a soaker hose

The principle of positive pressure can be illustrated with an ordinary soaker hose. Positive pressure is exerted against the sides of the hose as the water moves through it. Excess water is forced through the holes.

The same principle is true in the semipermeable membranes used in dialysis. The amount of fluid forced or removed through the pores depends partly upon the amount of pressure pushing the fluid through the line.
the dialysate (another solution) with a semipermeable membrane between them.

**FLUID COMPARTMENTS**

To understand how dialysis removes fluid, you must know how fluids work inside the body (see Figure 6). The human body is made mostly of fluids. Fluids are found inside the cells, tissues, and vasculature (blood vessels). Each of these three sites is a compartment:

- The intracellular compartment is fluid inside the cells.
- The interstitial compartment is fluid in between cells.
- The intravascular compartment is blood inside the blood vessels.

Differences in the level of sodium and electrolytes between compartments (gradients) cause water to move. The body tries to keep equilibrium to have the same level of osmotically-active solutes in all three compartments. If the level is different, water will move from one compartment to another until they are equal. During dialysis, only fluid from the intravascular compartment—the bloodstream—can be removed.

**FLUID DYNAMICS IN DIALYSIS**

Fluid dynamics create changes in pressure as blood is pumped out of the patient's body and through tubing and the dialyzer. Together, the tubing and dialyzer are called the extracorporeal (outside of the body) circuit. When the dialysis machine is switched on and treatment starts, the blood pump speeds the flow of blood from the patient. Blood passes through the needle—the first restriction in the circuit. Because the blood pump is pulling rather than pushing blood through this restriction, the pressure created is usually negative: less than zero. The amount of flow and restriction determine negative pressure, just as with positive pressure (see Figure 7).

As the flow or the restriction increases, the pressure will decrease. (The dialysis machine checks this pressure in the blood tubing before the blood pump [pre-pump arterial pressure].)

As the blood passes through the blood pump, it is pushed against the resistance of:
Perspiration and skin water loss
Dialysate loss
Residual urine
Vomiting
1. The tubing
2. The tiny hollow fibers in the dialyzer
3. The small opening of the (venous) bloodreturn needle (or catheter)

This resistance creates positive pressure inside the lines and dialyzer fibers. As blood passes through these resistances, the pressures change. The highest positive pressure is measured in the arterial header, where blood enters the dialyzer fibers (post-pump arterial pressure). As blood moves through the fibers, resistance drops, so pressure drops, too. The pressure measured after blood leaves the dialyzer (venous pressure) is the lowest positive pressure in the blood path. The average pressure of blood entering and leaving the dialyzer fibers is the true amount of force (positive hydraulic pressure) that aids UF of water out of the blood, through the membrane, and into the dialysate.2 Dialysate flows through the dialyzer and around the hollow fibers in one direction. Blood flows in the opposite direction for countercurrent flow. The machine can control the pressure differential between the blood and dialysate compartment as needed to reach the desired fluid removal. This pressure difference across the dialyzer membrane is called transmembrane pressure (TMP).2

DIFFUSION IN DIALYSIS

Let's review how diffusion takes place inside the dialyzer (see Figure 8 on page 84). The hollow fibers in the dialyzer are the semipermeable membrane. Blood passes through the insides of these tiny fibers (capillaries); dialysate surrounds them on the outside. Molecules of a certain size range pass back and forth between the blood and dialysate, always moving from an area of higher concentration to an area of lower concentration. Wastes in the patient's blood diffuse across the membrane and into the dialysate. Used dialysate is sent to a drain and replaced with fresh dialysate, to maintain a high concentration gradient. This gradient allows as much waste as possible to be removed from the blood during each pass through the dialyzer. Electrolyte balance is also maintained with diffusion. It is vital to patients' health to keep the right level of electrolytes in the blood. To control the balance, electrolytes can be added to the dialysate. 83 9

Figure 7: Actions of positive and negative pressure in dialysis
Drain
Pressure
Dialysate compartment
To
dialyzer
From
patient
Positive
pressure
Pressure
usually
negative
A major source of positive
pressure in the extracorporeal
circuit is the blood pump.
The pump pushes the blood
forward into the dialyzer.
The positive pressure causes
fluid to be pushed through the
membrane into the dialysate.
Dialysate pressure can be
controlled in the dialysate
compartment with a pump.
Fluid removed from the
dialysate lowers the
dialysate compartment
pressure and pulls
additional fluid from the
patient's blood.
Electrolytes will move until the concentration is equal on both sides of the membrane. Keeping a constant low level of an electrolyte in the dialysate ensures that the excess is removed without allowing the levels in the blood to drop too low. Diffusion occurs continuously in the patient’s body. As cleansed blood is returned to the patient, it slowly dilutes the rest of the blood. The drop in the concentration of solutes in the blood creates a gradient between the blood plasma (liquid portion of blood) and the fluid in the cells and tissues. Because these cells have their own membranes, solutes such as wastes and certain electrolytes slowly pass out of the patient’s cells and into the bloodstream. From there, they are dialyzed. This process allows some of the wastes from other body compartments to be cleared from the body by dialysis. This slow process of diffusion is why dialysis treatments require more than one pass of blood through the dialyzer to clear wastes from the blood.

The nephrologist factors in diffusion when prescribing a treatment. He or she can choose a large or small dialyzer, based on the patient’s body size, the length of the treatment needed, and the size of molecules to be removed. The only thing that cannot be chosen is the size of the patient. To get an adequate treatment in a large patient, the doctor can increase treatment time and/or dialyzer size (clearance) to remove more wastes.

UF IN DIALYSIS
UF requires pressure to force fluid through the membrane. The dialysis machine can create a hydraulic pressure difference, with higher pressure in the blood compartment than in the dialysate compartment. This TMP pushes excess water out of the blood and into the dialysate.

A dialysis prescription calls for taking off enough fluid to bring a patient to an estimated dry weight (EDW) by the end of the treatment. To figure out how much fluid you need to remove, just subtract a patient’s EDW from the predialysis weight. Then add the amount of any fluids the patient will receive during the treatment.

CONVECTION IN DIALYSIS
As water (a solvent) moves from the blood compartment to the dialysate compartment, molecules of dissolved solute are dragged along too (solvent drag). This process of solvent Figure 8: Diffusion inside the dialyzer
Dialysate
Dialysate
Blood
Hollow fibers
Blood compartment
Dialysate compartment
Blood
Solute moves between
dialysate and blood to
maintain equilibrium
Excess fluid moves
into dialysate
Cleansed blood
is returned to
the patient
Blood flows
through hollow
fiber; wastes are
removed with
excess water
Urea and
other wastes
move into the
dialysate
movement is called convection. The ease with which the solute is dragged along by the solvent is determined by the size of the solute molecule compared to the size of the membrane pores. Smaller solutes move easily, so the solution can sieve across the membrane without any change in concentration. But larger solutes move more slowly and the rate of convective transport is also slower. Thus, the convective transport of a solute depends on how porous (both size and numbers of holes) the membrane is. This measurement of porosity is known as the sieving coefficient (SC) of the membrane. An SC of 1.0 means that, barring other clinical factors, the membrane could allow 100% of a given solute to pass. An SC of 0.4 means that only 40% of a solute would pass and 60% would be kept in the blood.

OSMOSIS IN DIALYSIS

Osmosis also plays a key role in dialysis. The pressure of UF pushes fluid out of the blood and into the dialysate. But osmotic forces decide which way water will move from one body compartment to another. In hemodialysis, diffusion lowers the solute concentration in the blood. Higher solute concentration in the tissues and cells then pulls water out of the blood. Rapid drops in blood volume can occur, which causes drops in blood pressure and other symptoms. Often, sodium is added to the dialysate, so it diffuses into the blood. The higher blood sodium draws water from other body compartments into the blood, so it can be removed by UF. The sodium in the dialysate is then lowered towards the end of the dialysis treatment to pull the sodium back out of the bloodstream.

Conclusion

Understanding the principles of dialysis is key to knowing how the patient’s blood is cleaned by dialysis. Diffusion, filtration, UF, convection, and osmosis must occur in the right amounts at each treatment. If you understand dialysis well, you will see how the treatment can be tailored to meet the needs of each patient. You can play a crucial role in delivering the best dialysis treatment each patient can receive.
Learning Activities

INSTRUCTOR TOOLS
n Potassium permanganate (available from the lab or pharmacy)
n Sheets of cellophane (to make bag)
n 3-cc syringe (without needle, to fill bag)
n Clear glass beaker, large jar, or a bowl
n Soft rubber or silastic tubing or hose that will fit on end of faucet
n Tea bag
n Sodium chloride (table salt)

ACTIVITIES
n Select a patient dialysis record and review the principles of dialysis as seen in the chart.

n Demonstrate the principles of flow, pressure, and resistance by attaching a 12-inch segment of soft rubber tubing to a faucet. Hold the rubber tubing perpendicular to the faucet and turn the water on until water flows slowly out the end of the hose. Do not adjust the flow, but lower the hose into the sink or a bucket. You will notice that the flow of water is faster, because resistance to the flow has been decreased. By increasing the flow, the pressure of the water coming out is also increased. Now, gently pinch the tubing closer together, increasing the resistance to the flow. You will notice an increase in the pressure as the water comes out the end of the tubing. Flow, pressure, and resistance are closely related, and each has an effect on the others. This is also true in the hemodialysis circuit. An obstruction at the venous needle increases resistance to the blood flow, increasing the venous pressure reading.

n Demonstrate diffusion and filtration by placing a tea bag in a glass of hot water. Tea coloring will slowly diffuse through the glass of water. Meanwhile, the semipermeable membrane of the tea bag has filtered the tea leaves, preventing them from passing across the membrane.

n Demonstrate filtration and UF by soaking a sponge in water. Hold the sponge over the bucket of water and watch the sponge filter the water. Now apply positive pressure to the sponge (squeeze it) and see how much more water can be removed, or ultrafiltered, by applying pressure.

n Demonstrate diffusion and osmosis by making a bag out of a piece of cellophane. (Be sure to wet the membrane so that it does not tear as easily.) Into this bag, place 1 cc of potassium permanganate solution and suspend the bag in a beaker or glass of water. Very quickly, the potassium permanganate will diffuse into the water. At the same time, osmosis will take place. The volume inside the bag will increase as water enters the
bag to equalize the concentration on both sides of the membrane. This process can also be demonstrated with salt water in the bag instead of potassium permanganate. The water in the glass will become salty, while the volume in the bag will increase as water moves into the bag in an attempt to equilibrate the concentrations of salt on both sides of the bag.

Diagram the extracorporeal blood circuit; label compartments, direction of flow of blood and dialysate, and points of resistance.

Observe the calculation and application of TMP to dialysis.

Note patient predialysis and postdialysis weight.

Principles of Dialysis
References
Objectives
After completing this module, the learner will be able to:
1. Identify the purpose and characteristics of dialyzers.
2. Describe the purpose and chemical composition of dialysate.
3. Describe dialysate preparation and the three monitoring functions of the dialysate delivery subsystem.
4. Describe the extracorporeal blood circuit functions and monitoring systems.

Module 4 cover photo credit:
Photo of dialyzers reprinted with permission from Jim Curtis, 2005.
Introduction
A dialyzer (see Figure 1) lets the patient’s blood interact with dialysate through a semipermeable membrane. Dialysate is a blend of treated water and chemicals; it removes wastes and fluid, and balances electrolytes. A delivery system supplies fresh dialysate and removes used dialysate.
Modern, high-tech delivery systems include a blood pump, an ultrafiltration pump, a dialysate conductivity monitor, alarms, and pressure gauges. Better membranes, safety monitors, and the use of computers have made dialysis safer.

These advances allow today’s staff to turn more of their time to patients. Trained staff who know dialysis principles, equipment, and procedures are the most vital monitors of patient safety.

This module covers hemodialysis devices, including dialyzers, dialysate, and delivery systems. If you carefully follow your center’s procedures and apply the principles reviewed in this module, you can master the use and maintenance of each device and help deliver safe dialysis treatments.

Dialyzers
FUNCTIONS AND COMPONENTS
Healthy kidneys play a key role in one of the body’s most complex tasks—keeping a constant, stable setting for cell survival, even with changes in diet and fluids, exercise, and health or illness. This stable environment is called homeostasis.

The dialyzer, dialysate, and delivery system replace some tasks that failed kidneys can no longer do. Today’s dialysis treatment can remove wastes and excess fluid and help keep electrolytes and pH (acid and base balance) at levels that sustain life.

Every dialyzer has a blood and a dialysate compartment. The semipermeable membrane keeps the two compartments apart. The membrane is housed in a plastic case, which holds the dialyzer together and forms pathways for blood and dialysate to flow in and out.

During a treatment, the patient’s blood, with high levels of electrolytes, water, and wastes, flows through the blood compartment. Dialysate, a solution made of chemicals much like those in blood, flows through the dialysate compartment on the other side of the membrane.

DIALYZER CHARACTERISTICS
Many aspects of a dialyzer can affect treatment effectiveness, comfort, and patient safety. These include biocompatibility (how much a membrane is compatible with the human body), membrane...
Dialysate out
Blood
flow from
patient
Blood
back to
the patient
Dialysate in
Fibers
Figure 1:
Dialyzer
surface area, molecular weight cutoff (the solute size that can pass through the membrane), ultrafiltration coefficient, and clearance (the rate of solute removal).

Biocompatibility
Biocompatible means not harmful to biological function. When blood touches a foreign substance, immune cells in the blood react to defend the body. This defense, which involves complement activation and other mechanisms, can vary from clotting, which prevents blood loss, to severe allergic reactions. All materials used to make dialysis membranes react to some degree with immune cells in the blood. These effects may be so subtle that the patient does not notice them. They may cause minor symptoms during a treatment. Or, major life-threatening allergies (anaphylaxis) can occur. It is vital to use a membrane the patient can tolerate.

Biocompatibility of a membrane can be tested by checking the patient’s blood for certain proteins and chemicals. The body releases these when blood meets a foreign substance. Their levels suggest how biocompatible a membrane is with the patient’s blood.

A membrane’s ability to adsorb (attract and hold) proteins into the fiber wall is key to its biocompatibility. Adsorbed proteins coat the surface so blood does not touch the membrane. This protein coating explains why reprocessed (cleaned and reused) dialyzers can be more biocompatible than new ones (note: reprocessing dialyzers with bleach can strip the protein coating off the membrane).

In general, synthetic membranes are more biocompatible than cellulose membranes. Synthetic fibers are hydrophobic (waterrepelling); this makes them better able to adsorb blood proteins.

Surface Area
Surface area is key to how well a dialyzer can remove solutes. If all other aspects are equal, dialyzers with more surface area can expose more blood to dialysate. This means more solutes can be removed from the blood. Total dialyzer surface area can range from 0.5 to 2.4 square meters.

Mass Transfer Coefficient
Mass transfer coefficient (KoA) is the ability of a solute to pass through the pores of a dialyzer. The KoA, in theory, is the highest possible clearance of a given dialyzer at infinite blood and dialysate flow. The higher the KoA, the more permeable the dialyzer.

Molecular Weight Cutoff
Each membrane has a molecular weight cutoff which determines the largest molecule that can pass through the membrane (see Figure 2).
Molecular weight is measured in daltons (Da). It is the average weight of a molecule, expressed as the sum of the atomic weights of all the atoms in the molecule. Larger molecules have higher molecular weights; smaller molecules have lower ones (see Table 1). Knowing the range of molecular weights that each membrane will allow through helps doctors choose membranes that will remove certain molecules from the blood. Dialyzers can be chosen with molecular weight cutoffs ranging from 3,000 Da to more than 15,000 Da.
Ultrafiltration Coefficients

Another key aspect of a dialyzer is how much ultrafiltration (UF) of water can occur across the membrane. UF is a way to remove excess water from a patient during hemodialysis by applying pressure. Hydraulic pressure applied to the blood or dialysate compartment forces water across the membrane. The dialysis machine can vary the hydraulic pressure to control the ultrafiltration rate (UFR) and amount of water removed. High pressure in the blood compartment forces more fluid out of the blood and into the dialysate. The pressure difference across the membrane (blood compartment pressure minus dialysate compartment pressure) is transmembrane pressure (TMP). Each dialyzer has a manufacturer’s ultrafiltration coefficient (KUF). The KUF is the amount of fluid that will pass through the membrane in one hour, at a given pressure. The KUF helps the staff member predict how much fluid will be removed from the patient during a treatment.

For example, a dialyzer with a KUF of 10 will remove 10 mL of fluid per hour for each millimeter of mercury (mmHg) of pressure. This is stated as mL/mmHg/hr. Let’s say a dialyzer has a KUF of 10, and a TMP of 100 mmHg. In this case, the patient would lose 1,000 mL of fluid per hour of dialysis (10 x 100 = 1,000).

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Molecular Weight (Da)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin</td>
<td>66,000</td>
</tr>
<tr>
<td>Calcium (Ca++)</td>
<td>40</td>
</tr>
<tr>
<td>Creatinine</td>
<td>113</td>
</tr>
<tr>
<td>Nitric Oxide (NO3 -)</td>
<td>62</td>
</tr>
<tr>
<td>Phosphorus (PO4 2-)</td>
<td>94.9</td>
</tr>
<tr>
<td>Urea</td>
<td>60</td>
</tr>
<tr>
<td>Water (H2O)</td>
<td>18</td>
</tr>
<tr>
<td>Zinc (Zn2+)</td>
<td>65.3</td>
</tr>
</tbody>
</table>

Figure 2: Molecular weight cutoff
Drawing adapted with permission from Althin Academy, Miami Lakes, FL

Molecular weight (daltons)
Sieving coefficient*
0 100 1,000 10,000 20,000 50,000 60,000 100,000
<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Molecular Weights
*See page 94 for a definition of sieving coefficient.*
Clearance
Dialyzers vary in how well they remove solutes from the blood. The amount of blood that can be cleared of a solute in a given period of time is called clearance (K). Clearance rates for different molecules are given by the manufacturer for certain blood and dialysate flow rates. The Appendix on page 116 describes the formula for determining dialyzer solute clearance. There are three main ways to remove solutes that affect a dialyzer’s clearance: diffusion, convection, and adsorption.

Diffusion
Most solutes are removed during dialysis by diffusion: movement of solutes across a semipermeable membrane from an area of greater concentration to an area of lesser concentration, until both sides are equal. Diffusion is the best way to remove small, low molecular weight solutes. The diffusion rate depends on blood and dialysate flow rates; membrane surface area and thickness; number of pores; solution temperature; membrane resistance; concentration gradient; and size, weight, and charge of the solutes.

Convection
When fluid crosses a semipermeable membrane, some solutes are pulled along with it. This is called convection, or solvent drag. Convection is the best way to remove larger solutes. A sieving coefficient (see Figure 2 on page 93) is used to say how much solute is expected to be removed by convection. A sieving coefficient of 0.5 for a solute means that 50% of the solute will pass through the membrane to the dialysate side. The other 50% will be adsorbed or rejected by the membrane. Convective clearance depends on the molecular weight cutoff of the membrane, the membrane surface area, and the ultrafiltration rate (UFR).

Adsorption
Adsorption, as you’ve learned, occurs when material sticks to the dialyzer membrane. All dialyzers adsorb materials, usually small proteins, to some extent. Hydrophobic synthetic membranes adsorb more than cellulose membranes. Adsorption in dialysis has pros and cons. It is useful because the adsorbed protein keeps the membrane away from the blood, for better biocompatibility. But, adsorbed material can build up on the membrane and may prevent some diffusion and convection. Highly adsorptive membranes may become less effective when they are reprocessed many times. Testing dialyzers for total cell volume (also called fiber bundle volume) may not reveal this problem. Total cell volume is an indirect measure of changes in solute transport for hollow fiber dialyzers that are reused. A dialyzer’s adsorptive ability depends on the
membrane material, surface area, and how much material has already adsorbed to the membrane.

DIALYZER DESIGN
A hollow fiber dialyzer is a clear plastic cylinder that holds thousands of fiber tubes almost as thin as strands of hair. These fibers are held in place at each end by polyurethane, clay-like potting material that holds the fibers open so blood can flow inside them. Hollow fiber dialyzers allow for well-controlled, predictable UF.
During dialysis, blood enters the dialyzer at the top, flows through each fiber, and leaves at the bottom. Dialysate flows around the fibers in the opposite direction, in a countercurrent flow (see Figure 3). Because the fibers are rigid, there is no membrane compliance (change in shape or volume due to pressure). Instead, the fibers hold almost the same amount of fluid at high pressures as they do at low pressures. Resistance to blood flow is low in hollow fiber dialyzers.1

MEMBRANES
The semipermeable membrane acts in some ways like the vessel wall of a human nephron, because it is selective. Riddled with microscopic pores, the membrane allows only certain solutes and water to pass through. Large substances, such as protein and blood cells, simply won’t fit through the small pores.1 There are other membrane factors that affect removal of solutes and fluids during dialysis (see Figure 4). These include the membrane material and characteristics of each dialyzer. Each of these will be discussed below.

Membrane Materials
What the dialyzer membrane is made of can affect diffusion and UF. The dialyzer material can also affect the efficiency of dialysis and the patient’s comfort during treatment.

Cellulose membranes
Cellulose membranes are made from cotton-based material that is spun into hollow fibers.10 Dialyzers with cellulose membranes have thin fiber walls (8–15 microns).3 Solute pass

95 %

Figure 3: Blood and dialysate flow:
Countercurrent directions
Blood out
Blood in
Used dialysate and excess fluid
from the patient’s body out to drain
Each blood-filled fiber
is surrounded by
dialysate
Dialysate in Direction of blood flow
Direction of dialysate flow
Wall thickness
Internal diameter
190 to 240µ
Surface area
Number and
size of pores
Blood
Single, hollow fiber
Drawing adapted with permission from Althin Academy, Miami Lakes, FL

Figure 4: Membrane and fiber
characteristics affecting solute transport
through them mainly by diffusion. Low molecular weight substances readily pass from one side of the membrane to the other, with little regard to applied transmembrane pressure. The size of molecules cleared by these dialyzers is quite limited about 3,000 Da.3 Removal of molecules in the larger molecular weight range, such as beta-2-microglobulin (β2m, 11,800 Da), is slower. Cellulose dialyzers have surface areas that range from 0.5 to 2.1 meters. Larger cellulose membranes have in vitro (tested in a laboratory) urea and creatinine clearances that compare to synthetic dialyzers. Cellulose dialyzers are the least biocompatible, and cause the most complement activation. This type of membrane is also least able to remove solutes by adsorption.3

Modified cellulose membranes
Changes have been made to improve the way cellulose membranes work. The hydroxyl groups (OH-) are removed and replaced with acetate (cellulose acetate), amino acids, or synthetic molecules.10 Modified cellulose dialyzers have much thicker fiber walls, 22 to 40 microns.3 They use convection, diffusion, and adsorption to remove solutes. Clearance of solutes, especially middle molecules, depends mainly on UF rates. These dialyzers do a good job of removing solutes up to 15,000 Da, clearing β2m to some extent. Biocompatibility of these membranes ranges from good to very good. The best of these are close to pure synthetics.3

Synthetic membranes
Synthetic membranes are made from polymers that are formed into hollow fibers.10 The materials used in synthetic membranes are: polycarbonate, polyacrylonitrile (PAN), polysulfone (PSF), and polymethylmethacrylate (PMMA).5 These dialyzers have the thickest fiber walls, 30 to 55 microns.3 Solute are removed by convection, diffusion, and adsorption. Clearance of solutes, especially middle molecules, depends mainly on UF rates. Synthetic membranes do a good job of removing solutes up to 15,000 Da, clearing β2m to some extent. Biocompatibility of these membranes is very good. They are highly adsorptive, so they can quickly keep the blood from touching the membrane.3

Measuring Dialyzer Effectiveness
A dialyzer's effectiveness is checked by testing its clearance (K). Clearance is expressed as the amount of blood (in mL) that is completely cleared of a certain solute in one minute of treatment, at a given blood flow rate (Qb) and dialysate flow rate (Qd).9 For example, a dialyzer has a stated urea clearance of 250 mL/min at a Qb of 300 mL. In one minute, 250 mL of blood would be cleared.
of urea by the dialyzer. If 300 mL of blood is pumped through the dialyzer in one minute, only 250 mL of blood will be cleared of urea. During dialysis, the patient’s blood passes through the dialyzer many times, so much of the urea in the blood can be removed. The dialyzer’s surface area is fixed. So, either Qb or Qd must be increased to improve clearance. The Qb is always a factor that limits clearance, since there is a limit to how quickly blood can flow out of the patient’s vascular access.

Hemodialysis Devices
A higher Qd provides some increase in dialysis clearance; how much depends on dialyzer size and membrane permeability.1

DETERMINING DIALYZER CLEARANCE

Manufacturers test dialyzers in a lab (in vitro), using watery fluids that are thinner than blood. When measured during actual use on patients, a dialyzer’s real clearance can differ from the manufacturer’s stated values by ±10–30%. The clearance of urea, a small molecular weight solute, is most often used to test the overall effectiveness of a dialyzer. Clearance of a certain solute is checked by drawing samples of blood going into and leaving the dialyzer. Once the solute concentration of the blood samples is tested, actual clearance can be calculated (see Appendix on page 116).

Dialysate

PURPOSE OF DIALYSATE

Dialysate is a fluid that helps remove uremic wastes, such as urea and creatinine, and excess electrolytes, such as sodium and potassium, from the patient’s blood. Dialysate can also replace needed substances, such as calcium and bicarbonate, which helps keep the body’s pH balance. During a treatment, the patient’s blood is on one side of the membrane, in the blood compartment. The dialysate is on the other side, in the dialysate compartment. Dialysate and blood never mix, unless the membrane breaks.

Dialysis patients’ blood has high concentrations of waste products and excess water. Dialysate is prescribed to have desired levels of solutes the patient needs and none of the ones that must be removed completely. The osmolality (solute particle concentration) of dialysate should closely match the blood to keep too much fluid from moving across the membrane. The concentration gradients created decide the diffusion rates of each solute across the membrane. Unwanted solutes leave the blood and move into the dialysate; desired solutes stay in the blood.1 Some solutes are added to dialysate in amounts that can cause them to enter the patient’s blood. Most often, these are sodium, bicarbonate, and chloride.

COMPOSITION OF DIALYSATE

The doctor prescribes the dialysate. Dialysate starts out as two concentrated salt solutions: acid and bicarbonate (see Figure 5). n The acid concentrate has precise amounts of sodium chloride, potassium chloride, magnesium chloride, calcium chloride, glucose, and acetic acid. The acetic acid is added to lower the dialysate’s pH. n The bicarbonate concentrate has sodium bicarbonate and in some cases, sodium chloride.

Figure 5:
Dialysate contents
Bicarbonate buffer
Sodium
Potassium
Treated water
Chloride
Glucose
Calcium
Magnesium
The two concentrates are diluted with precise amounts of treated water to make the final dialysate. The concentrates come in three different formulations. Because there are three formulations, care must be taken to match the right acid concentrate with the right bicarbonate concentrate. The Association for the Advancement of Medical Instrumentation (AAMI) has set standard symbols to help match the concentrates. These symbols are shown in the right column of Table 2, above.11 The companies listed in the first column introduced a certain formulation to the American market. Today, almost all of the hemodialysis machines can use any of the formulations. When the concentrates are diluted with the prescribed amount of water, they will have the right concentration of electrolytes (particles that carry an electrical charge). Electrolytes are vital for cell function. Precise levels of sodium and potassium are needed on each side of cell membranes to allow nerve signals and other cell functions in the body. These levels are shown in Table 3. We will cover each substance briefly.

Sodium (Na+)
Sodium is a major electrolyte of the body’s blood plasma and interstitial (between the cells) fluid. In the body, sodium causes fluid to move across cell membranes. In this way, fluid shifts between the intracellular (inside the cells) space and the plasma and interstitial space. This fluid movement includes the intravascular space (in the blood vessels). Fluid and solutes must be in the plasma to be removed by dialysis. Normal sodium concentration in the blood is from 135 to 145 mEq/L. Sodium concentration in dialysate is most often kept in the same range. Higher levels are sometimes used if so, a careful patient assessment and a doctor’s prescription are needed. Dialysate delivery systems can adjust the dialysate sodium level during a treatment. The dialysate sodium level is changed according to a doctor’s prescription. This is called sodium modeling. These systems can, for example, start a treatment at a high sodium concentration and then slowly reduce it. This sodium change has been shown to create more efficient fluid shifts in the body, to remove fluid faster. Sodium modeling also provides for better control of blood pressure and fluid removal. This helps

Table 3: Typical Range of Substances in Dialysate

<table>
<thead>
<tr>
<th>Substance</th>
<th>Concentration in Dialysate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>135 to 145 mEq/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>0 to 4 mEq/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>2.5 to 3.5 mEq/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.5 to 1.0 mEq/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>100 to 124 mEq/L</td>
</tr>
</tbody>
</table>
Bicarbonate 32 to 40 mEq/L  
Glucose 0 to 250 mg/dL  

Table 2: Concentrate Proportioning Ratios  

<table>
<thead>
<tr>
<th>Type/Style</th>
<th>Acids</th>
<th>Bicarb Parts</th>
<th>Water Parts</th>
<th>Dialysate Parts</th>
<th>Dialysate X</th>
<th>WT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drake-Willock</td>
<td>1.00</td>
<td>1.83</td>
<td>34.00</td>
<td>36.83X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COBE Laboratories</td>
<td>1.00</td>
<td>1.72</td>
<td>42.28</td>
<td>45X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresenius</td>
<td>1.00</td>
<td>1.225</td>
<td>32.775</td>
<td>35X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table adapted with permission from AAMI
some patients tolerate more UF with fewer complications. However, the use of sodium modeling can increase thirst and body weight, and hypertension between dialysis treatments.12

Potassium (K+)
Potassium is a major electrolyte of the intracellular fluid. The body keeps precise amounts on both sides of cell membranes to send nerve signals. Just enough potassium is added to dialysate to bring the patient to a normal plasma potassium level: from 3.5 to 5.5 mEq/L. Potassium in the dialysate ranges from 0 to 4 mEq/L, based on the patient’s needs.1

Magnesium (Mg++)
Magnesium is vital to the nerves and muscles. It also triggers enzymes that are key to carbohydrate use. Magnesium is found in the plasma at levels from 1.4 to 2.1 mEq/L. The magnesium range in dialysate is 0.5 to 1.0 mEq/L.1

Calcium (Ca++)
Calcium is found in the body in extracellular (outside the cells) and intracellular (inside the cells) fluid. It builds bones and teeth, helps muscles move, is needed for blood clotting, and helps send nerve signals. The normal range of calcium in the plasma is 8.5 to 10.5 mg/dL (4.5 to 5.5 mEq/L); dialysate calcium is most often 2.5 to 3.5 mEq/L. Sometimes the lower range is used if patients take calcium-based phosphate binders and/or calcitriol (active vitamin D), which can raise serum calcium levels. Patients whose predialysis calcium levels are quite high or low may have their dialysate calcium changed by a doctor.

Chloride (Cl−)
The concentration of chloride in dialysate depends on the contents of chemicals such as sodium chloride, potassium chloride, magnesium chloride, and calcium chloride. Dialysate chloride ranges from 100 to 124 mEq/L. Normal plasma chloride levels are 98 to 111 millimoles per liter (mM/L).1

Glucose (C6H12O6)
Glucose may be added to dialysate to prevent loss of serum glucose and to reduce catabolism (muscle breakdown). Adding glucose calories can help patients who are diabetic or malnourished. Dialysate glucose levels may range from 0 to 250 mg/dL. The glucose in dialysate can be two to three times higher than in normal blood (70 to 105 mg/dL). This means that dialysate with glucose has an osmotic (water-pulling) effect that aids UF.

Bicarbonate (HCO3−)
Bicarbonate is a buffer—a substance that tends to maintain a constant pH in a solution, even if an acid or base is added. Healthy kidneys keep the body’s pH within the very tight limits that cells
need to survive. The kidneys do this by making and regulating bicarbonate. Bicarbonate is added to dialysate to help maintain patients’ pH. Bicarbonate is used by the body to neutralize acids that are formed when cells metabolize proteins and other foods used for fuel. People with chronic kidney disease can’t excrete enough acids in the urine, so they are in a constant state of metabolic acidosis (i.e., having too much acid in the blood). In dialysate, bicarbonate is used to replace the body’s stores of buffer. Bicarbonate can reduce
dialysis-related problems like hypotension, muscle cramps, nausea, and fatigue after treatment.

Hemodialysis Delivery Systems

PURPOSE

A delivery system is a machine that mixes and delivers dialysate, pumps blood through the dialyzer, and monitors various dialysis parameters to ensure a safe treatment (see Figure 6). Most delivery systems monitor patient and machine safety parameters. These include blood flow, dialysate flow, dialysate temperature, conductivity, venous and arterial pressure, blood in dialysate leaks, patient blood pressure, etc. The delivery system is two major subsystems: the dialysate delivery system and the extracorporeal blood circuit. We'll cover each one and its parts.

DIALYSATE DELIVERY SYSTEM

A dialysate delivery system controls the amounts of water and chemicals in dialysate, and checks its conductivity, temperature, pH, flow rate, and pressure. It also tests the dialysate for the presence of blood.

The Proportioning System

In a proportioning system, dialysate is made by mixing fresh concentrate with fixed amounts of treated water. The mixing is controlled by the internal mechanical and hydraulic design of the delivery system. The exact amount of water and concentrate is set by your center's policies and procedures (see Table 2, page 98).

Proportioning systems make dialysate in two ways. Both rely on a continuous supply of fresh concentrate and treated water:

- The first type of system mixes concentrate and water using fixed-ratio pumps. Fixed-ratio mixing uses diaphragm or piston pumps to deliver set volumes of concentrate and water to a mixing chamber.

- The other type of proportioning system uses servo-controlled mechanisms: these have conductivity control sensors that constantly check the dialysate's total ion concentration. Electronic circuits compare the solution's real conductivity to the prescribed level, and adjust the proportioning to reach the prescribed value.

Once mixed, dialysate is warmed and monitored for conductivity, temperature, pressure, and flow rate (see Figure 7).
After dialysate leaves the dialyzer, it passes through a blood leak detector. Blood in the dialysate could mean a tear in the membrane. So, blood leak detectors are often treated as extracorporeal alarms, even though they check the dialysate. Used dialysate that has passed through the blood leak detector is discarded down a drain.

The Monitoring System

Using the wrong dialysate can make a dialysis treatment less effective. This mistake may even cause illness or death to a patient. Dialysate must be checked throughout each treatment to ensure that it is the right concentration and temperature, and that it is flowing at the right rate. Some delivery systems also check the dialysate pH continuously. The following descriptions include general information that suits most dialysis machines. To learn how to check alarms on the equipment you will be using, see your center’s procedures manual.

Conductivity

Except for glucose, the chemicals in dialysate are all salts (electrolytes). Salts break apart in water to form positive and negative charged particles called ions. Dialysate electrolyte levels must be kept within certain limits to keep patients safe. The dialysate proportioning system checks the total electrolyte level in dialysate by testing conductivity (how much electricity the fluid will conduct). Conductivity is checked by placing a pair of electrodes in the dialysate. Voltage is applied to the electrodes, and the current is measured. The measurement gives the estimated total ion concentration of the dialysate. A sensor cell may be used instead of the electrodes.

Most hemodialysis delivery systems have two or more independent conductivity monitors with separate sensors and monitoring circuits. One sensor measures the mixture of the first concentrate (most often acid) with water. The other sensor measures the final dialysate after the second concentrate is added. Some machines use conductivity sensors to make the dialysate itself. These have a second set of sensors to check the mixtures, apart from the ones that control the mixing. This multiple single-patient proportioning systems like this one are most commonly used.
To drain
Ultrafiltration
pump
Blood leak
detector
Bypass
Dialyzer
Flow
meter
Throttle
Blood valve
in
Blood
out
Heater
Temperature
Pressure
Dialysate
Deaerator Proportioning
pump
Conductivity
sensor & meter
Concentrate
Figure 7:
Single-patient
dialysate delivery system
monitoring system, called redundant monitoring, is used so two sensors would have to fail before a patient could be harmed.15

Conductivity is usually checked at the point of mixing and again before the dialysate enters the dialyzer. Depending on the equipment at your center, conductivity may be stated in micromhos/cm, millimhos/cm, microsiemens/cm, or millisiemens/cm.16 A millisiemens/cm is 1/1000 of a siemens/cm and a microsiemens/cm is 1/1,000,000 of a siemens/cm. Siemens was formerly called mho because conductance in siemens is the reciprocal of resistance in ohms.16

Most dialysate delivery systems have internal, preset conductivity limits. When the dialysate concentration moves outside the preset safe limits, it triggers a conductivity monitoring circuit. The circuit stops the flow of dialysate to the dialyzer and shunts it to the drain. This is called bypass. Bypass keeps the wrong dialysate from reaching the patient. The circuit also sets off audible and visual alarms to alert the staff. The most common type of conductivity alarm is low conductivity. The most frequent cause is a lack of concentrate in one or both of the concentrate jugs. A high conductivity alarm is most often due to:

- Poor water flow to the proportioning system
- Untreated incoming water
- Use of the wrong dialysate concentrate

Before each treatment, check the conductivity alarm to be sure it is working, and check the machine readings against an independent meter. There must always be enough of both concentrates in the proportioning system to complete the whole treatment.15

Temperature

Too-hot dialysate can cause hemolysis (bursting of red blood cells). Too-cool dialysate is not life threatening, but it can make the patient cold and reduce diffusion so the treatment is less efficient. In all dialysate delivery systems, dialysate is kept in the range of 37°C to 38°C (98.6°F to 100.4°F).15

Water must be heated to a certain temperature before mixing with the concentrates. The method of warming the water depends on the delivery system design. Some systems use a heat exchanger before the heater, to save energy. In these systems, used dialysate transfers its heat to the incoming cold water, warming it before it enters the heater. Most systems use a heater controlled by a thermistor, a type of thermostat. To check dialysate temperature, a separate temperature monitor is placed in the dialysate path before the dialyzer. This monitor’s limits are preset, and it works independently of the heater control thermistor. Many alarm systems have a low setting, which should not be below 33°C (91°F). (With some delivery systems,
the patient is the only monitor of low temperature.) The high limit should be set at no higher than 41°C (105°F). If the temperature is too hot or cold, a circuit sets off audible and visual alarms. The circuit also triggers bypass to shunt dialysate to a drain. Before each dialysis treatment, check the dialysate temperature alarm to ensure that it is working properly.

Flow rate
Dialysate flow rate to the dialyzer is controlled by a flow pump. Some delivery systems have a preset flow rate; others let the flow vary as the Hemodialysis Devices.
In general, higher dialysate flow rates improve dialyzer efficiency, though little improvement occurs above 800 mL/min. Dialysate flow rates range from 0-1,000 mL/min. Some systems have flow meters that continuously display the dialysate flow rate on a gauge or a digital display. Others do not display flow rate at all. Dialysate flow rate audible and visual alarms may be set off by:
- Low water pressure
- Dialysate pump failure
- A blockage in the dialysate flow path
- A power failure
A high/low conductivity, high/low pH, high temperature, or in some cases blood leak alarm, can trigger the delivery system to switch into bypass mode. Check the delivery system before each treatment to be sure that the bypass mode works properly for all dialysate alarm conditions.

Blood leak detector
Dialyzer membranes are fragile and can tear, letting blood and dialysate mix. If this occurs, the patient could have major blood loss and/or the blood could be contaminated by the nonsterile dialysate. A blood leak detector (see Figure 8) is used to check for blood in the used dialysate. The detector can sense very small amounts of blood, less than can be seen with the naked eye. The blood leak detector shines a beam of light through the used dialysate and onto a photocell or photoresistor. Normally, dialysate is clear, so the light can pass through. But even a tiny amount of blood will break the light beam. The detector will sense such a break, triggering audible and visual alarms.

When a blood leak alarm occurs, the blood pump stops and the venous line clamps to prevent further blood loss. In some systems, a bypass mode shunts dialysate to the drain. This reduces negative pressure and keeps blood from being drawn through the tear into the dialysate. A Hemastix® (strip that reacts to blood) should be used to check the extent of the leak. The test must be taken where the dialysate leaves the dialyzer:
- If blood or pink color can be seen in the dialysate path, there is a major leak.
- Clear dialysate and a positive Hemastix test suggest a minor leak.
- Clear dialysate and a negative Hemastix test mean a false alarm.

Depending on your center’s procedures for a blood leak, you stop the treatment without returning the patient’s blood. This keeps possibly contaminated blood from reaching the patient, where it could cause an infection.
leak detector
If the light beam is interrupted by blood,
an alarm will sound, and the blood pump will stop.
Dialysate out Dialysate in
Light
bulb
Photoelectric
cell
The blood leak detector's basic sensitivity is usually preset by the manufacturer. Adjustments can be made within this limited range.17

**pH**

pH is a measure of how acidic or alkaline (basic) a solution is. The pH of a solution is based on the number of acid ions (hydronium ions) or alkali (base) ions (hydroxyl ions) it contains. A solution with:
- An equal number of acid and base ions is neutral and has a pH value of 7.0.
- More acid ions is acidic and the pH value will be less than 7.0.
- More base ions is alkaline and the pH will be greater than 7.0.

Bleach (sodium hypochlorite) is alkaline, with a pH of 11.0. White vinegar is an acid, with a pH of 2.9. The pH of blood is normally from 7.35 to 7.45; a weak base. Dialysate must have a pH close to blood so it does not change the blood pH. In general, the range of dialysate pH is from 7.0 to 7.4.

Some delivery systems monitor pH continuously throughout the treatment. Dialysate pH affects the patient's blood pH. Whether or not the delivery system has a pH monitor, at the start of each treatment, an external test must be done to ensure that the dialysate pH is in a safe range. The most accurate pH measure uses a pH electrode, which puts out a small voltage when placed in a solution. The voltage is read by a detection circuit that converts the signal into a pH value and displays it. Test strips coated with a chemical that changes color based on pH are another way to measure pH. For any method, you must have known test fluids on hand that can be used to check that the meter or strips are still accurate.

**Ultrafiltration Control**

**Ultrafiltration**

Removing excess fluid is another key part of an adequate treatment. Fluid removal is achieved through ultrafiltration (UF) (the movement of fluid across the dialyzer membrane in response to positive and negative pressures). UF occurs during the treatment when the pressure on the blood side of the dialyzer membrane is more positive than the pressure on the dialysate side. This pushes fluid in the blood across the membrane into the dialysate compartment where it is then expelled in the drain. The difference between these pressures (the pressure gradient) is the transmembrane pressure, or TMP.

TMP and dialysate pressure

The TMP determines how much fluid from the blood is forced across the membrane. In the past, dialysis machines used a manual system of setting the TMP or a negative dialysate pressure for achieving fluid removal. A technician or...
nurse needed to determine the total fluid loss required for the patient and then calculate the hourly UFR. Mathematical equations were used to find the TMP needed for the KUF of the dialyzer being used (see Module 6: Hemodialysis Procedures and Complications for TMP calculation). Depending on the type of machine, the technician or nurse would set the TMP or a negative dialysate pressure to achieve the calculated TMP. With today’s volumetric dialysis, TMP is calculated and set for you. All you need to enter is the desired fluid removal amount (in mL) and the treatment time. Fluid removal accuracy of the Hemodialysis Devices 104
older systems was not nearly as precise as today's UF control systems due to variables including:
- The KUF values reported by dialyzer companies are usually in vitro values. In practice, the in vivo KUF is often somewhat lower (5%-30%).
- Clotting of the dialyzer fibers reduces the KUF by reducing the surface area of the membrane.
- Increasing or decreasing the blood pump speed changes the venous pressure.
- An increase or decrease in the dialysate flow, or a kink or blockage in the dialysate lines changes the dialysate pressure.
These conditions have no effect on fluid removal accuracy with UF control machines.

UF control systems
UF control is the means by which the dialysis machine removes fluid from the patient and accurately measures it. The amount of fluid removed in a specific period of time is the ultrafiltration rate (UFR). Most dialysis machines use a volumetric fluid balancing system (see Figure 9). This type of system uses two chambers that fill and drain to control the volume of dialysate going to and coming from the dialyzer. This is known as volumetric control. Another type of machine uses sensors in the fluid path to and from the dialyzer to control and monitor the flow rate of the dialysate. This is known as flow control.

Figure 9: Volumetric UF control system
Drain
Dialyzer
Blood leak detector
Air separation chamber
UF pump
Drain
Flow pump 2
Flow pump 1
Proportioned dialysate
Used dialysate is pushed out to the drain
Fresh dialysate is pushed out to the dialyzer
Deaeration pump
Conductivity cell and temperature
sensor
Balance
chambers
Flexible
membrane
Dialysate
Used dialysate
Air
Unused path this cycle
Valve-open
Valve-closed
Volumetric UF Control

One of the main components of the volumetric UF control system is the balance chambers or balancing chambers. There are two identical chambers. Each chamber is divided in half by a flexible diaphragm. Each chamber half has an inlet and an outlet. One side of each chamber is in the to dialyzer, or fresh dialysate flow path. The other side is in the from dialyzer, or used dialysate flow path. There are valves on each inlet and outlet. These valves open and close so that as fluid enters on one side of the chamber, it pushes on the diaphragm and forces fluid out on the other side. The timing of the valves opening and closing is synchronized. One chamber is filling with used dialysate, pushing fresh dialysate to the dialyzer. At the same time, the other chamber is filling with fresh dialysate, pushing the used dialysate to the drain.

One pump moves the proportioned dialysate to the balance chambers. A second pump pulls dialysate from the dialyzer and pushes it to the balance chambers. This keeps a constant flow through the dialyzer. The movement of dialysate to and from the dialyzer takes place in a closed loop. The volume of dialysate entering and exiting the dialyzer is the same, because the volume entering one side of the balance chamber displaces the same amount on the other side. So, the flow to and from the dialyzer is balanced.

Another main component in the system is the ultrafiltration pump (UF pump) or the fluid removal pump. Its function is to remove fluid from the closed loop. This results in fluid removal from the patient through the dialyzer membrane. Most UF pumps are diaphragm or piston type, and are most often placed in the used dialysate flow path. The pumps work with a stroking movement that removes a small, fixed amount of fluid on each stroke (about 1cc or less). The removal of fluid from the closed loop creates a negative pressure in the loop. Therefore, pressure is negative in the dialysate compartment of the dialyzer, relative to the blood compartment pressure. This creates the pressure gradient that is needed for UF. When the UF pump is off, there is no pressure difference between the blood and dialysate and no fluid is removed.

As the pump removes fluid from the closed loop, the same amount is replaced, moving across the dialyzer membrane into the loop. This allows the machine to precisely remove the right amount of fluid from the patient. You or the nurse will determine the total amount of fluid that should be removed and use the machine controls to enter it along with the duration of
the treatment in hours. The machine[s] computer will calculate the UFR, which decides the rate at which the UF pump will run. Other important components in the system are used to perform control, monitoring, and safety functions. Pressure sensors serve functions such as controlling pump speeds, preventing overpressurization, calculating TMP, and detecting leaks within the system. Air separation chambers remove any air coming out of the dialyzer. (This will occur when priming a new [dry] dialyzer.) Any air in the system could result in incorrect fluid removal. The air separation chamber maintains a level of fluid while releasing air out the top that is routed to the drain.

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Flow Control

Another type of UF system is the flow control system (see Figure 10). This system has flow sensors on the inlet and the outlet side of the dialyzer to control dialysate flow through the dialyzer. Inlet and outlet flow pumps are set so the flow measured at the inlet and outlet flow sensors is equal. This flow balance is the key to the system’s accuracy and ensures that the only fluid removed from the patient is that which is removed by the UF pump. This UF control system uses a postdialyzer UF pump that removes fluid at the UFR calculated by the machine’s computer. The speed of the pump is equal to the UFR. It is determined by the time needed to fill a small chamber of a known volume (UF burette). There are high and low-level sensors in the UF burette that signal a valve to open and close. When the UF burette becomes full, the valve opens and a pump empties it by forcing air into the top and the contents to the drain. When it has emptied, the valve closes and the UF burette begins to fill again. This occurs repeatedly throughout the treatment. The outlet flow sensor does not measure the fluid removed by the UF pump. Flow control UF systems may also use pressure sensors and air separation chambers in the same way that volumetric systems do.

EXTRACORPOREAL CIRCUIT

The extracorporeal circuit carries blood from the patient’s access to the dialyzer and back to the access. It is the second major subsystem of the hemodialysis delivery system. The extracorporeal circuit includes the arterial and venous lines.
BLD
Dialysate
Used dialysate
Air
Pressure sensor
Valve direction of flow
(black segments = flow direction)
venous blood tubing, blood pump, heparin pump, dialyzer, venous line clamp, blood flow monitors, pressure monitors, and air monitors (see Figure 11). We will cover each part next.

Components and Monitoring

Blood tubing

During hemodialysis, blood from the patient’s vascular access (arterial needle) flows to the dialyzer. Blood flows back to the patient’s access (venous needle) through blood tubing, or lines (see Figure 12). The inner diameter of the blood tubing is small. Only a small amount—about 100–250 mL—of blood is outside the patient’s body at any time.

There are two parts of the blood tubing: arterial and venous. The arterial segment is most often color-coded red; the venous segment is most often color-coded blue. Bloodlines are smooth on the inside to reduce clotting and air bubbles. Many manufacturers offer custom-made blood tubing for various types of equipment and patients. Each set of blood tubing has different, specialized parts. The order in which those parts are installed in the delivery system varies with the system’s design, prescribed treatment, and the monitoring desired. Parts of blood tubing include:

- Patient connectors: A tip, or Luer-Lok® connector, at the end of the arterial and venous blood tubing segments connects the tubing to the patient’s needles or catheter ports.
- Dialyzer connectors: Luer-Lok connectors at the other end of the blood tubing segments connect the tubing to the dialyzer. The arterial blood tubing segment connects to the arterial end of the dialyzer. The venous blood tubing segment connects to the venous end of the dialyzer.
- Drip chamber/bubble trap: The drip chamber checks arterial or venous pressure in the blood circuit. It uses a monitoring line with transducer protectors (see page 109), and collects or traps any air that accidentally gets into the extracorporeal circuit. The drip chamber can also keep blood clots in the extracorporeal circuit from reaching the patient, by using a very fine mesh screen. This type of drip chamber is placed on the venous blood tubing segment, after the dialyzer and before the patient’s access.
- Blood pump segment: The blood pump segment is a durable, pliable, larger diameter part of the arterial blood tubing. It is threaded through the blood pump roller.

Hemodialysis Devices

Figure 11: Extracorporeal circuit
Used dialysate back to
machine and out to drain
Blood pump (Qb)
Arterial sample
port (CBi)
Arterial pressure
(pre-pump)
Drip chamber
Drip chamber
To patient
From patient
Venous pressure
Venous sample
port (CBo)
Fresh dialysate
from machine
n Heparin infusion line: During dialysis, heparin (a blood thinning drug) may be given to the patient through a very small diameter tube that extends out of the blood tubing. The heparin infusion line is most often placed on the arterial blood tubing segment just before the dialyzer.

n Saline infusion line: This line allows saline to be given to the patient during dialysis. It is most often placed on the arterial blood tubing segment just before the blood pump, so saline can be pulled into the circuit. If the saline infusion line is not clamped correctly, too much fluid or air can enter the extracorporeal circuit.

Transducer protectors
A transducer is a mechanical device inside the machine that converts air pressure into an electronic signal. This signal is used to display venous pressure, arterial pressure, and TMP. Moisture would damage the transducer. Transducer protectors are a barrier between blood in the tubing and the transducer in the machine. They connect to the machine's venous and/or arterial ports via a small tubing segment on top of the drip chamber. Transducer port lines have a small line clamp in the middle. The transducer protector connects to the end of these lines and is the link between the machine and the blood tubing set (drip chambers). Transducer protectors use membranes with a nominal pore size of 0.2 microns that are hydrophobic when wetted, to keep fluid from passing through. If these filters get wet, they prevent air flow. Wetted or clamped transducer protectors cause pressure reading errors. A wet or clamped venous transducer protector will also cause TMP problems, since TMP is partly venous pressure. A loose or damaged transducer protector on a pre-pump arterial drip chamber port could allow air into the bloodline circuit.

In May, 1999, the federal Food and Drug Administration (FDA) put out a safety alert on cross-contamination from wet transducer protectors. In April 2001, the Centers for Disease Control and Prevention (CDC) made recommendations. These require centers to change wet transducer protectors right away and inspect the machine side of the protector for contamination or wetting. If a fluid

Figure 12:
Circulation in human body
and extracorporeal circuit
Blood
pump
Dialyzer
Lines
Access
Kidneys
Heart
Arteries
and veins
During dialysis, the blood pump acts like the human heart, pushing blood through the lines (vessels). The dialyzer, or artificial kidney, cleans the blood, which is then returned to the patient's own circulation.
breakthrough is found on the removed transducer protector, the machine’s internal transducer protector (a back-up) must be inspected by a qualified technician. You may be required to disinfect the machine’s transducer protector port and replace the internal transducer protector before the next treatment can begin.23

Blood pump/blood flow rate
The blood pump (see Figure 13) moves blood from the patient’s arterial needle through the blood tubing, to the dialyzer, and then back to the patient through the venous needle. Most often, the type of blood pump used is a roller pump. This pump uses a motor that turns a roller head. Speed of the roller head determines blood flow rate, which is set by the staff person. The blood pump segment of the blood tubing is threaded between the rollers and the pump head. The rollers turn, blocking the tubing and pushing blood out of the segment. After the roller has passed, the segment resumes its shape and blood is drawn in to refill the pump segment. In this way, blood is pulled into and pushed out of the segment at the same time.

By changing the roller speed, blood flow through the extracorporeal circuit can be set according to the prescription. Blood flow rates can be varied between 0 mL/min and 600 mL/min. Some machines count blood pump turns and calculate the number of liters processed in a treatment. Knowing the number of liters prescribed to be processed allows calculation of the blood flow rate: divide liters processed by minutes of treatment. This value can be used as a quality assurance tool; it should equal the blood flow rate shown on the machine. For an effective treatment, the blood flow rate must be accurate and reflect the doctor’s prescription. The staff member must verify that the rate on the readout is correct.

Pump occlusion is the amount of space between the rollers and the pump housing. The blood pump rollers must press against the blood pump segment hard enough to pull and push the blood through the extracorporeal circuit. If the rollers are too tight, the blood pump segment may crack or red blood cells may be destroyed. If the rollers are too loose, blood may escape out the back of the segment, reducing blood flow below the prescribed level. Modern rollers use springs to create occlusion, so the pump segment must be inserted properly. Pulling down the ends of the pump segment in the housing will compress the Hemodialysis Devices

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The blood pump segment of the tubing is stronger and thicker to withstand the pressure of the pump.

Figure 13: Blood pump
Step one Blood enters the pump Step two Blood is pushed along by the rollers Step three A constant blood flow rate is created Housing Roller Blood pump segment
springs and cause the wrong occlusion. This will also reduce blood flow by decreasing the amount of pump segment in the blood pump. It has to be realized that the blood flow measured by the number of pump revolutions assumes a stable blood volume pushed with each revolution. A high negative pressure flattens the tubing in the roller pump and decreases its volume. The blood flow indicated by the dialysis blood roller pump is always greater than the delivered blood flow, and this difference is in turn conditioned by the negative pressure induced by the blood roller pump in the arterial bloodline. Pump occlusion must be checked periodically and adjusted per the manufacturer’s instructions. The occlusion should also be checked when the tubing size or manufacturer changes. In case of emergency, all blood pumps have a way to allow hand cranking. Most often, the pump will have a handle, either with the pump head or one that can be inserted into the pump, which can be used to crank the pump. The pump head should be hand cranked just fast enough to keep the venous pressure at the pre-alarm level. Extracorporeal pressure monitors Pressure in the extracorporeal circuit depends on blood flow rate and resistance to the flow. Resistance occurs in nearly every part of the extracorporeal circuit: access needles or catheters, blood tubing, and the dialyzer. The blood pump is used to overcome this resistance. Pressures are displayed in millimeters of mercury (mmHg) on a gauge, meter, or screen. Depending on the equipment, pressure can be read at several sites. Extracorporeal pressure monitoring is needed to calculate TMP and ensure patient safety. In some systems, pressure monitors have upper and lower limits that can be set. In others, they have a preset range within which staff can choose a midpoint. When pressure exceeds the high or low setting, the system will trigger audible and visual alarms, stop the blood pump, and clamp the venous line. You must check the extracorporeal blood pressure alarm to ensure that it works properly before each treatment. A pre-pump or post-pump drip chamber may be placed on the arterial bloodline. A monitoring line or pressure gauge connection at each drip chamber is used to check arterial and/or venous pressure in the extracorporeal circuit (see Figure 14).

Figure 14: Pressure monitoring devices on arterial and venous bloodlines. The extracorporeal circuit has gauges to measure venous and arterial pressures.
Line clamp
Blood pump
Air detector
Arterial bloodline
Arterial pressure gauge (negative, pre-pump pressure)
Arterial pressure gauge (positive, post-pump pressure)
Venous bloodline
Arterial (pre-pump) pressure
Vascular access
Venous pressure gauge (positive, postdialyzer pressure)
The pressures described below may be monitored, depending on the dialysate delivery system used:

- **Arterial pressure** is pressure from the patient's access to the blood pump. It is also called prepump pressure. When a blood pump is used with a fistula or graft, arterial pressure will usually be less than zero, or negative. Resistance from the vascular access and the pulling of the blood pump creates this negative pressure.

- **Predialyzer pressure** is pressure between the blood pump and the dialyzer, also called post-pump pressure, predialyzer pressure, or post-pump arterial pressure. Pressure in this segment of the blood tubing is greater than zero, or positive. Predialyzer pressure is monitored to detect clotting in the dialyzer. Suspect clotting if there is a large pressure differential on each side of the dialyzer.

- **Venous pressure** is pressure from the monitoring site to the venous return. Venous pressure is often called postdialyzer pressure. Pressure in this segment is positive.

### Hemodialysis Devices

<table>
<thead>
<tr>
<th>LOW ALARM</th>
<th>HIGH ALARM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arterial pressure (negative) (pre-pump)</strong></td>
<td></td>
</tr>
<tr>
<td>Blockage of arterial blood flow from the vascular access</td>
<td></td>
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<tr>
<td>Compression or kinking of the arterial bloodline</td>
<td></td>
</tr>
<tr>
<td>Wrong position or infiltration of the arterial needle</td>
<td></td>
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<tr>
<td>Blood pump set at a rate higher than the vascular access can supply</td>
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<tr>
<td>Hypotension</td>
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<tr>
<td>Vasoconstriction (tightening of the patient’s blood vessels)</td>
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<tr>
<td>Poorly working central catheter</td>
<td></td>
</tr>
<tr>
<td>A bloodline separation (if the upper limit is set below zero)</td>
<td></td>
</tr>
<tr>
<td>A leak between the patient and the monitoring site</td>
<td></td>
</tr>
<tr>
<td>A decrease in the blood pump speed</td>
<td></td>
</tr>
<tr>
<td>Infusion of saline or medications</td>
<td></td>
</tr>
</tbody>
</table>

| Predialyzer pressure (positive) (post-pump) | |
| A bloodline separation or leak between the monitoring point and the dialyzer, or at the needle | |
| Occlusion in the blood tubing between the blood pump segment and the monitoring site | |
| A kink in the blood tubing anywhere from the patient to the monitoring site | |
| Poor blood flow or drop in blood flow rate | |
| A clotted dialyzer | |
| Poor placement or infiltration of the venous needle or catheter | |
| A rise in the blood flow rate | |
| A kink in the blood tubing from the dialyzer back to the monitoring site | |
| Venous pressure (positive) | |
| Separation of blood tubing from the venous needle | |
or catheter
- Drop in blood flow rate
- Blockage in the blood tubing before the monitoring site
- A severely clotted dialyzer
- A blockage in the blood tubing between the monitoring site and the venous needle
- Poor position or infiltration of the venous needle
- Poorly working central catheter
- Clotting access

Table 4: Pressure Alarm Triggers
Common causes of high and low pressure alarms for arterial pressure, predialyzer pressure, and venous pressure are shown in Table 4.25.

Air detectors
Air can cause death if it gets into the patient’s bloodstream. Air/foam detectors continuously check the blood in the venous tubing segment for air and foam (see Figure 15). The system may check for air at the venous drip chamber or at the blood tubing just below it. Air detectors are ultrasonic devices that check for changes in a sound wave sent through a cross-section of the blood path. Sound travels faster through air than liquid. Therefore, any air in the blood will raise the speed at which the sound wave passes through the blood, setting off an alarm. An air detector’s alarm sensitivity limits are most often preset by the manufacturer, but can be calibrated by qualified technicians. When the air detector senses air, it will trigger audible and visual alarms, stop the blood pump, and clamp the venous blood tubing to keep air from getting into the patient’s bloodstream.
You must check the air detector to be sure it is working properly before each treatment, following the manufacturer’s instructions. The air detector must always be used during the dialysis treatment and venous line clamps engaged with the tubing segment.

Heparin system
When the patient’s blood touches the artificial materials of the lines and dialyzer, it tends to clot. Heparin, an anti-clotting drug, or anticoagulant, is used to prevent clotting in the extracorporeal blood circuit.
Some centers give heparin intermittently (on and off) during dialysis; a prescribed amount is injected into the arterial bloodline at prescribed times. Also, heparin can be given by bolus (the full prescribed amount is given all at once just before the treatment.) Other centers give heparin by continuous infusion (a prescribed rate throughout the treatment.) A syringe filled with heparin, a heparin infusion line (see Figure 16), and an infusion pump are used and the pump slowly injects heparin into the extracorporeal circuit.

Figure 15:
Air detector
Figure 16:
Heparin infusion line
#1 #2
Sensor device
Sensor device
Line clamp
Line clamp
#2 uses a photocell
to monitor change
in light transmission
#1 uses an ultrasonic sensor device to monitor change in sound transmission.
To dialyzer
Heparin infusion line
Heparin pump
For most patients, heparin is stopped before the end of the treatment so blood clotting can go back to normal. A continuous infusion heparin pump has four parts:
1. A syringe holder
2. A piston to drive the plunger of the syringe
3. An electric motor to drive the plunger forward and infuse heparin from the syringe
4. A way to set the prescribed infusion rate
Heparin pumps have variable speeds that can be set to the physician’s prescription. Heparin is infused into the heparin line on the arterial blood tubing before the dialyzer. Most heparin lines are placed after the blood pump segment. This helps avoid negative pressure at the part of the blood circuit that could otherwise draw air into the extracorporeal circuit through the heparin line.
SORBENT DIALYSIS
Sorbent dialysis can be used for acute, home, and chronic dialysis treatments. A sorbent dialysis system (see Figure 17) needs no water treatment system. It does not contain water and concentrate proportioning pumps. Instead, premixed chemicals are added to 6 L of tap water. The water and chemicals are cycled through a sorbent regenerative cartridge to purify the dialysate. Then the dialysate is

Figure 17:
Allient sorbent dialysis system
Drawing adapted with permission from RenalSolutions, Inc.

HISORB +
SORB +
F
L
O
W
SORB + and HISORB + Cartridge Detail
Used dialysate
Activated carbon & purification layer
Urease layer
Zirconium phosphate layer
Zirconium oxide & zirconium carbonate layer
Cartridge effluent composition:
NaAc, NaHCO3, NaCl, CO2, H2O
BINDS: RELEASES:
- Phosphate
- Fluoride
- Heavy metals
- Ammonium
- Calcium
- Magnesium
Potassium
Metals
Other cations
Sodium (less)
Hydrogen
Acetate
Bicarbonate (more)
Sodium
Nothing
(converts urea)
Ammonium carbonate
Heavy metals
Oxidants
Chloramines
Creatinine
Uric acid
Other organics
Middle molecules
Nothing
collected in a disposable bag in the device and circulated to the dialyzer. Used dialysate is then cycled through the cartridge, where it is chemically converted back into fresh dialysate and returned to the storage bag. The sorbent cartridge also removes all calcium, magnesium, and potassium from the used dialysate, since their concentrations were altered by passage through the dialyzer. These electrolytes are added back into the regenerated dialysate in the prescribed amounts by an infusion system. The patient’s ultrafiltrate is also converted into dialysate by passage through the cartridge. Each increase in the total volume of dialysate is a direct reflection of total UF and is continuously displayed. The sorbent cartridge has four chemical layers. Besides regenerating dialysate, the layers serve as a water treatment system; they purify the 6 L of dialysate made with tap water. The sorbent cartridge also serves as a continuous dialysate disinfection system, keeping bacteria and endotoxin levels below 1 cfu/mL and 0.5 EU/mL, respectively. Depending on which cartridge is used, the system can do short (3-5 hour) treatments at dialysate flow rates up to 400 mL/min, or long, slow (5-8 hour) treatments at dialysate flows between 200-300 mL/min. Since using the sorbent cartridge means no continuous water source, floor drain, or water treatment system are needed, sorbent systems can be used anywhere that an electrical outlet (or suitable generator) is present.

Conclusion
As you have read in this module, the delivery system plays a key role in monitoring dialysis. During each treatment, the machinery checks almost every aspect of the patient’s care except one: you. The dialysis staff person is the most important monitor of all to keep patients safe. Alarms are of no use if someone forgets to turn them on or to check them against an independent meter. The patient can be in great danger if a staff person hooks up the wrong dialysate to the machine. It is vital to recall that dialyzers and delivery systems are not just machines, and dialysate is not just salty water. They are precise parts of a medical treatment that can help patients with kidney failure lead full and active lives. Your attention to detail and skill at finding and troubleshooting problems will make all the difference in patients’ outcomes. Your job is to help them by staying alert at all times and by learning all you can about the equipment and procedures at your center.
FORMULA FOR DIALYZER SOLUTE CLEARANCE

Where:

- $K$ is clearance
- $C_{Bi}$ (concentration at the blood inlet) is the concentration of solute in the blood entering the dialyzer (arterial sample)
- $C_{Bo}$ (concentration at the blood outlet) is the concentration of solute in the blood leaving the dialyzer (venous sample)
- $Q_b$ is blood flow rate in mL/min

For example, imagine that you wanted to calculate the clearance of urea in a patient for whom:

- $C_{Bi} = 82$ mg/dL (arterial BUN sample)
- $C_{Bo} = 8$ mg/dL (venous BUN sample)
- $Q_b = 350$ mL/min

Step 1:

$$K = \frac{C_{Bi} - C_{Bo}}{Q_b}$$

Step 2:

$$0.9 \times 350 = 316 \text{ mL/min}$$

Therefore, during each minute of dialysis, 316 mL of this patient’s blood has been cleared of urea.
References
Objectives
After completing this module, the learner will be able to:
1. Describe the three main types of vascular access.
2. Identify the predialysis assessments for all types of vascular access.
3. Describe the methods of needle insertion for AVFs and grafts.
4. Describe the predialysis assessment, accessing procedure, exit site care, and monitoring of catheters.

Module 5 cover photo credit:
Photograph of fistula by Stephen Z. Fadem, MD, FACP. © 2005. Used with permission.
Introduction
Vascular access makes chronic hemodialysis possible because it allows the care team to access the patient’s blood. An access can be internal (inside the body) or external (outside the body). It must:
- Allow repeat access to the blood
- Handle blood flow rates that will ensure effective treatments
- Be made of materials that are not prone to causing reactions or infections
The three main types of access are fistulae, grafts, and catheters.

To create a fistula, a surgeon sews an artery and a vein together, most often in an arm. Arteries carry oxygen-rich blood from the heart and lungs to the rest of the body. The vessels selected for a fistula are large and have good blood flow, but are deep below the skin and hard to reach with needles. Veins bring blood back to the heart and lungs; they are easy to reach, but too small and too slow flowing for dialysis (see Figure 1). Linking an artery and a vein is the best of both worlds. In 4–6 weeks, high-pressure blood flow from the artery thickens the vein wall and makes it dilate (enlarge) so large needles can be used. Because a fistula is below the skin and is the patient’s own tissue, it is less prone to infection and clotting than other types of access. A fistula can last for years—even decades—and research shows it is the best type of access now available. New surgical techniques and ways to assess and preserve blood vessels have made fistulae an option for more patients.

To insert a graft, a surgeon links an artery and vein with a piece of artificial blood vessel. Like a fistula, a graft allows access to the large volume of blood needed for dialysis. Grafts are more prone to stenosis (narrowing of blood vessels), which can cause thrombosis (blood clots). Grafts are also more prone to infection than fistulas, and have a shorter useful lifespan (less than 5 years on average). Grafts are an option for patients who do not have blood vessels suited to create a fistula.

A catheter is a plastic, hollow tube placed in a deep central vein in the chest or leg (see Figure 2).

Figure 1: Venous/arterial anatomy of the arm
Figure 2: Anatomy of veins
Radial artery
Ulnar artery
Brachial artery
Axillary artery
Cephalic vein
Basilic vein
Antecubital vein
Basilic vein
Distal cephalic vein
Basilic vein
Femoral vein
Cephalic vein
Inferior vena cava
Superior vena cava
Subclavian vein
External jugular vein
Internal jugular vein
They allow short-term or long-term access to patients' blood. Deep central veins have a blood flow rate that allows adequate treatment. Catheters are made of plastic that is foreign to the body, and they pass through the skin, creating a portal for bacteria. They are prone to stenosis, blood clots, and infection. Due to these problems, catheters must often be replaced in the same or new vessels. Catheters are used for patients who:

- Can't have a fistula or graft
- Are waiting for a fistula or graft to be placed or to mature
- Have acute kidney failure and may soon recover kidney function
- Are waiting for a peritoneal dialysis catheter
- Are waiting for a live donor kidney transplant

Despite more than 65 years of effort, access is still the one greatest challenge to the success of dialysis. Between 25%–50% of all hemodialysis patient hospital stays are due to access problems. The costs add more than $1 billion to Medicare inpatient bills each year. Patients whose accesses don't work well don't get enough dialysis. They may become uremic and feel ill and tired. They don't feel well enough to work, exercise, or do hobbies that could improve their quality of life. When patients feel ill, it affects their family and friends and the care team. Access problems frustrate the care team and the patient. Trouble cannulating (putting needles into) fistulae and grafts is a source of stress for both. Poor cannulation can lead to problems that may cause access failure. Access failure means loss of the dialysis lifeline. The access must be repaired or replaced if the patient has a site left. Access problems cause hospital stays, surgery, illness, loss of limb, even death. Access problems also use staff time, disrupt schedules, and reduce center income while patients are in the hospital. All forms of access involve some compromise and have problems. Research is being done to seek the best vascular access for dialysis patients.

The NKF Kidney Disease Outcomes Quality Initiative (KDOQI) and the Fistula First program (see page 127) are two, ongoing efforts to improve access outcomes. The guidelines include assessment and preservation of blood vessels for fistulae, and promote early fistula placement when possible. In this module, we'll tell you about fistulae, grafts, catheters, and other devices. Each section includes definitions, assessment, and monitoring. We also cover the KDOQI guidelines, patient teaching, and complications of each type of access. You have the vital task of helping patients to keep their lifelines. Proper access care and use can improve quality of life for your patients and job satisfaction for the
how to care for the whole care team.

Fistulae

HOW FISTULAE ARE CREATED

A native arteriovenous fistula (AVF) is made by surgically linking an artery to a vein. This link is the anastomosis, and the site is marked by a scar. It takes 1 to 3 months for an AVF to be strong enough to use large-gauge needles, so it is best to create one long before dialysis is needed.

Vascular Access

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As soon as the surgery is done, rapid and strong arterial blood flow sent to the vein starts to enlarge the fistula vein and make it tougher. This is called arterialization, and we say the fistula is maturing. About a week after the surgery, patients should start to do exercises that can help their fistulae to mature, like squeezing a rubber ball or lifting light weights.3,4

The most common type of native AVF links the radial artery and the cephalic vein in the distal forearm (between the wrist and the elbow). This is called a radiocephalic fistula (see Figure 3). The brachiocephalic (brachial artery and cephalic vein) fistula is also used, and is the most common AVF of the upper arm. If these vessel pairs can’t be used for some reason, others can be used instead. These may include:

- Basilic vein
- Transposed basilic vein (the deep vein is brought closer to the surface of the skin and the vein is moved to the anterior [front] surface of the upper arm for easier needle insertion)
- Transposed one of the brachial veins (a pair of veins closely accompanying brachial artery and draining to the axillary vein)
- Perforated vein in the antecubital fossa anastomosed to the brachial artery (perforating veins connect superficial and deep veins)
- Ulnar artery
- Proximal radial artery

While the AVF is the best type of access, not every patient can have one. Surgeons must be sure there will be good blood flow for the hand once the fistula is created. The chosen veins must be healthy, straight, large enough to allow for large-gauge needles, and long enough to permit a number of needle sites. Patients must also be able to handle a 10% or more increase in cardiac output (the amount of blood passing through the heart) to have a fistula. A new access strains the heart, because arterial blood quickly short-circuits through the fistula instead of passing slowly through tiny capillary blood vessels. The heart must work harder due to the rapid blood flow.

There are many reasons why a patient may not be able to have an AVF. These include:

- Damage to veins due to intravenous drugs
- Previous surgeries on the arteries and/or veins

Figure 3: Examples of AVF locations

Great saphenous vein
Femoral artery
Basilic vein
Ulnar artery
Distal cephalic vein
Radial artery
Atherosclerosis: plaque or waxy cholesterol that blocks the vessels

Poor quality arteries due to peripheral vascular disease (PVD) or advanced diabetes

Only one working artery to bring blood to the hand

Damage to blood vessels due to intravenous drugs

**FISTULA PROCEDURE**

Before surgery, patients should have vessel mapping done to find the best vessels for a fistula. To create a fistula, blood vessel sites are marked on the skin. An incision is made in the skin over the chosen vessels. Then the vessels are sewn together.

There are four ways that arteries and veins can be joined to create an AVF (see Figure 4). Each has pros and cons:

- **The side-to-side (artery-side to vein-side) anastomosis** is easiest for a surgeon to do. It is also the most likely to cause venous hypertension. This is a problem in which the hand fills with fluid due to high pressure in the veins. Sometimes the surgeon will do a side-to-side anastomosis, then tie off one or more of the vessels leading to the hand.

- **The side-to-end (artery-side to vein-end) anastomosis** is preferred by many surgeons, even though it is hardest to do. This method gives high blood flows with few complications.

- **The end-to-side (artery-end to vein-side) anastomosis** has slightly lower blood flow rates than the side-to-side.

- **The end-to-end (artery-end to vein-end) anastomosis** permits less blood flow through the access.

After the incision is closed, a thrill, or purring vibration, should be present over the new fistula. You should be able to hear a whooshing bruit with a stethoscope along the course of the vein. The bruit should be continuous and low-pitched. Both the thrill and the bruit help prove that the new fistula is patent (open).

**PROS AND CONS OF FISTULAE**

**Pros**

The AVF is the gold standard for hemodialysis access. In general, it lasts longest and has the fewest problems, including infection. Using the patient’s own vessels is always best when it can be done.

**Cons**

The main disadvantage of an AVF is how long it can take to mature: 4-6 weeks or more. Some fistulae also fail to mature at all, a problem.

Vascular Access

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Figure 4:

Types of anastomosis

End-to-end
End-to-side
Side-to-end
Side-to-side
called early or primary failure. A fistula may not mature if:
- The anastomosis is too small, so less blood flows into the fistula
- A stenosis develops at the inflow between the anastomosis and the fistula
- Side veins off of the AVF (accessory veins) reduce pressure in the fistula, so it does not arterialize
- The vessel chosen by the surgeon was too small (<2 mm)

Vessel mapping can help a surgeon choose good vessels so this problem is less likely.

ASSESSING MATURITY OF A FISTULA

As a new technician, you will not be cannulating brand new fistulae. But, you will still need to assess a new fistula at each treatment to be sure it is developing. To do this, you will need to:
- Look for signs of infection — redness, drainage or abscess formation.
- Look for signs of wound healing of the surgical incision.
- Feel for a thrill — it should be continuous and feel like purring or vibration, but not a strong pulsation.
- Feel the diameter of the vessel — it should start growing larger immediately after surgery and the growth should be evident within 2 weeks. Note any flat spots.
- Listen for a bruit — the pitch should be low, and one sound should connect to the next sound.
- After the first week, apply a tourniquet and feel for firmness of the fistula vein; this will tell you that the vessel walls are getting thicker/stronger.

Fistula First: Increasing Use of Fistulae in the U.S.

The Centers for Medicare and Medicaid Services (CMS) started Fistula First in 2003. It is the first breakthrough initiative of CMS, and its goals are to raise the use of AVFs to 40% of hemodialysis patients and decrease the use of catheters. Fistula First includes nephrologists, vascular surgeons, interventional nephrologists, nurses, primary care doctors, patients, and others. These partners are working to change practice and assure that AVFs are the first choice for all patients who can have one. The ESRD Networks and CMS run the program.

Fistula First has 11 Change Concepts that centers can use to increase the use of fistulae:
1. Routine continuous quality improvement (CQI) review of vascular access
2. Timely referral to a nephrologist
3. Early referral to a surgeon for AVF only evaluation and timely placement
4. Surgeon choice based on best outcomes, willingness, and ability to provide access services
5. Full range of appropriate surgical approaches to AVF evaluation and placement
6. Secondary AVF placement in patients with AV grafts
7. AVF placement in patients with catheters where indicated
8. AVF cannulation training for patient care staff
9. Monitoring and maintenance to ensure adequate access function
10. Education for caregivers and patients
11. Outcomes feedback to guide practice

Your role in Fistula First includes being on your center’s vascular access CQI team, learning to correctly cannulate fistulae, and taking continuing education on vascular access.
After 2\frac{1}{3} weeks if there is no change in the size of the fistula vein, the nephrologist and surgeon should be told. Dialysis patients should have a post-op visit 4\frac{1}{6} weeks after fistula surgery. According to access expert Gerald Beathard, MD, if access development is not seen by the second week after surgery, the access will not mature unless an evaluation is done and treatment occurs.9 When the vessel wall is firm and the diameter has grown, the doctor will order the fistula to be cannulated. To cannulate a new AVF, smaller needles (17-gauge) and low blood flows (200–250 ml/min) should be used for the first week of treatment.10 This will help reduce cuts in the vessel from the needle, help reduce pressure, and help prevent infiltration (pushing the needle through both fistula walls so blood leaks out into the tissues). After the first week, needle gauge size (see Figure 5) can be increased, and blood pump speeds can be turned up.

INITIATING DIALYSIS WITH A FISTULA

Wash Your Hands

Washing your hands is always the first step before you touch any dialysis access. Clean hands and clean gloves help prevent bacteria on the skin’s surface from being pushed into the patient’s bloodstream by the needle. Change your gloves if they get contaminated by such things as touching your face or hair, the chair, or any other surface. The Occupational Safety and Health Administration (OSHA) requires handwashing and gloves to protect both you and patients from infections.11 The Centers for Disease Control and Prevention (CDC) recommend the use of hemodialysis infection control precautions (gloves, gown, eye protection, and face mask) any time there may be a risk of blood splatters12 (see Module 6: Hemodialysis Procedures and Complications for more information on handwashing and hemodialysis infection control precautions).

Examine the Fistula

At each treatment, you will need to assess a patient’s fistula to be sure it has no problems and will work well and give the patient the best dialysis possible. You will need to learn how to inspect (look), auscultate (listen), and palpate (feel) the access, as we describe below.

Look for:

n Signs and symptoms of infection: Redness, drainage, pus, abscesses, open skin, fever
n Steal syndrome (not enough blood flow to the hand): Pale, bluish nail beds or skin
n Stenosis (narrowing): Swollen access arm, pale skin, small blue or purple veins on the chest wall where the arm meets the body
n Cannulation sites: Scabs from needles, the
anastomosis, curves, flat spots, aneurysms (ballooning of the blood vessels) and their width, height, and appearance
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128
25
17, 16,
15, or
14
Figure 5:
Types of needles
Butterfly needle
Gauge size
Shaft Hub
Bevel
Listen for:
- Bruit: The sound and pitch of the whooshing noise (a higher or louder pitch may mean stenosis)
- Deep access location: Place the stethoscope flat over the access and listen for the bruit. Then, move stethoscope from side to side and listen for the bruit to stop. This will help you find the exact location of the access.

Feel for:
- Skin temperature: Note warmth (possible infection) or cold (decreased blood supply)
- Thrill: Should be present and continuous, but not a strong pulse
- Stenosis: Feel for flat spots, check flat spots for a thrill
- Vein diameter: Start at the anastomosis with your thumb and forefinger on either side of the fistula. Is the diameter the same along the whole fistula? If there are aneurysms, how wide are they? Are there any flat spots? The diameter of the vessel needs to exceed the gauge of the needle. How deep is the access? This will determine your angle of needle entry.
- Identify sites for cannulation: Stay 1.5 inches away from the anastomosis, keep the needles at least 1.5 inches apart, avoid curves, flat spots, and aneurysms. When rotating sites, avoid prior cannulation sites (scabs).
- Steal syndrome: Cold hand temperature in the patient’s access hand (compare with the other hand); have the patient squeeze your hand; note any changes in motor skills.

Assess Blood Flow
The next step before inserting needles into an AVF is to check the blood flow. Each fistula should have a strong flow of blood from the artery through the access and into the vein. The fistula should have a strong thrill at the anastomosis, as arterial blood is pumped by the heart through the fistula. You will also need to check the bruit: place your stethoscope on top of the access and listen to the whooshing sound. It should be strong and continuous, with each sound linked to the one before. A change in the bruit to a high-pitched or louder whooshing may mean that stenosis is present. Teach patients to listen and report any changes to the charge nurse and/or nephrologist right away. A change in the thrill or in the volume of the bruit can also mean that blood flow through the access is slowing down. This is a sign that the fistula may be clotting. Tell the nurse in charge so he or she can assess it before the needles are inserted. You will need to learn how each patient’s access normally sounds. Alerting the nurse to a change in the thrill or bruit may allow a failing access to be repaired in time.
Prepare Access Skin
Clean the patient’s access site before needle insertion to keep bacteria from getting into the bloodstream through the skin. Staphylococcus aureus, or “staph” infection, is common in dialysis patients because:

- Patients are at a high risk for infection
- Many have diabetes
- There are large numbers of catheters
- Patients have frequent hospital stays and surgeries, exposing them to infectious agents
- Dialysis is a community-based setting
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A study by Kaplowitz et al found that staph in the nose and the skin is common in hemodialysis patients. This is why it is vital to teach patients to wash their access sites using antibacterial soap and water or an alcohol-based gel before they come to their chairs. This will help reduce the number of bacteria on the skin before you insert the needles, and lower the patient's risk of infection.

Clean and prep the patient's skin with a solution of 70% alcohol, 10% povidone iodine, or chlorhexidine gluconate with 70% alcohol, following your center's procedures:

- Alcohol kills bacteria only while it is wet, so use a 60 second circular rub on each site.
- Povidone iodine (Betadine®) kills bacteria only after it dries, so wait 3-5 minutes.
- Chlorhexidine gluconate (ChloraPrep®) with 70% alcohol kills bacteria only after it dries, so wait 30 seconds.
- Sodium hypochlorite (ExSept® Plus) the manufacturer recommends you wait 2 minutes before cannulating.

Start on top of the sites you will put needles into and move outward in a circular, rubbing motion. This will carry bacteria away from the point of insertion.

Apply a Tourniquet

Always use a tourniquet when you insert needles into a fistula, even when the size of the vessels does not seem to need it. The tourniquet helps you to see the fistula better, holds it in place (prevents rolling), and gives you a better feel for cannulation. The tighter skin also promotes a cleaner entry. Apply the tourniquet as far from the fistula as you can (just below the armpit) to help distribute pressure evenly along the vein and decrease the risk of infiltration. Tourniquets should never be so tight that they cause pain, tingling, or cut off blood flow to the fingers. They should only be used for cannulation, not during dialysis.

Insert Needles

Feel for the depth of the access before you insert your needles into a fistula. The angle of entry for a fistula will vary based on the depth of the access. The deeper the access, the steeper the angle of entry should be for you to have most of the needle inside the access. This will prevent infiltration if the patient moves the access limb during dialysis.

Your center should have a written cannulation training program, with a checklist to be sure that you have learned all of the steps: proper site cleaning, needle insertion, and taping. Practice these skills in a lab setting, on a practice arm, before you try to cannulate a patient. It takes a lot of practice to be a good cannulator. New patient...
care staff should never cannulate brand new AVFs; they are delicate and require an experienced, expert cannulator. Only the most skilled staff in your center should cannulate new fistulae.

The key point to remember about cannulation is that it is a gentle technique. You choose your angle of insertion based on the depth of the vein, push the needle through the skin and tissue until you feel a release of pressure, check that you get a flashback (blood in the tubing), drop the angle down, and advance the needle. This sequence should be a fluid motion with no jabbing, digging, or probing with needles.
Do not flip the needle (turn it 180° after it is in the vessel). Flipping the needle can:

- Stretch the needle hole, which can lead to oozing during treatment after the patient is heparinized.
- Tear the lining of the vessel.
- Cause infiltration.

By doing a complete assessment, you will know just where to go and how deep the access is there should be no guessing. Determine where you will place both needles ahead of time. Try to leave space beyond the venous needle to place another needle in case the first attempt is not successful or infiltrates. The venous needle is usually closest to the heart. Remember how much is at stake for your patient, and how vital it is for you to learn good technique to help preserve their lifelines. Depending on your center’s procedures and how easy or hard it is to insert needles into a certain patient’s access, you may do wet cannulation or dry cannulation. Wet cannulation is done with a saline-filled syringe, and can be useful for hard insertions or patients who clot very quickly. Dry cannulation uses the dialysis needles without saline. Follow your center’s procedure for inserting needles after properly cleansing the needle puncture sites.

**Antegrade and retrograde needle direction**

You may wonder which way to point the needles. The venous needle should always be placed antegrade (in the direction of blood flow). This helps prevent turbulence when the blood returns from the extracorporeal circuit. It is important to be sure that this needle is downstream from the arterial needle to prevent recirculation of the newly dialyzed blood back through the dialyzer circuit.

The arterial needle is so called because it is the one placed closest to the anastomosis and receives blood from the artery. This needle can be placed antegrade or retrograde (into the flow of blood). No matter which way your center suggests for the needles, always keep the needle tips at least 1.5 inches apart and stay at least 1.5 inches away from the anastomosis. These rules will prevent recirculation and decreased adequacy.

**Rope ladder technique (rotating sites)**

Each time a needle pierces a vein, it makes a hole. When you take the needle out, a clot forms to close up the hole until the vessel heals. When the patient comes in for the next treatment, you will look for the scabs from the last holes and choose different sites so the first ones can heal. This is called rotating sites, or the rope ladder.
technique. Picture a ladder with rungs—the first day you put needles on two different rungs. Then, at each treatment, you choose two new rungs until you reach the top of the ladder, then start over again at the bottom. Sites are rotated to help prevent aneurysms (weak spots in the vessel wall that balloon out). It may seem easier and faster to place needles in the same general area at each treatment, but this weakens the wall of the blood vessel. If you spread out the sites, you will reduce the risk of
Aneurysms along the fistula. Patients may ask you to cannulate aneurysms because it hurts less. Explain that aneurysms can rupture (break open) because the skin gets very thin; they could lose a lot of blood and need surgery to repair their access.

Buttonhole technique (constant-site)
The buttonhole technique has been used in Europe and Japan for more than 25 years, and is becoming more popular in the United States. It was first used on an access that had limited surface area for needles. Dr. Zbylut Twardowski, who invented the technique, found that it has fewer infections, missed needle insertions, hematomas (bruises), and infiltrations.

Both needles (arterial and venous) should be inserted in an antegrade direction to aid hemostasis after needle removal. To use this technique, remove the scabs from the last cannulation sites. Moisten the scabs first so they don’t break into little pieces. To remove the old scab:

- Apply saline or alcohol-based gels to a 2 x 2 gauze pad and lay one over each site, then use antiseptic tweezers.
- Provide alcohol squares and tape for the patient to take home, and ask him or her to tape an alcohol square over each scab before coming to dialysis.

After the scab is gone, prepare the sites according to your center’s policy. Once the sites are ready, you will reinsert sharp needles at the same angle into the same two holes (see Figure 6). Over the course of 3–4 weeks, a well-healed scar track/tunnel forms like a pierced earring hole. During this time, the same person should place the needles to be sure the same angle is used each time. This person can be the patient, since he or she is always there at each treatment. Once the scar tracks/tunnels are formed, blunt needles (see Figure 7) should be used to avoid cutting the track/tunnel, which can cause oozing during dialysis.

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Figure 6:
Buttonhole technique

Drawings used with permission from Medisystems Corporation

Using a sharp AV fistula needle, grasp the needle wings, and remove the tip protector. Align the needle cannula, with the bevel facing up, over the cannulation site and pull the skin taut.
Cannulate the site. It is important to cannulate the developing constant-site
in the exact same place, using the same insertion angle and depth of penetration each time. This requires that a single cannulator perform all cannulations until the sites are well established. A flashback of blood indicates the needle is in the access. Lower the angle of insertion. Continue to advance the needle into the AV fistula until it is appropriately positioned within the vessel. Securely tape the AV fistula needle and proceed with dialysis treatment per center protocol.
Securing the Needles
After Insertion
After the needles are inserted, they need to be secured. The butterfly tape technique is a method of securing the needles (see Figure 6). Carefully place a piece of 1-inch wide adhesive tape, 6 inches or greater in length, under the fistula needle and then fold it so it crosses over the needle site. Then place a bandage or 2 x 2 gauze pad over the needle and secure it with another 6-inch piece of tape. You must secure the needles to keep them from moving or pulling out of the access. Monitor the needles for movement during the dialysis treatment.23

Coping with Patients
Needle Fear
In the general public, at least 1 person in 10 has a physical fear of needles, injection, blood, or injury type of specific phobia.26,27 People with this fear have an involuntary vasovagal response to needles, the sight of blood, surgery, etc.:27

- First, the pulse speeds up and blood pressure rises
- Then, the pulse slows, blood pressure drops, stress hormones are released, and heart rhythms may change
- Patients may become pale, sweaty, nauseated, dizzy, and may pass out

Some of these fearful patients may choose peritoneal dialysis (PD) to avoid needles, but PD patients may one day need to switch to hemodialysis. Patients who have needle phobia may be able to learn to short-circuit the vasovagal response. Some tips that may help:
- Lay the chair flat to keep blood in the brain so the patient doesn’t pass out.
- With the patient’s doctor’s permission, have the patient tense the muscles of his or her non-access limbs for 10 or 20 seconds, relax, then re-tense them until the needles are in. This can temporarily raise the blood pressure and prevent the vasovagal response.27
- Reduce needle pain, using the techniques listed in the next section. Pain is part of the cause for the fear.
- Teach patients how to insert their own needles. This distracts them from the pain and replaces it with control.

Reduce pain from needle insertion
Dialysis needles are quite large to allow enough blood flow. So, needle insertion can be painful. The goal is to insert the fistula needles easily and as painlessly as possible, while causing the least amount of trauma to the access. The 3-point technique can help reduce the pain of needle insertion and aid in successful
First, apply a tourniquet to stabilize the fistula vein. To minimize vein
Figure 7: Buttonhole versus regular needle
Drawing adapted with permission from Lynda Ball
Buttonhole needle (blunt)
Regular needle (sharp)
movement, place the thumb and forefinger of your non-needle hand on either side of the fistula vein, just above where the needle will go. Then, with your pinky or ring finger of the needle hand, pull the skin taut (tight) and press down on the skin (see Figure 8). The tighter the skin, the more easily the needle can puncture it, which will reduce pain. Pressing on the skin will temporarily block the pain-to-brain sensation for up to 20 seconds, giving staff enough time to insert a needle.

Patients who insert their own needles say that they feel much less pain than if someone else does the job. Patients who learn to put in their own needles are taking a vital role in their own care that can help them to feel better. They also help to preserve their access sites. Because they can feel the access from both the outside and the inside, it may be easier for patients to avoid infiltration. Another way to help patients with needle phobia if they have AVFs is to use the buttonhole technique, which causes less pain.

Other ways that patients can reduce pain include breathing techniques, guided imagery, and listening to music. Distraction can work quite well. Have the patient in the next chair or a staff person talk with your patient while you insert the needles. Patients may be given the choice of a local anesthetic (a product to numb the skin). Options include intradermal (injected into the skin) lidocaine, ethyl chloride spray, and topical creams or gels that are applied to the skin's surface.

The KDOQI Clinical Practice Recommendations for Vascular Access say that patients who are capable and whose access is suitably positioned should be encouraged to self-cannulate and the preferred method is the buttonhole technique.

Lidocaine injection

An injection of 1% intradermal lidocaine can be used to numb the tissue (see Figure 9). The needle sites must be prepped first. Use a separate 1-cc or tuberculin syringe and needle for each site. Inject the lidocaine just below the skin into the tissue above the graft or fistula. (Never inject lidocaine into the patient's fistula vein; this would allow it to enter the bloodstream.)

The lidocaine will form a bubble or wheal just under the skin. Lidocaine burns, so only a small amount should be used. The lidocaine may leak back out from the injection site and/or bleeding may occur at the injection site. Use a sterile gauze pad to wipe away any leakage or bleeding. Note: Because lidocaine is injected with needles, it may not be helpful for patients who have needle fear.
Three-point technique for needle insertion
Figure 9: Intradermal injection of local anesthetic
Drawing adapted with permission from Lynda Ball
Lidocaine is a vasoconstrictor that can make the fistula vein smaller in diameter and pull it a little deeper under the skin. This may make cannulation more difficult. Patients whose fistula vein is very close to the skin’s surface may have less pain when needles are inserted without lidocaine. The patient can compare the amount of pain if you use lidocaine with one needle and not the other. Per your center’s policy, allow the patient to choose which method he or she prefers.

Ethyl chloride spray
Ethyl chloride spray can be used to numb the skin. The spray creates a cold feeling. It does not numb the tissue under the skin, so a patient with a deep access will still feel the needle enter the tissue and will feel pain. Ethyl chloride spray is not sterile. The site must be cleaned by the patient, sprayed, and then prepped by staff prior to needle insertion.

Topical anesthetics
Patients can use topical anesthetics (gels or creams that numb skin and tissue). These products must be applied to the skin, then wrapped in plastic wrap at home by the patient at least an hour before the treatment. Topical anesthetics work by contact time, not by the amount applied. In order for the top 3-mm of tissue to be numb, apply the cream 60 minutes before treatment. If you want the top 5-mm of tissue to be numb (for deeper accesses), have the patient apply the cream 120 minutes before treatment. Some examples are:

- Prescription EMLA cream (2.5% lidocaine/2.5% prilocaine)
- Over-the-counter Less-n-pain (4% lidocaine)
- Over-the-counter L.M.X.® (4% lidocaine)
- Over-the-counter Topicaine® (4% or 5% lidocaine)

At the center, the patient takes off the plastic wrap and washes off the cream. Remind patients to wash their hands after putting on the cream and to keep their hands away from their eyes to prevent damage to their mucous membranes. Like injected lidocaine, the creams cause vasoconstriction of the fistula.

FISTULA CARE
POSTDIALYSIS
At the end of a treatment, you will untape and remove the needles per your center’s policy. Make sure you have completely removed the needle before applying pressure to the skin; you could cut the patient’s access if you press too early. Follow your center’s policy to apply the right amount of pressure to the puncture sites. The goal is to stop bleeding, but not damage the access or stop blood flow through the fistula.

Tips to Increase Fistula Life
To help an access last longer:

- Use the buttonhole technique or rotate needle sites at each treatment. Do not keep cannulating a fistula in the same general area. This could cause an aneurysm.
- Teach the patient not to permit IVs, routine blood draws, or blood pressure checks on the access arm. A “Save the Vein” card is helpful for patients to carry and give to medical staff if blood draws are needed.
- Keep accurate and detailed records of each treatment. If you see any problems with the patient’s fistula, tell the nurse or the doctor.
it, which could raise the risk of a blood clot. Teach your patients how to hold their own sites after a treatment.

**FISTULA COMPLICATIONS**

For patients, access problems can lead to access failure, inadequate dialysis, hospital stays, and even early death. If an access is lost, a new one must be created. This means surgery and recovery, which disrupt the patient’s routine and reduce quality of life. With only about 10 sites in the body that can be used for an access, each new surgery limits the patient’s future options. Each year, some patients die because they have run out of access sites.

Access problems also affect the care team. They disrupt schedules and make treatment more difficult. Treatment of access problems uses valuable staff time.

You need to know about common access problems and how they are treated so you can help preserve your patient's dialysis lifelines and quality of life. By learning how to prevent access complications, you can help your patients keep their accesses longer.

**Infection**

Never cannulate an AVF that looks infected. The fistula needle can transfer an infection on the skin into the patient’s bloodstream. This can cause sepsis, blood poisoning, one of the leading causes of death in people on dialysis. Tell the nurse right away if you see signs of infection so he or she can call the nephrologist. The nephrologist will give orders about cannulation, follow-up, and antibiotics.

**DIALYSIS-RELATED COMPLICATIONS OF FISTULAE**

Certain problems with fistulae occur only during a treatment.

**Line Separation**

Exsanguination (severe loss of blood) can occur if a needle comes out, the lines come apart, or the fistula ruptures (burst). To keep needles from being pulled out, follow your center’s procedures for taping (see Securing the Needles After Insertion on page 133). Fasten the bloodlines securely and set the arterial and venous pressure monitor limits so you will know right away if a problem occurs.

The air/foam detector and venous and arterial pressure monitors can help prevent exsanguination if they are armed and working. But, sometimes a dislodged needle can cause a slow loss of blood over the course of a treatment. In this case, the drop in venous pressure may not be enough to set off the alarm, and you may not see the blood if the patient’s arm is hidden by a blanket.
If a patient is losing blood through the tubing, turn off the blood pump and clamp the bloodlines. Apply pressure to the needle site if the needles were pulled out. Oxygen, saline, or blood volume expanders may be needed if a lot of blood was lost. If needed, start emergency procedures (e.g., call 911) per center policy.

Air Embolism

Air that enters the patient’s bloodstream can stop the flow of blood, much like a blood clot.

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If enough air enters the bloodstream, the heart pumps foam instead of fluid blood. This reduces cardiac efficiency and can cause cardiac arrest. Bloody foam in the lungs makes it hard to breathe. An air embolus in the brain can mimic a stroke. Depending on where the air goes, the patient may be highly anxious; have trouble breathing; become cyanotic (turn blue); have vision problems or low blood pressure; or become confused, paralyzed, or unconscious.

Newer dialysis machines do not permit alarm overrides. If your center has older machines, always check to be sure that the air/foam detector is armed and working before each treatment and when you return the patient’s blood after dialysis. If the air/foam detector alarm sounds, look at the venous line to see if any air is present before you override the alarm. Tape or Luer-Lok® all line connections securely to keep them from coming apart. Look at the blood tubing injection ports for micro bubbles after you draw samples or give IV solutions. You can also teach patients to watch their bloodlines to be sure air does not enter the tubing. No air should be present in the tubing between the air/foam detector (or below the venous drip chamber) and the patient. Air in the arterial line before the dialyzer should be caught in the arterial drip chamber before it can enter the dialyzer. The air/foam detector should stop the blood pump if there is air in the venous drip chamber. If you suspect that a large amount of air entered the venous system, have the patient lie on his or her left side and tell a nurse. Lying on the left side decreases the chance that air will travel to the brain and the pulmonary artery.

Infiltration/Hematoma
An infiltration occurs when the needle tip goes into the vein and out the other side, or nicks the side of the vessel, letting blood escape into the patient’s tissues (see Figure 10). Infiltration is the most common complication of needle insertion. It occurs less often once staff have more practice placing needles. Infiltration harms the access, which can lead to access failure. For patients, infiltration causes pain, bruising, the need for an extra cannulation, and loss of trust in the staff. Blood that leaks into the tissue around the

Tips to Prevent Blood Loss During Dialysis
To prevent blood loss during dialysis:

1. Never let patients cover their needles or bloodlines with sheets or blankets. You must always be able to see the access.
2. Secure all bloodlines and access connections before you start a treatment, and tape the needles so they can’t be pulled loose.
3. Don’t let blood tubing touch the floor; it could be stepped on and pulled apart.
Check to be sure that the air/foam detector and arterial and venous pressure monitors are working before you start a treatment, and that the monitors are armed once dialysis begins.

Figure 10:
Needle infiltration
Skin
Soft tissue
Vein
blood vessel (hematoma) makes the area swollen, hard, and sometimes red. An infiltrated venous needle will raise the venous pressure, which will set off the venous pressure alarm to stop the blood pump. An infiltration of the arterial needle will cause the arterial pressure to become more negative.

To prevent infiltration, closely follow the needle placement technique used at your center, and:
- Use a gentle technique.
- Do not rush.
- Develop a feel for the least bit of resistance in the vessel.
- Level the needle to the surface of the skin. Advance it slowly up to the hub as soon as you feel a pressure change and can see a flashback of blood in the needle tubing.
- Don’t flip the needles.
- Flush the needles with saline after insertion to check for good placement (no pain, swelling, or resistance to the saline flush).
- Use the wet needle cannulation technique.

Remove a needle that infiltrates before heparin is used. Have the patient apply pressure to the site, just as he or she would at the end of a treatment. If infiltration occurs after the patient receives heparin, the nurse may tell you to leave the needle in place. You will then need to insert another one beyond the site of the infiltration (usually above). If a hematoma forms, give the patient an ice pack and something to act as a barrier (i.e., washcloth) between the ice and the skin to hold in place during treatment, to help reduce the swelling. The patient should keep ice on for 20 minutes, off for 20 minutes, on for 20 minutes, etc.

Finally, do not subtract the time you spend taking care of a needle infiltration from the patient’s total dialysis run time. Lost minutes lead to inadequate treatment. Add the lost time to the end of the treatment to be sure that the patient receives the prescribed dialysis dose.

Bleeding During Dialysis

Bleeding around the needles during a treatment may be a minor problem (oozing at needle sites) or a life-threatening emergency (needle falling out with the blood pump running). Frequent loss of small amounts of blood during dialysis adds to the risk of anemia, a shortage of red blood cells.

Do not flip the dialysis needles. This practice causes the hole to stretch until it is larger than the needle size, causing oozing during dialysis. (If oozing does occur, place a sterile dressing over the site.) Use a back eye needle for the arterial draw to eliminate the need to flip the needle. Profuse bleeding may suggest a tear in the blood vessel or bleeding from a remote site within the access. Uncontrolled bleeding is...
a life-threatening situation. Call the nurse or doctor right away.

Recirculation

Recirculation occurs when dialyzed blood returning through the venous needle mixes with blood entering the arterial needle. The mixing means that already-dialyzed blood goes back through the dialyzer to be cleaned again, while the rest of the patient’s blood is not cleaned enough. So, recirculation makes Vascular Access

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treatment less efficient. Over time, poor 
dialysis can lead to symptoms of uremia. 
Recirculation can occur when:
- The blood flow within the AVF is lower than 
  that in the dialyzer (<300-500 mL/min)
- The needles are placed too close together 
- Lines are reversed
- A stenosis is present
In severe cases, recirculation will re-clean the 
same blood so much that it turns dark from 
lack of oxygen ([black blood syndrome]). More 
often, recirculation may not cause any shortterm 
symptoms. Recirculation studies may be 
done if the delivered dialysis dose drops as 
noted by a decrease in URR or Kt/V the blood 
flow rate drops due to higher venous pressures, 
or the team thinks stenosis is present.

These steps can help ensure proper needle 
placement to prevent recirculation:
- Palpate the patient's access to find the 
direction of blood flow.
- Assure that the tips of the arterial and 
  venous needles are at least 1.5 inches apart.

LONG-TERM 
COMPLICATIONS 
OF FISTULAE
Steal Syndrome
Steal syndrome is a set of symptoms caused 
by hypoxia (lack of oxygen to the tissues).
When an access is created, sometimes it steals 
too much blood away from the hand and sends 
it through the access. Patients feel pain that can 
range from minor to severe. In most patients, 
steal syndrome pain lessens over time because 
extra blood vessels grow and supply blood to 
the area (collateral circulation). Vascular 
surgeons say that people with diabetic 
neuropathy or peripheral vascular disease must 
be watched very closely. Their symptoms may 
get worse, and they will often need some form 
of intervention.

Some of the symptoms to watch for or ask 
your patients about include:
- Pain in the access limb
- Tingling in the access limb
- Cold feeling in the access limb
- A change in motor skills in the hand
- Nail beds that are blue in color
- Necrotic (dead, blackened) spots on 
  the skin
- Decreased feeling in the access limb

Tell the nurse or nephrologist if you suspect steal 
syndrome so they can call the vascular surgeon. 
Try to keep the patient's hand warm during 
dialysis, perhaps with a mitten, blanket, or tube 
sock. Changing the position of the patient's 
arm may help increase blood flow in the hand. 
Henriksson and Bergqvist stated that 5% of 
AVFs cause steal syndrome. They have also
found that steal syndrome can be treated by reducing blood flow through the fistula, making the vessels larger, or tying off some blood vessels surgically. You need to know that steal syndrome can be treated, so tell the nurse as soon as you notice any signs of it. Early follow-up with the surgeon is critical.
Aneurysm

Putting needles in the access in the same general area time after time can cause an aneurysm. This pattern of cannulation weakens the vessel wall and causes a bulge or gumdrop or ballooning to form on the access. With time, flow in an otherwise normal AVF continues to increase, and the vein may keep enlarging. Aneurysms are more likely to occur upstream (retrograde) from a venous stenosis, especially at sites of repeat needle insertion. The sites are easy to see. Follow their progress and note any associated skin changes.32

Rotate needle puncture sites or use the buttonhole technique to prevent aneurysms. Do not insert needles into areas of aneurysm. Aneurysms leave less surface area for cannulation. Surgery is needed when the skin over the fistula has signs of impending access rupture such as marked thinning, ulceration, or bleeding.32

Stenosis

Stenosis is a narrowing of the blood vessel that slows the flow of blood through the access (see Figure 11). The KDOQI Clinical Practice Guidelines for Vascular Access say that reduced blood flow through a fistula predicts clotting and access failure.1 There are three major sites where stenosis is likely to form:

1. Inflow - the most common type of inflow stenosis is called juxta-anastomotic stenosis (JAS). It is found in the vein right next to the anastomosis. A JAS will keep a fistula from maturing because it does not allow enough blood flow to enter the fistula. A JAS may be due to stretching, twisting, or other trauma during the fistula surgery.32 You may be able to feel a JAS as a flat spot just past the anastomosis.
2. Outflow - stenosis can occur anywhere along the outflow vein. It may occur in an area where the patient has had an IV placed in the past. The area past the stenosis may appear smaller, making needle insertion more difficult for fear of infiltration.
3. Central vein - central venous stenosis occurs in the large draining vein of the arm, often in the shoulder area. If a stenosis is suspected, the venous system should be checked from the fistula to the heart, so a central stenosis can be found. These stenoses are most likely caused by catheter placement in the past.

All patient care staff need to watch for these symptoms:

- A high-pitched or louder-pitched bruit
- Harsh or water-hammer pulse
- Discontinuous bruit (each sound separate whoosh whoosh whoosh)
- Decreased thrill
- Trouble inserting or threading the dialysis
needles 
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Figure 11: 
Stenosis in a fistula 
Cephalic vein 
Radial artery Stenosis
n Swelling of the patient’s access limb
n Increased venous pressure during treatment, forcing you to turn the blood pump down
n Recirculation
n Extracorporeal system clotting off during treatment
n Increased bleeding after needles are removed postdialysis
n [Black blood syndrome]

Black blood syndrome
n Decrease in Kt/V and URR
n Inability to obtain prescribed blood flow rate

Stenosis is caused by injury of the blood vessel lining that scars the blood vessel and creates flow turbulence. This leads to overgrowth of smooth muscle cells or aneurysm formation. Stenoses may recur after treatment.

To find venous or arterial stenoses, dye is injected into the vessel. With the dye, any narrowing will show up on an x-ray (fistulogram, venogram). Stenosis may also be found by color Doppler ultrasound.1 Ultrasound is a non-invasive way to look at blood vessels and blood flow.33 These methods allow the doctor to pinpoint the narrowing.

Some cases of stenosis can be treated with angioplasty, which is an outpatient procedure. The doctor threads a catheter with an inflatable balloon tip into the vessel. Once the balloon is in place, he or she inflates it to expand the vessel lumen. In other cases, access revision surgery may be needed to try to repair the access.

Thrombosis

Thrombosis (formation of a thrombus, or blood clot) occurs in all types of vascular access, but less than 1/6 as often in AVFs than in grafts.9 Blood has a number of components to stop a wound from bleeding by forming a clot. These include clotting proteins called plasma coagulants and platelets—tiny blood cells that stick together to seal off damaged blood vessels. Platelets clump when they are activated by contact with damaged blood vessel walls or by turbulence inside a blood vessel. Activated platelets and damaged tissues signal blood clotting proteins to form a strong net of fibers (fibrin). This net traps more platelets and red blood cells, so the clot gets more solid as it 141 21

Patient Actions to Prevent Thrombosis

To avoid thrombosis, patients should:

1. Prevent medical staff from using the access or access limb for routine blood draws, IVs, or blood pressure checks
2. Feel for the thrill and listen to the bruit daily to ensure patency
3. Think about learning how to self-cannulate to reduce the risk of mispuncture

Patients should not:

1. Sleep on the access arm
- Put too much pressure on the puncture site after removing the dialysis needles
- Wear tight-fitting clothing or jewelry that squeeze the access arm
- Carry heavy objects across the arms that compress the access, such as a purse
- Use the access for IV drugs
- Wear a watch on the hand that has a radiocephalic or lower arm fistula
grows bigger (see Figure 12). A clot may start to form any time there is low blood flow due to low blood pressure, dehydration, or too much pressure on the access. These conditions let blood pool at a damaged surface, like a needle site. In a fistula, blood flow through an area of stenosis may cause enough turbulence to activate platelets, so they stick to the vessel wall. Repeated cannulations also damage vessel walls, causing rough surfaces that activate platelets. Early thrombosis is most often caused by surgical problems with the anastomosis or twisting of the blood vessel. It can also be caused by stenosis, reduced blood flow due to hypotension at dialysis, a cardiac arrest, or compression of the vessel. The vessel can be compressed after surgery if blood leaks into the tissues causing swelling and hematoma. Hematomas may also form at the site of an infiltration, or if an access is used too soon after surgery. Applying too much pressure for too long to the puncture site after treatment may also lead to thrombosis. Pressure should not be placed on a puncture site for more than 20 minutes. If bleeding lasts longer than 20 minutes, the nurse should look at the heparin dose and check for an access problem, like stenosis. Late thrombosis may develop in a fistula that was working. It can be caused by increased turbulence from stenosis. Untreated thrombosis can destroy an access. According to interventional radiologist Dr. Perry Arnold, a thrombosed fistula can be rescued for up to 14 days after it clots. Thrombosis is most often caused by stenosis and low blood flow. The following signs may be present in a patient with pending access thrombosis:

- Reduced thrill and bruit
- Poor blood flow through the access
- Inability to obtain prescribed blood flow rate
- Sudden swelling of the hand on the access arm in a patient with a history of stenosis and blood flow problems
- Abnormally high venous pressure readings during dialysis
- A high recirculation rate; always check if the needle placement may have had an effect before calling the nephrologist
- Increased transmembrane pressure (TMP)

Suspect thrombosis if you feel no pulse or thrill and hear no bruit along the outflow vein.

Vascular Access

Figure 12: Blood clotting at a needle puncture site

Clot

Surface clot (scab)

Needle insertion Platelet activation Fibrin trapping platelets and blood cells
Thrombosis in a previously working access often follows stenosis. Early detection and repair of stenoses may help save the access. You can offer the team key information about signs of stenosis and thrombosis. Report signs of poor blood flow through the access, including reduced bruit or thrill and swelling of the hand. When you follow proper technique to insert needles and apply moderate, but not heavy, pressure to the puncture site posttreatment, you help reduce the risk of thrombosis. Vascular access monitoring can identify patients at risk for developing thrombosis.

Vascular access monitoring can identify patients at risk for developing thrombosis. The KDOQI Clinical Practice Guidelines for Vascular Access recommend that centers have an access monitoring program. AVFs can be monitored through measurement of dynamic and static venous pressure, access flow measurement, and duplex ultrasound. An access monitoring program helps to improve patients’ vascular access outcomes by identifying problems early.

Thrombosis can be treated by surgical, mechanical, or chemical (use of a drug to dissolve the clot) thrombectomy. In more than 90% of cases, a stenosis is the cause of the clot. This may be corrected by surgery to revise the access, or by angioplasty after the clot is removed.

High Output Cardiac Failure
An AVF can be one cause of high output cardiac failure. This is a complex condition in which:
1. The fistula brings more blood to the heart
2. The heart works harder, reducing resistance in the arteries
3. Arterial blood pressure falls
4. The drop in arterial blood pressure triggers the renin-angiotensin system

Patients with high output cardiac failure may have rapid pulses as their hearts try to make up for the extra blood flow (20% or greater) caused by the access. They may be short of breath if the blood does not contain enough oxygen. Swelling may occur in the hands and feet because return circulation to the heart is poor. Over time, if the problem is not treated, it can cause chest pain, fluid in the lungs, abnormal heart rhythms, and death. High output cardiac failure can also be caused by anemia or by heart disease the patient had before the vascular access. So, prevention is best aimed at treating anemia and creating an access that will not tax the patient’s heart.

If high output cardiac failure occurs, limiting fluid gain between treatments will reduce the strain on the heart. Longer and/or more frequent treatments may help with fluid gains, reducing the strain. Medication may also be given to help the heart beat more strongly. Instruct patients to report any changes in their
overall health and energy level. Surgery may be needed to reduce blood flow through the access. In this case, surgery is done either to band the arterial anastomosis or to tie off the fistula.

Grafts
An arteriovenous graft (AVG) is an artificial blood vessel used to connect an artery and a vein. Grafts can be long enough to connect vessels in very different parts of the body, if
needed. This can be important for patients who have few usable veins left for dialysis access.

**GRAFT MATERIALS**

Many types of materials can be used for AVGs. These materials can be divided into biologic and synthetic categories.

**Biologic**

Human and animal materials have been used for grafts, but are rarely used today. Some human biologic AVGs were made from a vein from the patient’s leg. Veins from the umbilical cords of newborn infants were also used. Umbilical veins had high rates of infection and aneurysms. Bovine (cow) and ovine (sheep) carotid arteries used for grafts were treated to remove proteins that would cause the human body to reject them. These grafts also had high rates of infection and aneurysm.

**Synthetic**

Synthetic materials are now used for nearly all grafts. The most widely used synthetic graft material today is expanded polytetrafluoroethylene, or ePTFE. Collagen is another material that is used to make grafts. Grafts may be straight, curved, or looped. Some designs provide a larger surface area for needle insertion.

**GRAFT PROCEDURE**

Construction of a graft is a surgical procedure that bridges an artery and a vein. During the surgery, incisions are made over the vessel entry sites. The vein is checked to ensure that there is enough blood flow. A tunnel is then made under the skin, and the graft is attached to one vessel, passed through the tunnel, and attached to the other vessel (anastomosis) (see Figure 13). Straight grafts are usually placed in the forearm (radial artery to basilic vein). Loop grafts are placed in either the forearm (brachial artery to basilic vein), the upper arm, or the thigh.38 The most common graft in the upper arm is curved from the brachial artery to either the basilic or axillary vein. A new graft should be placed at least 3–6 weeks before use, unless a graft material is used that can be cannulated right away.1

**GRAFT PROS AND CONS**

**Pros**

Grafts take less time to mature before the first cannulation. Graft size and blood flows don’t

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**Figure 13:**

Examples of graft locations

- Looped graft in thigh
- Straight graft in upper arm
- Straight graft in forearm
- Looped graft
in forearm
depend on the maturation. Grafts may also have larger cannulation areas than fistulae, and be easier for staff to cannulate. Grafts are often used in patients who are not good candidates for native fistulae due to advanced age or other health problems, like diabetes, that damage blood vessels. Grafts make dialysis possible for patients whose veins are not suited for a fistula. They are readily available and come in a variety of sizes and shapes.

Cons
The biggest problems with all grafts are infection and thrombosis. Grafts develop stenosis at the venous anastomosis most commonly, and clot at a much higher rate than native fistulae. No graft material now exists that is as good as a native blood vessel.

STARTING DIALYSIS WITH A GRAFT

Wash Your Hands
Washing your hands is always the first step before you touch any dialysis access. Clean hands and clean gloves help keep bacteria on the skin's surface from being pushed into the patient's bloodstream by the needle (see Module 6: Hemodialysis Procedures and Complications for more information on handwashing and hemodialysis infection control precautions).

Graft Assessment
As with fistulae, grafts must be assessed before each dialysis treatment. Below is a general outline for assessment of an AVG:

Things to look for when assessing a graft include:
- Swelling and redness
- Pain and tenderness
- Drainage from puncture sites, or from the skin around the graft
- Bruises
- Healing at previous cannulation sites
- Localized warmth and fever

Something to listen for when assessing a graft is:
- Bruit should be low-pitched and continuous

Things to feel for when assessing a graft include:
- Pulse should feel for a soft, compressible pulse
- Thrill should be continuous (feel without compression only)
- Skin temperature should be normal, not hot
- Hardness or pain

Confirm the Direction of Blood Flow
To find the direction of the blood flow, feel the entire length of the graft. Compress the middle of the graft with two middle fingers and feel for the pulse and/or thrill on both sides of the area being compressed. You will feel the strongest pulse on the arterial side. The pulse or thrill will be faint or not palpable at the venous end.

Assess Blood Flow
Every graft should have a strong flow of blood.
from the artery through the access and into the vein. The pulse of a graft feels like a pounding or buzzing with each heartbeat, as arterial blood is pumped by the heart to the rest of the body. This pulse, or thrill, should be strong, and you should be able to palpate it over the entire length of the access. The thrill should decrease over the venous portion of the graft.

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Listen to the sound of the blood flow through the graft. The blood flow creates a bruit that you can hear by placing your stethoscope over the access and listening to the swooshing sound. The sound should be strong and steady. Like the thrill, the bruit should decrease over the venous portion of the graft. It is important to learn how each patient’s access normally sounds. Alerting the charge nurse to a change in the thrill or bruit may allow early intervention to save a failing graft.

PREPARING TO USE A GRAFT

The steps for preparing access skin, reducing pain from injection, applying tourniquets, and inserting needles used for grafts (see Figure 14) are exactly the same as for fistulae (see Initiating Dialysis with a Fistula on page 128.) Refer to the specific graft material manufacturer’s recommendations for graft care and use. The different graft materials may have unique instructions for use.

INSERTING NEEDLES

Selecting a Cannulation Site

Prior to cannulation, you need to choose a site for needle insertion. Select a site that is at least a half inch away from any previous needle sites. Do not cannulate near anastomoses. The site should be at least one inch from an anastomosis, obstructions, or restrictions. Keep arterial and venous needles at least 2 inches apart.39

Site Rotation of a Straight Graft

To decide the needle site rotation in a straight graft, first divide the graft into equal halves at its middle. Use the middle as a reference. Cannulate the arterial half of the graft by moving toward the arterial anastomosis. Cannulate the venous half by moving towards the venous anastomosis. Each time you use a graft, space the needle sites equally along the length of the graft. Each needle insertion should be .25-.5 inches from the last site. Place needles along all three sides of the graft, not just along the top.39

Site Rotation of Loop Graft

To decide the needle site rotation in a loop graft, first divide the graft into equal halves at the middle of the loop. Use the middle as a reference. Cannulate the arterial half by moving towards the arterial anastomosis. Cannulate the venous half by moving towards the venous anastomosis. Rotate sites by equally spacing the sites along the graft. The space should be between .25-.5 inches away from last sites. Place needles along all three sides of the graft, not just along the top.39

Needle Direction

You will need to know how to find the direction of blood flow in the graft. The venous needle is inserted in antegrade (in the direction of blood flow) placement. This is needed to prevent excessive venous return pressure and damage to the blood cells. The arterial needle can be
placed antegrade or retrograde (against the
direction of blood flow). Retrograde placement
of the arterial needle is preferred.39

**GRAFT CARE POSTDIALYSIS**

Postdialysis graft care is the same as
postdialysis fistula care (see page 135.)

**GRAFT COMPLICATIONS**

Complications associated with AVGs include
infection, stenosis, thrombosis, and

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pseudoaneurysm. The rate of infection and thrombosis is higher in AVGs than in native AVFs.

Infection
Infection is more common in grafts than in fistulae. A break in the use of aseptic technique is the main cause of infection. Your center has policies and procedures on how to prepare the cannulation site using aseptic technique. You must follow these steps to lower the risk of infection.

Signs and symptoms of an infected graft include redness, swelling, pain, fever, and chills. Tell the nurse about a possible infection right away so he or she can call the nephrologist. The nephrologist will give orders about cannulation, follow-up, and antibiotics.

Stenosis
Stenosis at the venous end of a graft anastomosis is a common problem. Stenosis can also develop along the length of a graft. Graft-vein stenosis develops when smooth muscle cells at the venous anastomosis grow more than they should. The cells form extra layers that fill up the graft lumen, reducing blood flow. This process is called neointimal hyperplasia.

Turbulence at either anastomosis and/or within the graft may play a role in this problem. KDOQI Clinical Practice Guidelines for Vascular Access recommend that grafts be checked for stenosis at least monthly. Grafts can be tested by measuring venous pressure or access flow. Learn your center’s policies and procedures on the test(s) used to monitor for stenosis (see Stenosis on page 140 for more information on the causes, signs and symptoms, and treatment of stenosis.)

Thrombosis
Thrombosis is the most common reason for AVGs to fail. A decreased or absent thrill/pulse is a sign of thrombosis. To check for thrombosis, look at the graft and palpate for a thrill/pulse throughout the length of the graft. Teach patients how to palpate for the thrill/pulse in their access and report any

Figure 14:
Needle insertion in a graft
Needle punctures the skin
Needle travels through subcutaneous tissue
Needle enters the vessel
Needle is leveled out and threaded into vessel lumen
Skin
Soft tissue
Vessel lumen
changes to dialysis staff right away (see Thrombosis on page 141 for more information on the causes, prevention, and treatment of thrombosis).

Steal Syndrome
Steal syndrome can occur with grafts as well as fistulae. Some symptoms to watch for include pain, tingling, coldness, a change in motor skills in the hand, blue nail beds, and/or decreased sensation in the access hand. The access surgeon should be told, so alert the nurse or nephrologist if you suspect steal syndrome. Try to keep the patient’s hand warm during dialysis, perhaps with a mitten or tube sock. Changing the position of the patient’s arm may help increase blood circulation in the hand.

DIALYSIS-RELATED COMPLICATIONS OF GRAFTS
The same dialysis-related complications that happen with fistulas also occur with grafts (see Dialysis-related Complications of Fistulae on page 136 for complete information about line separation, air embolism, bleeding, infiltration/hematoma, and recirculation).

COMPLICATIONS RELATED TO POOR NEEDLE SITE ROTATION
Pseudoaneurysm (a bubble-like blister in the graft caused by weakness in the graft wall) and graft collapse can occur if needle sites are not rotated well. For a pseudoaneurysm to develop, the graft needs a defect and increased pressure from a venous stenosis. Each time a graft is cannulated, the needle cuts a hole in the graft. If the cannulation sites are not rotated, the holes will come together to form larger holes (see Figure 15).32 Informally termed “one-site-itis,” this overuse of the graft can have grave consequences. The graft may start to come apart, which leads to graft collapse.39 At the same time, the frequent placement of needles in the same area damages the tissue above the graft, slowing healing and weakening all the protective skin layers. In time, the pressure of the blood flow following the path of least resistance will be stronger than the tissue covering it, and the pseudoaneurysm may rupture. If this occurs, the patient can die in a matter of minutes if he or she is alone. No graft Vascular Access

Figure 15:
[One-site-itis photos]
Photos reprinted with permission from Bard Peripheral Vascular
should be allowed to reach this point. Careful predialysis assessment and consultation with other team members can prevent pseudoaneurysms from becoming life-threatening problems.

Central Venous Catheters

Some patients start hemodialysis without a permanent access, and these patients will most often have a catheter. For example, patients may have an urgent need for treatment and no access due to:

- Acute renal failure
- Peritonitis from peritoneal dialysis
- Uremia from chronic kidney disease (CKD) with no matured fistula
- A wait for a scheduled transplant
- An agreement with a doctor to have a trial of dialysis
- Refusal of fistula surgery
- Access failure or infection

All of these events occur often, so it is good that we can access the blood quickly using a percutaneous (through the skin) catheter or a subcutaneous (under the skin) port/catheter device. These devices are made for short-term use (days to weeks) but some patients may need them for months or even years. Unfortunately, patients who use catheters are more likely to develop blood infections that can be fatal.40

Central venous catheters can damage the central blood vessels as well as the heart. So, patients with catheters should be encouraged to be assessed for a fistula as soon as possible. Some patients resist fistulae due to a fear of needles and/or of unsightly scarring and vein enlargement, but the longer they wait, the higher the risk of sepsis.41

**TYPES OF CATHETER AND PORT/CATHETER DEVICES**

A central venous catheter is a relatively large tube placed into a high-flowing central vein that leads into the heart. Because hemodialysis removes and returns blood at the same time, the tube has two side-by-side chambers called lumens. The end of the catheter that enters the patient's bloodstream is the tip; it has holes for blood entry and exit (see Figure 16). The other end, the tail, is outside the body with the two lumens apart. Each lumen has an adapter-connector on the end. The connectors attach to the bloodlines through specially-designed needles that are placed at the start of a treatment. The exit site, where the catheter comes out through the skin, is covered by a sterile dressing, especially when the catheter is not in use.

**Short-term Catheter**

Sometimes a patient needs only a few treatments with a catheter. For example,

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Figure 16:

Internal jugular catheter
Dual lumens
Exit site
Subclavian vein
Collarbone
Internal jugular
Catheter tip
patients with acute renal failure, infection, or a clotted fistula or graft may use a short-term catheter. This type of catheter is short in length because it exits the skin directly over the venotomy (the site where the catheter enters the vein). If the patient still needs a catheter upon discharge from the hospital, this catheter should be exchanged for a tunneled catheter.

**Tunneled, Cuffed Catheter**

A tunneled, cuffed catheter (TCC) is longer than a short-term catheter because the tail is tunneled under the skin from the venotomy to the exit site, a few centimeters away. Most tunneled catheters have a cuff. The cuff of the catheter is a fibrous material about 5 mm wide, wrapped around the catheter. The cuff is placed about 1 cm up the tunnel from the exit site. Healing tissue inside the tunnel bonds with the cuff; this keeps the catheter from pulling out and bacteria from migrating up the tunnel and into the bloodstream. For this reason, TCCs are safer and are the preferred type.

Another style of TCC is the single lumen catheter. Two single lumen catheters must be placed to do conventional hemodialysis; one to take blood to the dialyzer and the other to return it. These catheters are called twin catheters.

**Port/Catheter Device**

A port/catheter device is usually a combination of a port and a single lumen catheter. The catheter has a tip like a percutaneous single catheter, but the tail connects to a metal port placed under the skin (see Figure 17). Two port/catheter devices are needed to do hemodialysis. The shorter catheter is the pull, or arterial, line; the longer one is the return, or venous, line. The bloodstream is accessed by placing a needle into the metal port and opening the valve. The dialysis needles are treated like extensions of the catheters. The heparin is removed and the needles are flushed with saline prior to connection with the lines. At the end of treatment, the procedure is reversed. Removing the needles at the end of each treatment closes a valve that seals each port device internally. At press time, no port/catheter devices were on the market, though some previously placed port/catheter devices were still in use.

**CATHETER AND PORT/CATHETER DEVICE SITES**

Catheters for hemodialysis are always placed in veins that are able to support the high blood flows needed for dialysis. The very large veins in the neck and chest that empty into the right Vascular Access

Figure 17: Vasca LifeSite®

Hemodialysis Access System
Drawing used with permission from Vasca, Inc.
atrium of the heart are the most suitable. The largest of these, the superior vena cava, collects blood from the head and neck veins (internal and external jugular) and from the arms via the subclavian veins. The right internal jugular (RIJ) vein is the very best because:

- In most people, it is the largest vessel
- In most people, it is the shortest and straightest distance to the right atrium of the heart
- The RIJ has the lowest rate of stenosis and/or clots, that would prevent return blood flow from a future fistula or graft in the arm.

NOTE: A catheter should not be placed on the same side as a working fistula or graft.

The left internal jugular (LIJ) is the second choice, but it is longer and has two large curves to navigate. This reduces blood flow. The subclavian veins should not be used for a catheter unless a surgeon has found that no fistula or graft can ever be placed in the ipsilateral (same side) arm or there is a lifethreatening emergency.

The femoral veins in the groin can be used for catheter access (see Figure 18) when:

- Temporary access is needed for urgent dialysis and the RIJ cannot be used
- Long-term catheter access is needed and none of the upper central veins can be used

There are other, more exotic catheter placements such as translumbar or transhepatic for patients who no longer have any of the usual placement sites. See a vascular access text for more details.

The following principles of venous entry are true for all hemodialysis catheters, whether percutaneous or subcutaneous. The tips of all catheters inserted into the chest should be placed well into the right atrium of the heart and the tips of all femoral veins should be well up into the inferior vena cava (IVC). This tip placement assures the best flow into the catheter, for the best dialysis.

**PLACEMENT OF CATHETERS AND PORT/CATHETER DEVICES**

Most catheters are placed in vascular interventional outpatient centers by a radiologist or a nephrologist.

Telling an IJ Catheter Apart from a Subclavian

The subclavian vein is, as its name suggests, below the clavicle (collarbone). Because IJ TCC exit sites are often in the same place as the exit site of a short-term or TCC subclavian catheter, there can be confusion over which vein the catheter enters:

- If a TCC is seen and/or felt over the clavicle, it is IJ.
- If the catheter disappears under the clavicle, it is subclavian.

Figure 18:
Femoral catheter placement
Exit site
Venous
Arterial
Vascular, transplant, and general surgeons also place them, often at the same time as they create a fistula or place a graft. Most port/catheter devices are placed in hospitals. The main advantage of using a vascular interventional suite or operating room is that X-rays can be done during the procedure, to reduce placement problems. Catheters must be placed with strict aseptic technique. Procedures done at the patient’s bedside or in a doctor’s office are less than ideal, and must be followed by a chest X-ray to confirm catheter placement before starting hemodialysis. All newly placed catheters are tested by saline flushing to assure function and then locked with heparin to prevent clotting. Local anesthetics and conscious sedation IV medications to relieve pain and sedate the patient are used during catheter placements. Uncomplicated catheter placements take less than 30 minutes. Port/catheter device placement takes longer and is more complex.

**IJ Placement**

The IJ vein is 2-3 cm above the clavicle. It is found by an ultrasound device, then punctured with a large needle. Dark, venous blood is pulled back to prove that the vein was reached. A guide wire is inserted through the needle, the needle is removed, and the catheter is advanced into the vessel over the wire. Once the catheter is in the vein, the guidewire is removed. The tunnel under the skin for a TCC placement may be formed first, depending on the type of catheter used. The tunnel is usually brought over the clavicle, with the exit site 2-3 cm below. Stitches are placed around the catheter at the exit sites of both temporary and tunnel-cuffed catheters. The stitches can be removed from a TCC after 10-14 days, but should not be removed from a short-term catheter until the catheter itself is removed.

Placement of any chest catheter can cause:
- Bleeding
- Hematoma (blood that has collected under the skin)
- Air embolus
- Pneumothorax
- Hemothorax

**Subclavian Placement**

As stressed before, the subclavian vein is the large vein in the shoulder that drains the majority of blood from the arm on the same side should be the catheter site of last resort. It is much more likely than an IJ to become stenosed. If it must be used, general placement technique and procedure is the same as for an IJ catheter. The doctor must take care to prevent kinking of the catheter due to the sharp angle needed to enter the vein under the clavicle. The risk of pneumothorax and hemothorax may be higher due to the need to puncture directly over the lungs.
Femoral Placement
The femoral vein is next to the femoral artery in the groin. The method for finding the vessel and placing femoral catheters is similar to IJ placement. The most frequent complication of femoral placement is femoral artery puncture and hematoma.

Port/Catheter Device Placement
The port is inserted through an incision into a pocket that is formed under the skin. After the catheter’s placement and tunneling, it is Vascular Access 152
Prior to closing with sutures, all pocket bleeding must be stopped. The pocket may be flushed with an antibiotic solution to prevent infection.

**PROS AND CONS OF CATHETERS AND PORT/CATHETER DEVICES**

**Pros**
- Patients can have vascular access for urgent treatment.
- Catheters and port/catheter devices can be hidden under most clothing.
- The patient's hands and arms can move freely during dialysis.
- Patients can shower or swim with port/catheter devices, once the incision is healed and the stitches are removed.
- Patients will say that no needles is the main advantage of catheters. This must be weighed against the proven higher risk of death and severe illness from long-term catheter use.

**Cons**
- Catheters and port/catheter devices are more likely to cause life-threatening bacteremias (blood infections).
- Catheters are foreign bodies in the bloodstream and can cause inflammation and clotting in the blood vessels, leading to stenosis and occlusion (blockages).
- Catheters generally have lower blood flows over time, for less adequate dialysis and more frequent procedures. Port/catheter devices usually have more reliably high flows over time.

**CARE OF CATHETERS AND PORT/CATHETER DEVICES**

Catheter and port/catheter cannulation and care are usually done by registered nurses. Refer to your center's protocol for care instructions.

**Preventing Infection**

The following steps will help prevent infection in catheters and port/catheter devices:
- Always make sure you have washed your hands and changed your gloves prior to touching the patient and his or her equipment.
- Always make sure you and the patient each wear a mask covering both the mouth and nose whenever the catheter is opened or the exit site exposed. Airborne bacteria that can infect catheters and therefore the patient's blood can be found in mouths and noses of both patients and staff.
- Assess the catheter exit site or port site before starting treatment. Look for any signs of redness, or drainage or pus.
- Always use aseptic technique when opening, handling, cleaning, or cannulating the port, or connecting and dressing the catheter.
n Teach patients how to protect the catheter and its dressing. Most dialysis centers change the dressing at each treatment, and patients shouldn't need to do this between treatments. If the dressing gets wet, it is best to remove the wet dressing, dry carefully around the catheter exit site, and cover the site with a large elastic bandage. To prevent the dressing from getting wet, most centers suggest no
showers or swimming for patients with catheters. However, there are devices that are made to keep catheters dry in the shower. Check with your center’s catheter care protocol.

- Patients must also be taught not to use sharp objects such as pins or scissors around their catheters. Pinholes put the patient at risk for infection and also require catheter changing before the next treatment. Accidentally cutting the catheter can cause severe blood loss or air entry. The patient should be shown how to pinch off the catheter securely and seek medical help immediately.

- Report any problems with the catheter to the nursing staff as soon as possible.

Preparing to Use a Catheter

- Predialysis assessment
  - Ask the patient about any problems with the catheter during previous treatments or at home.
  - Remove the dressing and note any changes in catheter position, such as the cuff becoming visible at the exit site.
  - Observe for any redness and drainage (fluid or material coming out around the catheter) such as pus.
  - Assess the ease of heparin removal and saline flushing before connecting the bloodlines. Presence of clots and/or sluggish saline flushing suggests that the catheter is blocked or compressed, or that catheter position has changed. This must be corrected before connecting the bloodlines. The nursing staff will further assess the problem and may instill a thrombolytic enzyme to dissolve the clot.43

Considerations for accessing catheters and cleansing exit sites

- Prepare procedure site using dialysis precautions.
  - Conduct procedures using aseptic technique (correct handwashing, masks for patient and staff, no-touch technique, and disposable clean gloves).

- Chlorhexidine 2% with 70% alcohol is the preferred solution for cleansing of central venous catheter sites (check catheter manufacturer’s warnings about the effect of disinfectants on catheter material).

- For patients who are sensitive to chlorhexidine 2% with 70% alcohol, chlorhexidine aqueous may be used instead (check catheter manufacturer’s warnings about the effect of disinfectants on catheter material).

- For patients who are sensitive to chlorhexidine aqueous, povidone
solution may be used (use according to manufacturer’s directions).

Skin cleansing should include the following steps:
1. Apply solution/swab in a circular motion working from catheter exit site outwards.
2. Cover an area 10 cm in diameter.
3. Perform this step twice. Do not rinse off or blot excess solution from skin.

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4. Allow solution to dry completely before applying dressing.

n To cleanse the connection between any CVC catheter hub and cap use two swabs:
1. Hold up the catheter at the connection site with one swab.
2. Use second swab to clean from catheter connection up catheter for 10 cm.
3. Cleanse hub connection site and cap vigorously with the first swab. Discard swab.
4. Do not drop a connection site once it is cleaned.

n To cleanse the section of the catheter that lies next to the skin, gently swab the top and underside of the catheter starting at the exit site and working outwards.

n Always be sure the clamps are closed before opening the catheter to air when pulling off the catheter caps, removing a syringe, or undoing the Luer-Lok® connectors in the lines.

Monitoring Catheters During the Treatments

If pressure alarms signal that the flow cannot be maintained at the prescribed rate, you must:
1. Look at the patient and the lines to make sure there is no major bleeding or air entry.
   Call immediately for help if there is.
2. Next, assess for mechanical obstruction. Are the lines kinked anywhere along the circuit? Check again that the catheter is in place.
3. Reposition the patient, lower the head of the chair, have the patient turn his head, cough, etc., to help move the tip of the catheter for better flow.
4. Flush with saline to help further assess the condition of the catheter.
5. Switch or reverse the lines so that blood is pulled through the venous port and returned through the arterial port. This should be done to complete a treatment only with the permission of the charge nurse. Line reversing creates recirculation of the blood, which leads to less adequate dialysis and does not correct the problem. It is also another chance for infection, and all the precautions taken to start dialysis must be repeated.
6. Ask the nurse to assess the problem. He or she may give a thrombolytic enzyme to clear the catheter of a clot.
   If these measures do not restore the prescribed blood flow, the patient should be referred to the interventional doctors or surgeons to correct the problem. This may require a new catheter placement.

Monitor blood flow through the dialyzer, noting the amount of arterial and venous pressure exerted on the catheter to achieve the prescribed blood flow. Always keep the prepump arterial monitor connected and open.
It tells you the condition of the arterial catheter lumen, as does the venous pressure monitor for the returning lumen. Patient safety is our main concern during dialysis. A catheter accident can quickly become fatal. For this reason, staff must pay a great deal of attention to securing the connections and lines and making sure the catheter or needle site are visible during the treatment. Patients can bleed to death under 155 35
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a blanket, or an air embolus can occur if air is sucked
in through a dislodged catheter or connection.
Good catheter care is good patient care.
Improving
Vascular Access
Outcomes
CONTINUOUS QUALITY
IMPROVEMENT (CQI)
Issues related to vascular access are often a
challenge to manage. Continuous quality
improvement (CQI) can be a powerful tool to
help reduce the rate of vascular access problems
and provide the best outcomes (see Figure 19).
Collecting data and forming a CQI team are the
first steps toward making a plan. For example,
it might be helpful to begin a log or computer
database to track vascular access problems.
The log could include:
- Access type
- Date of placement
- Surgeon
- Type of complication
- Action taken
- Data from monitoring tests
Identify Improvement
Needs
- Collect data
- Analyze data
- Identify problem statement
- Prioritize activities
1
Analyze the Process
- Select a team
- Review the data
- Study the process/problem
- Identify partners/trends
2
- Identify probable root
causes
- Define/refine the problem
Identify Root Causes
3
4
Implement the solution, change
or modify facility-wide tests,
revise standards and
specifications, incorporate
revisions into day-to-day practices.
Obtain judgments of improvement
achieved (performance, process
measurements, outcomes);
determine if solution, change,
or medication has been successful
Deliver care, perform policy or
procedure in limited trial run.
Design or redesign policies,
procedures, services, or products.
Specify objectives or degree of improvement desired.

Figure 19:
CQI process
Clinical assessments
Dialysis adequacy measurements
Rates of hospitalization, etc.

By charting this information on bar graphs, patterns can be seen. Based on a pattern, your team can devise a plan to solve a problem or improve the practice or process. The data patterns are only as good as the data gathered. If incorrect data are collected, incorrect patterns will appear.
The plan should include information about the desired objectives, steps to take, timetable, and staff member assigned to each step. Do the plan on a small scale as a trial run. (For example, try improved methods for handling access sites.) Then collect more data to check the results.

Did the plan work? If it did, implement the plan in day-to-day practice and go on to another problem. If the plan did not work, rework the plan and try again. Recheck past findings at a later date to detect any changes.

CLINICAL PRACTICE GUIDELINES

The KDOQI Clinical Practice Guidelines for Vascular Access give ways to check and preserve a patient’s access. You can help protect patients’ accesses when you use good technique to put in needles, help patients put the right pressure on needle sites after a treatment, and report problems to a nurse or doctor right away. The dialysis staff should consider ways to use the guidelines on a day-to-day basis. The end result will be better vascular access care for patients.

KDOQI and Fistula First both use a combination approach to look at the data and provide expert opinions to improve patient care. Vascular access requires a team approach to achieve the goals set forth by KDOQI and Fistula First. Each member of the care team and the patient must know his or her role. The team must be trained to identify, collect, and process data, and follow best practice standards when working with vascular accesses.

Three of the KDOQI Clinical Practice Guidelines for Vascular Access are part of the ESRD Networks’ clinical performance measures (CPMs) project. Each year, data are collected on the percent of AVFs in new and ongoing hemodialysis patients, the percent of patients with catheters, and the way grafts are monitored for stenosis. Fistula First collects data on the percentage of AVFs each month by Network to follow the progress of the program.

Conclusion

Vascular access is one of the most important and challenging parts of dialysis. As a dialysis technician, you have a vital role in caring for your patients’ vascular accesses. It is your job
to learn how to correctly cannulate AVFs and grafts and to assess access sites for problems. At all times, remember that each patient’s vascular access is a lifeline and must be treated with a great degree of care.
References


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Objectives
After completing this module, the learner will be able to:
1. Describe the predialysis set-up of the hemodialysis machine and extracorporeal circuit.
2. Explain the start, monitoring, and end of a routine treatment.
3. Identify the vital signs that should be monitored before, during, and after treatments.
4. Discuss the basics of infection control.
5. Explain how to draw up and give intravenous medications.
6. Describe how to draw a blood sample.
7. Discuss the importance of documenting patient care.
8. Identify causes, signs and symptoms, and prevention of clinical and technical complications that may occur during dialysis.

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Introduction
Cleaning a patient’s blood with dialysis is a complex process with many steps and each step may be crucial to keeping patients safe and maintaining their comfort. Dialysis treatments can only be uncomplicated and routine when staff pay close attention.

This module covers the types of patient care tasks, technical tasks, and skills you will need to learn to deliver safe and effective treatment. It goes over the processes of dialysis, from set-up through clean-up. Your actions at each step affect your patients.

The authors wrote this module assuming that you will work with a preceptor, or teacher, who will show you each step. We do not provide step-by-step checklists, but rather descriptions of processes and the reasons for key procedures. Each step may be done in various ways. Your center will have its own policies and procedures that you will need to learn and follow.

This module is a general review of procedures and complications you may encounter. The exact tasks that you can do will vary with the Nurse Practice Acts, regulations, and laws in each state; and with your center’s policy. A team of technicians, nurses, nephrologists, social workers, dietitians, pharmacists, and others cares for dialysis patients. The authors assume that patient assessment is the job of registered nurses, but that you can help by gathering data, noting and reporting unexpected findings, and providing input into the care plan.

Patient and Staff Safety

BODY MECHANICS
You will use your musculoskeletal system on the job to stand, walk, sit, or squat to carry, lift, push, or pull objects. These tasks can injure your muscles and back. When you use good body mechanics (moving your body to prevent injury), you can avoid muscle strain and fatigue (see Figure 1). Awkward postures, repetitive motion, and heavy lifting are the three main risk factors in musculoskeletal injury. To move effectively, you need to make friction, leverage, and gravity work for you. Your teacher will

Figure 1:
Good body mechanics
center of gravity
resistance
fulcrum
force line of gravity
show you the basics of good body mechanics. Use what you learn in your day-to-day work.

**Lifting and Carrying**

The proper way to lift objects like supply boxes is to stand with your feet shoulderwidth apart and bend from your hips and knees. Never bend at the waist or turn your body when you lift, push, or pull an object. Put your hands around the object and pick it up, holding it close to your body. Bend your knees and keep your back straight; you want to use your arm and leg muscles not your back. If the object is too heavy for you to lift by yourself, don’t try it; get help instead.

**TRANSFERRING PATIENTS**

Many dialysis patients need help to transfer (move from place to place). The Occupational Safety & Health Administration (OSHA) publication Ergonomics for the Prevention of Musculoskeletal Disorders has techniques for safe transfers in any healthcare setting. In the center, you will learn to do several types of patient transfers. Use the steps you learn to prevent injuries to yourself, other staff, and patients.

Which technique you use will vary with how well a patient can stand up and bear his/her own weight. Patients who can bear their own weight can transfer alone, but a staff member should stand by in case the patient needs help especially after a treatment when he or she may be dizzy. You may need more than one staff member or a lift device if a patient can’t bear his or her full weight.

Before you move a patient, check his or her general condition. If possible, do not move a patient who has unusual fatigue, nausea, or unstable pulse or blood pressure; an unstable patient may fall. Learn how to minimize a fall: if a patient stands up and is unsteady, help him or her to sit back on the edge of the chair/bed that he or she started from. If you can’t prevent a fall, try to slowly ease the patient down to the floor, then call for help.

**Patients Who Use Walkers**

You may need to help patients who use walkers to be sure they can balance and will not fall. Even though it may be faster for you to put a patient in a wheelchair, it is physically better for the patient to use the walker.

**Chair-to-Chair Transfers**

Some patients transfer from a wheelchair to the dialysis chair and back to a wheelchair after treatment. Patients who use wheelchairs use walkers.

**Back-saving Tips**

- Think before you lift.
- Lift with your legs and hold the object close to your body.
Stay at your ideal body weight.
- Strengthen your leg and stomach muscles.
- Exercise for 30 minutes, at least 3/4 times a week.
- Improve your flexibility; do gentle stretches every day.
- Never twist and lift at the same time. Keep your feet, knees, and torso pointed in the same direction.
- Test the weight of the object or patient before you lift. If something is too heavy, get help from a coworker or a mechanical aid.
- Push, don't pull. You'll have twice as much power and less chance of injury.
- Slow, smooth movements are safer than fast, jerky ones.
- If you develop back pain, stop what you are doing!
need help to transfer to the dialysis chair (see Figure 2).
Lock the wheelchair and apply the brakes any time you move a patient to or from a wheelchair. Even with the brakes on, hold the wheelchair in place or put one foot against a wheel during a transfer to keep it from slipping or tipping over.

Stand and pivot technique
If a patient can bear enough weight to stand, you may be able to transfer him or her by yourself, using the stand and pivot technique. Following your center’s procedure, help the patient sit on the edge of the chair. Put a gait belt (heavy canvas belt) around the patient’s waist to provide stability and control during the transfer. Stand in front of the patient and help him or her to stand by pulling the belt to bring the patient toward you. Then, slowly pivot with the patient until you can lower the patient into another chair and then remove the belt. Use good body mechanics to prevent back injury.4

Using a slide board
You can do a chair-to-chair lateral (sideways) transfer from the sitting position using a slide board (smooth, shiny board) to reduce friction. When you use a slide board:

- Hold the board steady during the transfer.
- Lock the wheelchair and hold onto it during the transfer.
- Have a spotter standing by someone who can help the patient to the floor if he or she slips or the board moves.
- Ask a staff person to hold the dialysis chair to keep it from moving during the transfer.

Portable lift devices
Portable lift devices like Hoyer lifts or sling lifts are usually used for patients who can’t bear weight, are very heavy, or can’t help with their own transfers. Make sure the device will hold the weight of the patient you are moving before you try a transfer (the weight limit will be in the owner’s manual). Patient transfers using portable lift devices require at least two staff members: one to move the lift and one to pull the patient to the correct part of the chair. When you use a portable lift device:

- Make sure the sling is under the patient’s body from shoulders to hips.
- Check that the hooks are all in the correct slots on the sling holder.
- Raise the patient up just enough to clear the chair.
- Be sure the patient’s fingers are clear of any hooks that could pinch.

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Figure 2:
Patient transfer
Release the patient down into the chair gently.

Reposition the patient as needed.

**Stretcher-to-Chair Transfers**

Some patients, often those from nursing homes, come to dialysis on stretchers. If a patient can bear some weight, follow your center's procedure to place the stretcher in a low position and use the stand and pivot technique. If the patient can't bear any weight, use a portable lift device, as previously described.4

**Stretcher-to-Bed (Lateral) Transfers**

Lateral transfers are used for bed-bound patients. You can use assist devices, like sheets or boards with rollers, to help push and pull a patient from a stretcher to a bed. You will need several staff members, but these devices avoid the need for a complete lift, which reduces the risk of injury. For all lateral moves, the surface to which the patient is being transferred should be a half inch lower then the surface the patient is on.4 Using an assist device, some of the staff members will push and the others will pull the patient onto the new surface.

**EMERGENCY PREPAREDNESS**

An emergency is an unexpected event, like a fire, tornado, hurricane, flood, blizzard, ice storm, or earthquake, that requires help or immediate action. In an emergency, patients and staff may have to evacuate the center, and you need to know how to help. Your center must have an emergency action plan.5 Key points of emergency preparedness include:

- Follow your center's plan to notify staff and emergency services personnel.
- Know where to find all exit doors, how to locate and use fire extinguishers, and your role if there is an emergency.
- In case of fire, remember R.A.C.E.:
  - Rescue
  - Activate the alarm
  - Contain the fire (only if small)
  - Evacuate
- To use a fire extinguisher, remember P.A.S.S.:
  - Pull the pin
  - Aim the nozzle at the base of the flames
  - Squeeze the handle
  - Spray from side to side at the base of the flames
- Disconnect patients from the machine to evacuate in this order:
  1. Patients who can walk without help
  2. Patients who can walk, but will need some staff help to do so
  3. Patients who cannot walk and will need
staff help to evacuate

Evacuate the premises using the safest and closest exit.

INFECTION CONTROL

Pathogens (agents that cause disease, like bacteria, viruses, or fungi) that invade the body can cause infection. Infectious disease is the

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second most common cause of death in dialysis patients. The most common pathogens normally live on the skin and on mucous membranes (e.g., the lining of the nose, mouth, and bowels). Others are found in the soil, in water, on clothing, and on all surfaces. Some pathogens cause more severe disease than others, and some are more communicable (easy to spread) than others. Nosocomial infections are picked up in a hospital or other healthcare setting. Your goal is to prevent infections in your center for patients and staff. Communicable disease can be spread in several ways:
1. Direct contact: touching an infected person, such as shaking hands or kissing
2. Indirect contact: touching contaminated objects such as clothing, towels, cups, water faucets, telephones, doorknobs, and equipment
3. Droplet spread: breathing in sneezed or coughed droplets from the nose, mouth, throat, or lungs of an infected person
Infection can also occur when contaminated fluids enter the body, such as through a needle stick. A bite by an insect or animal can cause disease. Some diseases are caused by breathing in airborne fungi, bacteria, or viruses in dust or lint. In a dialysis center, pathogens can be spread by patients, staff, visitors, equipment, water, dialysate, and air.

Aseptic Technique
Aseptic (free from infection) technique is used to keep an object or area sterile (free from all germs). Other terms that relate to aseptic technique are:
- Clean: not free of germs, but disinfected and usable for some steps in the treatment
- Contaminated: an object that was sterile, but then was touched by a non-sterile object (germs could now be on the object)
- Dirty: neither clean nor sterile; cannot be used for dialysis steps that require an object to be clean or sterile
Learn aseptic technique, understand it, watch closely, and practice it with supervision.

Hemodialysis Infection Control Precautions
In 2001, the Centers for Disease Control and Prevention (CDC) recommended ways to

Guidelines for Aseptic Technique
- Prepackaged sterile items are sterile only if the package is closed and intact. Open sterile solutions or supplies only when you need them. Once open, they are exposed to airborne pathogens.
- Wash your hands before you touch a package that contains a sterile item. This will help keep you from getting germs on the item. Packages that contain sterile items should not be allowed to get wet—moisture allows pathogens to pass through the wrapper and contaminate the object.
- A contaminated object contaminates a sterile object. For example, when you spike a bag of saline, take care to insert the spike directly into
the port. If the spike touches the outside of the bag or any other unsterile object, it becomes contaminated itself, and you cannot use it.

Before you use a multidose vial, scrub the rubber stopper with disinfectant. Mark the vial with the date and time of first use.

All fistula needles, syringe tips, and needles used to give medications or draw blood must be sterile, because they enter the bloodlines or the patient’s body. When you start a treatment, do not touch the fistula needle or ends of the bloodlines to the patient or dialyzer. When you attach a heparin syringe to the heparin line, do not touch the syringe tip or the end of the heparin line.
prevent bloodborne infections in hemodialysis patients (see Figure 3). The CDC’s guidelines are more strict than the standard precautions often used in hospitals. Using the CDC infection control steps will reduce the chances for disease to transfer from patient to patient, directly or indirectly, through contaminated equipment, supplies, surfaces, or staff’s hands. Use these steps for all patients in your center.7

**Handwashing**

Washing your hands correctly is the single most important thing you can do to prevent the spread of infection. It protects you as well as the patient. The goal is to remove pathogens that might be transferred to patients, visitors, or other staff. Research shows that handwashing can reduce infection rates, stop an outbreak of disease, and reduce the spread of drug-resistant bacteria. The CDC recommends that when you wash your hands with soap and water, wet your hands first with water. Apply the amount of soap recommended by the manufacturer, and rub hands together briskly for at least 15 seconds, covering all surfaces of the hands and fingers. Rinse your hands with water and dry thoroughly with a paper towel. Use a paper towel to turn off the faucet. The CDC also recommends that healthcare personnel who have direct contact with high risk patients, which includes Hemodialysis Procedures and Complications.

**When to Wash Your Hands**

- Between contact with all patients
- Before and after you do any invasive procedure like putting in dialysis needles even if you wear sterile gloves
- Before you touch a wound, whether it is surgical, due to trauma, or caused by an invasive device like a dialysis needle
- Before you touch patients who have diseases that make them more susceptible to infection
- After you touch any body substance or mucous membrane
- After you take off your gloves
- Between tasks and between procedures on the same patient to prevent cross contamination of different body sites
- When you enter and leave the center, to reduce the chance of spreading germs to your family, the patients, and other staff

**BIOHAZARD**

1
2
3
4
5cc
1
2
3
4
5cc

**Figure 3:**
Components of dialysis precautions
Wash hands before and after removing gloves, or after exposure to body fluids
Never mix food and medical supplies in the same refrigerator
Maintain accurate records
Wear employee protective clothing, like gowns, masks, goggles, and gloves
Use sharps box
Clean all work surfaces
Place infectious waste in color-coded receptacles Store properly
Dialysis patients avoid wearing artificial nails. Keep your nails less than one quarter of an inch long. If your hands are not visibly dirty, you can use an alcohol-based handrub. Apply the product to the palm of one hand and rub your hands together to cover all surfaces until your hands are dry. Always wash your hands with either soap or an alcohol-based handrub if your hands are not visibly dirty; after you take off gloves; each time you work with a different patient; and after you touch blood, body fluids, and contaminated items. Due to frequent handwashing, your hands may become dry and/or chapped. Use hand lotion or cream after washing your hands to prevent dryness and chapping.

Protective equipment
During a treatment, you can be exposed to blood and contaminated items. You must wear gloves when you care for a patient or touch the equipment. You must also change your gloves between patients; failing to change gloves is a common error made in healthcare settings.

Follow these steps to properly remove gloves:
1. With both hands gloved, peel one glove off from the top (wrist) to the bottom (fingers) and hold it in the gloved hand.
2. With the exposed hand, peel the second glove off from the inside, tucking the first glove inside the second.
3. Do not snap the gloves when you take them off.
4. Throw out the soiled gloves promptly.

Wear a gown, face shield, eyewear, or mask to protect yourself and keep your clothes clean when you do tasks that put you in possible contact with blood (e.g., start and end of treatment, cleaning dialyzers). Throw out any disposable protective equipment that is soiled with blood or other body fluids. Wash any contaminated non-disposable protective equipment per your center policy.

When to Use Protective Equipment

Change your gloves:
- After each patient contact
- When they are bloodstained
- After you handle infectious waste containers
- After starting a treatment
- Before you touch any surface such as machine dials, charts, and phones

Wear a gown:
- When you do tasks that may cause blood or body fluid to splash or spray (e.g., start and end of a treatment, injecting into a bloodline, putting in needles)
- When you handle patient care equipment that is soiled with blood or body fluids, to prevent contamination of clothing or skin

Wear a face shield and protective eyewear:
- During tasks that may cause droplets of blood or body fluids
- At the start or end of a treatment
When troubleshooting the vascular access
- When you inject into the bloodlines or change the transducer protector

To avoid sticking yourself with sharps (needles):
- Never recap needles if at all possible. If, for some reason, you must recap, use a mechanical recapping device or a one-handed method. Learn your center’s policy and recapping devices, if used.
- Do not bend, shear, or break contaminated needles.
- Dispose of needles in puncture-resistant, color-coded boxes.
- Always point needles away from yourself.
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Protection from contamination
Items used in dialysis can be contaminated with blood and body fluids by patients or staff. Any items used in the treatment—even those placed on top of the machine—should be thrown out, assigned to one patient, or cleaned and disinfected before going back to a clean area (storage space for sterile and clean items). Your center will have policies and procedures about how to handle supplies after treatment. Learn about the clean and dirty areas in your center.

Cleaning and disinfecting
You can help prevent the spread of disease in your center. One way is to remove all (or nearly all) pathogens by sterilizing and disinfecting equipment, and keeping shared equipment to a minimum. Your center has policies and procedures on how to clean and disinfect surfaces and equipment after each treatment. Learn which products your center uses and how to use them correctly.

Disposing of Infectious Wastes
There are rules and laws in each county and state for how to identify, handle, package, and transport infectious waste. Throw out needles in leak-proof, puncture-resistant boxes. Label sharps containers and do not allow them to overfill. Disposable material such as gloves, gauze, and aprons that are contaminated with body fluids need to be thrown out in red or color-coded garbage bags. Laundry contaminated with blood or other pathogens must be placed in labeled or color-coded, leak-proof bags; some centers double-bag all contaminated laundry. Learn your center’s policies and procedures, which are based on your local and state regulations.

Bloodborne Diseases
Three primary bloodborne pathogens pose a risk to dialysis patients, and are therefore a risk in the center: hepatitis B (HBV), hepatitis C (HCV), and human immunodeficiency virus (HIV).

Hepatitis B
Hepatitis B (HBV) is a highly contagious virus. It can be transmitted through infected blood.

Guidelines for Preventing Contamination
In your personal hygiene:
- Follow your center’s policy for washing your hands.
- Never eat, smoke, apply cosmetics or lip balm, or handle contact lenses in treatment areas.
- If you have a cold or a cough, wear a mask to prevent spreading germs to patients.

To avoid environmental contamination:
- After each treatment, clean surfaces at the station, including the bed or chair, counters, and outside of the machine.
- Promptly clean up blood spills.
- Do not use common carts in the patient treatment area to prepare or give out medications. If trays are used to give out medications, clean them before using them for a different patient.
Use a separate room if possible, a dedicated machine, and avoid dialyzer reuse for patients who test positive for hepatitis B surface antigen (see Hepatitis B section).

Never store food and drink in refrigerators, freezers, shelves, cabinets, or counters where blood or other body fluids may be present.

Use fresh external venous and arterial pressure transducer protectors for each treatment. These keep the machine’s pressure monitors free from blood. Change protectors between each patient; do not reuse them.

Cap dialyzer ports and clamp tubing on dialyzers and blood tubing that will be reprocessed. Place all used dialyzers and tubing in leakproof containers for transport from the station to the reprocessing or disposal area.
and body fluids. The virus is hardy and can live for 7 days or more on surfaces. You can destroy the virus by cleaning with disinfectants and germicides. Most HBV outbreaks in hemodialysis patients are due to cross-contamination of patients via: n Surfaces, supplies (e.g., hemostats, clamps), or equipment that did not get disinfected after each use n Multidose drug vials and IV solutions used for more than one patient n Drugs drawn up for injection near areas where blood samples are handled n Staff members who care for both HBV-infected and susceptible patients at the same time The most common ways that HBV is spread in dialysis centers are: n A sharp object such as a needle, scalpel, or broken blood tube breaks the skin n Broken skin or mucous membranes of the eyes, mouth, or nose come in contact with blood

Hepatitis C
Like HBV, Hepatitis C (HCV) is spread by contact with infected blood and can be killed by disinfectants and germicides. HCV is not nearly as easy to transmit as HBV, so patients do not need to be in separate rooms, and their dialyzers can be reused. Outbreaks of HCV in dialysis centers have been linked to these types of cross-contamination among patients: n Equipment, machine surfaces, and supplies that were not disinfected between uses n Use of common carts to prepare and give out medications n Sharing of multidose drug vials which were placed on top of machines n Contaminated priming buckets that were not changed or cleaned and disinfected between patients n Blood spills that were not cleaned up promptly n Supply carts that were moved from one station to another with both clean supplies and blood-contaminated items, including small biohazard containers, sharps disposal boxes, and used vacutainers with patients’ blood

Hemodialysis infection control precautions must be taken with all patients, whether or not they have HCV.

Human Immunodeficiency Virus (HIV)
HIV is a virus that attacks the immune system. HIV is the cause of AIDS (acquired immunodeficiency syndrome). HIV is transmitted by blood and other body fluids

Precautions to Prevent Transmission of HBV
Centers can help avoid the spread of HBV if they:
Follow hemodialysis infection control precautions with all patients.
- Dialyze HBV positive patients in a separate room with separate machines, equipment, instruments, and supplies.
- Keep staff who care for HBV positive patients away from patients who may be susceptible (e.g., on the same shift or during a shift change).
- Test patients for HBV per CDC guidelines.
- Do not reuse dialyzers of HBV positive patients.
- Vaccinate staff and patients against HBV.
that contain blood. In the general public, HIV is most often spread through sexual contact and shared IV drug needles.9 Infection control precautions recommended for all hemodialysis patients are sufficient to prevent HIV transmission between patients. HIV-infected patients do not have to be isolated from other patients or dialyzed separately on dedicated machines. They can also take part in dialyzer reuse programs. HIV is not transmitted efficiently through occupational exposures, so reprocessing dialyzers from HIV-positive patients should not place staff at a higher risk for infection.7

Antibiotic-resistant Bacteria
Dialysis patients and staff could be exposed to drug-resistant bacteria that can cause infection. The two most common are methicillin-resistant Staphylococcus aureus and vancomycin-resistant Enterococcus. Methicillin-resistant Staphylococcus Aureus (MRSA)
Staphylococcus (staph) aureus is a bacterium that lives on skin and mucous membranes and in the respiratory, gastrointestinal, and urinary tracts. MRSA is a type of staph that has become resistant to certain antibiotics. It is most common in wounds, exit sites, and access sites, and can also cause sepsis (blood infections) and pneumonia. Sepsis caused by MRSA can be severe. Entry of MRSA into the bloodstream of a dialysis patient is most often through the vascular access or dialysis catheter.7 MRSA causes many nosocomial (hospital-related) infections in the United States. Certain people (especially those with weak immune systems like dialysis patients) may be more likely to become infected with pathogens like MRSA. MRSA can be spread by healthcare staff’s hands. MRSA may also be present on equipment,7 and can live for a long time on surfaces.

Vancomycin-resistant Enterococcus (VRE)
Vancomycin-resistant Enterococcus (VRE) has also become a common nosocomial infection in U.S. hospitals. Enterococcus bacteria live in the intestines and are harmless to healthy people. VRE can cause severe infections in people with weak immune systems. Hemodialysis patients have played a key role in the growth of vancomycin resistance. One of the first cases of VRE was reported in 1988 by a dialysis center in London, England. CDC data have shown that from 12% to 22% of hospital patients who had VRE were on hemodialysis.7 Outbreaks due to enterococci, including VRE, have shown that it can spread from patient to patient. This transmission can be through direct contact, or indirectly through staff’s hands or contaminated equipment or surfaces.7
Antibiotic-resistant Bacteria Precautions

Using infection control precautions (dialysis precautions) for all of your patients will help prevent the spread of drug-resistant bacteria, too.

Hemodialysis Procedures and Complications

Precautions to Prevent Transmission of HIV

Centers can help avoid the spread of HIV if they:

- Follow hemodialysis infection control precautions with all patients.
- Ask patients with risk factors for HIV to be tested; if infected, they can get proper care and counseling to prevent spreading the virus.
Your center may use extra precautions to treat patients who may be at a higher risk for transmitting pathogenic bacteria, such as patients who have:

- An infected skin wound with drainage that seeps out of dressings
- Fecal incontinence or uncontrolled diarrhea

For these patients, extra precautions may mean that you:

- Wear a gown over your clothing and remove the gown when you're done caring for that patient
- Dialyze the patient at a station with as few stations next to it as possible (e.g., at the end or corner of the center)
- Use a dedicated blood pressure cuff and stethoscope

Tuberculosis (TB)

Tuberculosis (TB) is an infectious disease that spreads from person to person on airborne droplets. The droplets are formed when someone with pulmonary (lung) TB coughs, sneezes, or speaks. Anyone who is exposed may contract TB.10

TB infection can be active or latent (inactive). Someone with latent TB will have a positive skin test, but no outward signs of TB. Latent TB is not contagious, but without treatment the TB may become active and contagious. Active TB can cause a persistent cough, fever, weakness, weight loss, and night sweats. The number of cases of TB has risen in the United States, and some outbreaks have been reported in dialysis centers.10

MEDICATIONS
AND SOLUTIONS

Each state regulates dialysis technician practice and what drugs and solutions you can or can't give. Some states allow patient care technicians to draw up and administer heparin and/or normal saline. In other states the patient care technicians are not allowed to draw up or administer any medication.11 Learn the policies and procedures in your center, and the right equipment and techniques to give drugs and solutions correctly.

Needles

Needles are made of stainless steel and are thrown out after one use. The slanted part of a needle's tip is called the bevel. The diameter of the needle is called the gauge. Needles come in different bevel and gauge sizes. Needles must be used with aseptic technique (method of using equipment without contamination). Throw away contaminated needles in a sharps container.

Syringes

Syringes are made of plastic, and are packaged in sterile paper or plastic containers. They come in different sizes, and have three parts (see Figure 4 on page 176). The top of the syringe is the tip. A needle connects to a syringe at the tip, so the tip must be sterile at all times. The outside of the syringe is the barrel,
which has scales printed on it to indicate the
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Precautions to Prevent Transmission of TB
Centers can help avoid the spread of TB if they:
- Require an annual TB skin test for patients and staff.
- Dialyze patients with infectious TB in an acute care setting or
  isolation room with negative air flow (air is pulled into the room).
- Require patients to take medication to prevent or treat infectious
  TB, and take all of the prescribed pills to prevent relapse and
development of drug-resistant TB.
dose. The plunger fits into the barrel to push the medication out through the needle.

Using Syringes and Needles Safely

Wash your hands before you use a syringe and needle. Use only sterile syringes and needles to avoid contamination. Throw out used needles and syringes in a sharps container without cutting or recapping them, to prevent accidental needle sticks.

In 2001, the Occupational Safety Health Administration (OSHA) passed the Needlestick Safety and Prevention Act. This act requires safety devices to reduce exposure to bloodborne diseases, like sharps disposal containers, selfsheathing needles, and needleless systems (see Figure 5). Devices to prevent needle stick injuries are required in all dialysis centers.12

Drawing Up Medication

Vials are small plastic or glass bottles that have sealed rubber caps, usually covered by protective metal or plastic caps. Vials come in different sizes and can contain one or more doses of medication. If your role includes drawing up medications, learn how to draw up the right amount of a medication without contamination (see Figure 6). The basic steps to drawing up solutions and medications are:

1. Read the drug name on the vial before, during, and after drawing up a solution to make sure you have the right one.
2. Check the expiration date on the vial.
3. Clean the vial’s rubber cap with a disinfectant to remove any contaminants.
4. Use a single dose vial only once.
5. Write your initials and the date on a multidose vial if you are the first one to use it.
6. Draw air into the syringe and inject as much air into the vial as solution you want to draw up. This will prevent a vacuum from forming, which would make it hard for you to draw up the solution.
7. Expel any air bubbles once you have withdrawn the needle from the vial.

Using IV Solutions

Normal saline used during the treatment is given through an intravenous (IV; into a vein) bag. Spike

Figure 4:

Syringe
Tip
Barrel
Plunger

Figure 5:

Needleless system
(open) the bag and let the saline flow through the tubing to prime it (get it ready). Spiking the bag and priming the tubing before use expels all the air, so it can't enter the extracorporeal circuit or reach the patient's bloodstream. Follow your center's procedure for connecting the IV tubing to the insertion port of the bag. The port usually has a protective cap or tear tab that you must remove from the port. Place the bag on a flat surface or hang it up on an IV pole to make it easier to get a firm grasp of the port, so you can insert the spike of the IV tubing. Spiking IV solution is an aseptic procedure. After you spike the bag and attach it to the IV tubing, prime the tubing by letting the saline fill it until no air is left.

**DOCUMENTATION**

Information about each dialysis treatment becomes part of the patient's permanent medical record. Documentation (charting the patient's care in the medical record) also makes long-term follow-up of each patient's response to treatment possible. The chart is a written record of the care given by staff to a patient. A patient's record is kept to provide:

- A way for staff taking care of the same patient to share information
- A basis to prescribe medical treatment
- A diagnostic aid for the team
- Data for research and quality assurance
- A legal document, admissible in court as evidence of care the patient did or did not receive. Legally, if something was not charted, it was not done.

Each center has policies and procedures for how to document patient care. Know your role in the patient's medical record.

**Figure 6:**

Drawing up a solution

Read the drug name, check the expiration date, and clean the vial.

Draw as much air into the syringe as solution you want to draw up.

Inject the air into the vial to prevent a vacuum.

Draw up the solution and expel any air bubbles from the syringe.
Writing an Entry in the Medical Record

Proper charting techniques are vital for legal reasons. In most cases, entries can be printed or in script as long as they are legible and in ink. Each entry must be followed by the writer’s name and title, in the format used by your center, for example, J. Smith. D.T. Ditto marks, erasures, and correction fluid are not acceptable, because they could lead to legal questions if the chart is used in a court case. Instead, most centers require you to correct errors by drawing a single line through the wrong material, writing ‘error’ or ‘mistaken entry’ (ME) above it, and initialing the mistake: ME or error (A.K.)

Example: Patient dialyzed for 4 hrs. 3.5 hrs.

Never leave lines in a chart partly or completely blank. If the end of a line is not filled in, draw a single line through it to keep someone else from charting there. Record the time on all entries. Refer to your center’s policy manual for specific how-to information.

Always be accurate and factual when charting:

n Write the patient’s full name on each page of the chart, or stamp it with the correct addressograph plate, to be sure that a page of one patient’s chart is not accidentally placed in the wrong chart.

n Use only abbreviations and initials that are approved by your center.

n Include the effects and results of all treatments and procedures.

n Include detailed descriptions when you chart about pain, patient complaints, etc.

Electronic Charting

Your center may use electronic rather than paper charting. In this case, all of the patient’s medical record is kept on the computer. To ensure that the electronic chart is not tampered with, and to keep patient confidentiality:

n Never share your password or computer signature with anyone—even another technician or nurse in the center, someone working temporarily in the center, or a doctor.

n Log off if you are not using your terminal, even if you just plan to step away for a moment.

n Follow your center’s protocol for correcting errors. Computer entries are part of the patient’s permanent record and, as such, cannot be deleted. In most cases, you can correct an entry error before you store the entry.

n Make sure that stored records have backup files—a vital safety feature. If you accidentally delete part of the permanent record, type an explanation into the file with the date, time, and your initials.

n Never display patient information. Don’t leave information about a patient on a
monitor where others can see it. Also, don’t leave printed versions or excerpts of the patient’s medical record unattended.

Hemodialysis Procedures and Complications

Dialysis Treatment Orders

Dialysis treatment orders include:

- Length and frequency of the treatments
- Dialyzer brand, model, and size
- Dialysate composition
- Heparin dose
- Blood and dialysate flow rates
- Ultrafiltration (UF) parameters
Predialysis Treatment Procedures
Several tasks must be done before a patient’s treatment can start. This section will cover the treatment plan, preparing the dialysis equipment, and predialysis patient assessment.

TREATMENT PLAN
Dialysis is done according to a doctor’s prescription. Each patient has a specific treatment plan. It is vital to know where to find these plans and how to carry them out as ordered. While dialysis treatments for all patients are similar, the nephrologist tailors each patient’s treatment plan to meet the patient’s needs. One patient may have a longer treatment time, while a second patient may use a different dialyzer. The physician continually evaluates each patient and varies the treatment plan, when needed, by writing new orders.

EQUIPMENT PREPARATION
You will set up the equipment before each treatment and check the dialysate, extracorporeal circuit, dialyzer, and alarms. Module 4, Hemodialysis Devices, covers all of the equipment in detail. This section will give you an overview of what you need to do before each treatment.

Dialysate
Dialysate fluid helps remove wastes from the patient’s blood. It can also replace needed substances, such as bicarbonate, to maintain the patient’s acid-base balance. Since only a semipermeable membrane keeps the patient’s blood apart from the dialysate, the exact make-up of the dialysate is key to your patient’s well-being.

Dialyzer and Bloodlines
The extracorporeal circuit includes the:
- Dialyzer
- Bloodlines
- Monitoring lines
- Heparin line
- Transducer protectors

Key Points to Learn about Dialysate Set-up
Your task is to learn:
- How and when to verify that there are no chemical disinfectants in the dialysate lines
- How to choose the right dialysate concentrate for each patient and connect it to the machine
- How to check that the prepared dialysate temperature, conductivity, and pH are within acceptable limits

Key Points to Learn about Setting Up the Dialyzer and Bloodlines
- Learn how to check a dialyzer to verify that:
  - It is the one the doctor ordered
  - It is not defective (caps are on, no cracks or leaks etc.)
- Learn how to check a reprocessed dialyzer to verify that:
  - The patient’s name is correct
- Germicide is present
- The time interval since the dialyzer was reprocessed is safe (not too long or too short)
- Learn how to correctly place the bloodlines, saline, and dialyzer on the machine.
- Learn how to keep the inside of the bloodlines sterile.
You must use aseptic technique when you take any cap off of a bloodline, so you don’t contaminate the inside of the bloodlines and cause an infection.

Priming and recirculation
You will learn to prepare the bloodlines and dialyzer for the treatment by priming (rinsing and filling the extracorporeal circuit with saline) them with normal saline. Then you will learn to attach the venous and arterial bloodlines together to form a loop, and recirculate the prime (send it around the loop). Priming removes air and germicide from the bloodlines and dialyzer; recirculation keeps the process going. During recirculation, UF and diffusion help dialyze off any germicide that is left. The germicide moves from the blood side of the dialyzer to the dialysate side, then down the drain. Priming also warms the saline so the patient does not get too cool when the treatment begins.

Predialysis safety check
Completing this check is vital for patient safety. If an alarm is not working correctly and the treatment is started, the patient could be harmed. All alarm checks must be successfully completed before the machine is used for a treatment. If any of the alarm checks fail, remove the machine from the patient area for inspection.

Predialysis patient evaluation
Part of your job will be to help evaluate the patient’s health before a treatment. You will learn to compare this information with data from past treatment. You will also learn what abnormal findings should be reported to the nurse. This is an important task since, in rare cases, the nurse may then decide that the patient’s health is not stable and that treatment in an outpatient setting may not be safe.

Hemodialysis Procedures and Complications
Key Points to Learn about Priming and Recirculation
Learn the correct way to:
- Do priming and recirculation
- Remove air from the bloodlines and dialyzer (air bubbles can cause blood clotting during the treatment)
- Test to be sure the germicide has been rinsed out of a reprocessed dialyzer

Key Points to Learn about Predialysis Alarm Checks
Learn how to:
- Complete these extracorporeal alarm checks:
  - Air detector (detects air in the bloodline after the dialyzer)
  - Blood leak detector (detects blood in the dialysate after the dialyzer)
  - Arterial pressure high/low alarm (detects pressure in the arterial bloodline that is outside set limits)
  - Venous pressure high/low alarm (detects postdialyzer pressure that is outside set limits)

If each of the above alarms is working, (1) the blood pump will stop, (2) the venous line should clamp, (3) the audio alarm will sound, and (4) the visual alarm message will appear.

- Complete the following dialysate alarm checks:
  - Conductivity alarm (detects if dialysate concentration is outside set limits)
Temperature alarm (detects if dialysate temperature is outside set limits)

pH alarm (if present, detects if dialysate pH is outside set limits)

If each of the above alarms is working, the machine will go into bypass mode (dialysate flow to the dialyzer should stop).

Complete the UF check to verify that the volumetric/fluid removal components of the machine are working.

Complete the negative germicide test to verify that the germicide has been removed from a reprocessed dialyzer.
Weight

Most dialysis patients make little or no urine. Between treatments, much of the fluid they drink stays in their bodies, so they gain weight. Signs and symptoms of too much fluid include edema from extra fluid in the tissues, shortness of breath from extra fluid in the lungs, and a rise in blood pressure from extra fluid in the blood. The patient's pretreatment weight is used to decide (1) how much fluid weight the patient gained since the last treatment, and (2) how much fluid weight to take off at this treatment. With respect to weight, your task is to learn:

- How the scale works and how to balance it to make sure it is accurate
- Your center's guidelines on recommended maximum weight gains between treatments
- When to tell the nurse about abnormal weight changes (too much or too little weight gained)

The dry weight or estimated dry weight (EDW) is what the patient's weight would be with no extra fluid and with a normal blood pressure. The doctor prescribes a dry weight for each patient. This number is then used to decide how much fluid weight is to be removed during the treatment. In an ideal case, by the end of a treatment the patient will be at or near dry weight. Not all weight gain is fluid; many factors can affect a patient's actual dry weight:

- A hospital stay or illness with loss of appetite, diarrhea, or vomiting can cause the dry weight to drop.
- The holidays often cause increases in dry weight because patients eat more than usual.
- Patients may lift weights to build muscle, and may gain real weight.
- Wearing different clothes or shoes to dialysis can raise or lower a patient's weight on the scale.

Taking off too much fluid can make the patient feel very ill; not taking off enough is also harmful. Because a patient's dry weight can change, its accuracy must be checked often.

Components of the Predialysis Patient Evaluation

- Weight
- Edema (swelling)
- Pulse
- Blood pressure
- Respiration
- Temperature
- General physical and emotional state
- Problems since the last treatment
- Access status

Dry Weight Assessments

- After a treatment, a patient at dry weight should have:
  - Normal blood pressure
  - No edema (swelling)
  - No shortness of breath
After a treatment, a patient above dry weight may have:

- High blood pressure (hypertension)
- Edema
- Shortness of breath

After a treatment, a patient below dry weight may have:

- Low blood pressure (hypotension)
- Light headedness or dizziness when standing
- Muscle cramping
If you or the patient thinks the dry weight has changed, tell the nurse. A doctor’s order is needed to change a patient’s dry weight number.

Edema

Edema occurs when extra fluid builds up in the patient’s tissues. Due to gravity, it is often seen in the feet or ankles. Edema may also be seen in the hands, face, abdomen, or back. Asking simple questions like, “How do your shoes fit?” and, “Are your rings tighter than normal?” can help you to find problems with edema. You can also check for the amount of edema by gently pressing your thumb over the foot, ankle, or leg with slow, steady pressure. Be sure to learn:

- How your center wants you to check patients for edema
- When to tell the nurse about a patient’s edema

Pulse

With each heartbeat, the heart muscle pushes a wave of blood into the arteries. This wave, or pulse, can be felt or heard at various points on the body. You will learn to measure a patient’s pulse rate by feeling or listening at a pulse point (see Figure 7) and to record the number of heart beats per minute. The rhythm of the pulse can also be recorded. A normal pulse for an adult is between 60 and 100 beats per minute with a regular rhythm.

Blood Pressure (BP)

The pulse wave formed by each heartbeat causes pressure inside the arteries. The highest pressure in an artery occurs during a heartbeat, when the heart contracts. The lowest pressure is between contractions, when the heart is at rest.

A BP reading records both the high number (systolic) and the low number (diastolic). So, if a BP reading is 120/70 (said as, “120 over 70”), the systolic pressure is 120 millimeters of mercury (mmHg) and the diastolic pressure is 70 mmHg.16

Hemodialysis Procedures and Complications

Key Points to Learn about Taking a Pulse

Your task is to learn:

- When to tell the nurse about an abnormal pulse rate or rhythm
- Where to check for the pulse. Sites include:
  - A radial pulse (at the wrist)
  - A brachial pulse (in the crease of the elbow)
  - An apical pulse (over the heart, using a stethoscope)
  - A pedal pulse (on the foot)

Figure 7:

Sites used for assessing a pulse

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Temporal

Carotid

Apical*

Brachial*

Radial*

Ulnar

Femoral
Popliteal*
Posterior
Tibial
Pedal
Pulse*
The patient's pulse may be taken at several points.
*These pulse sites are commonly used for dialysis patients.
A stethoscope and sphygmomanometer (blood pressure cuff) are used to check BP. You will take BP readings while the patient is seated and standing. In centers, BP readings are often taken by the dialysis machine, but you also should know how to take a manual BP. If a patient becomes light-headed in the waiting room, for example, a portable BP machine will be needed. While you will usually check a patient’s BP on his or her arm, you can also check BP on the leg (see Figure 8). You may need to do this in a patient who has accesses in both arms, or who has only one arm which has an access in it. Two sites for taking the leg BP are:
1. Placing the cuff above the knee, using the popliteal pulse
2. Placing the cuff above the ankle, using either the posterior tibial or dorsalis pedis pulse

According to the American Heart Association (AHA), the site of blood pressure measurement should be at the heart level. If the site (e.g., upper arm) is below the level of the right atrium, the readings will be too high; if the upper arm is above heart level, the readings will be too low. The difference will be greatest if blood pressure in the leg is taken when the patient is standing. So, the leg blood pressure should be taken in the supine position with the leg at the level of the heart. Blood pressure reading on the leg is usually higher than pressures taken in the arm; even more so if a too-small cuff (same as for the arm) is used.

Key Points to Learn about Taking a BP
Your task is to learn:
- When to tell the nurse about an abnormally high or low predialysis BP reading
- How to correctly take a machine and a manual BP
- How to correctly take both an arm and a leg BP

Key Points to Learn about Taking Respirations
Your task is to learn:
- How to correctly count the respiration rate and check respiratory status
- When to tell the nurse about an abnormal respiration pattern

Figure 8:
Blood pressure on the arm and leg
183 21
Popliteal artery
Posterior tibial artery
Fibular artery
Brachial artery
Bulb
Valve
Cuff
Anaeroid sphygmomanometer
On the other hand, patients with peripheral artery disease (PAD) will have lower popliteal and ankle blood pressures. Both where you put the BP cuff and the cuff size can change the accuracy of a BP reading. Cuffs that are too wide compared to the patients body size will cause a falsely-low reading. Cuffs that are too narrow will cause a falsely-high reading. BP cuffs that are wrapped too loosely or unevenly will also cause a falsely-high reading. The cuff bladder length recommended by the AHA is 80% of the patient’s site circumference (arm or leg), and the ideal width is at least 40%. In patients with kidney failure, changes in fluid status are the key reason that BP readings rise or fall. As fluid weight increases, the BP also increases (extra fluid in the blood raises pressure inside the blood vessels). As fluid weight is removed, the BP goes down (total blood volume drops).

Respiration
With each breath, oxygen from the air enters the lungs and carbon dioxide leaves the lungs. This exchange of gases affects the health of every cell in the body. An adult’s respirations are normally regular at a rate of about 12-16 per minute. Patients may unconsciously (or unknowingly) change their breathing patterns if they know their respirations are being counted. So, you will usually count respirations while you are taking a patient’s pulse.

In dialysis patients, fluid weight gains may cause fluid to enter the lungs. This leads to shortness of breath or labored, difficult breathing. Report these symptoms to the nurse. He or she may use a pulse oximeter (pulse-ox machine with a sensor probe) to check the oxygen level in the patient’s blood. The probe, which looks like a clothespin, is placed on a finger, and the machine then displays the oxygen saturation (SaO2). A pulse-ox reading of less than 90% is considered abnormally low.

Temperature
A variety of thermometers are used to measure temperature (see Figure 9). No one temperature reading is normal for all people. For young adults, the average oral (mouth) temperature is 98.6 degrees Fahrenheit (°F) or 37 degrees centigrade (°C). In older adults, temperature is often lower, around 96.8°F (36°C). Hemodialysis patients also tend to have low baseline (predialysis) temperatures, for unknown reasons. A high temperature before a treatment could be due to a cold or flu, or an infection (e.g., in an access, the urinary tract, or an infected foot common with diabetes). Inflammation, such as pericarditis (an inflammation of the sac around the heart)
Your task is to learn:
- What type of thermometer your center uses and how to use it correctly
- When to tell the nurse about an abnormal temperature reading

Figure 9:
Thermometer types
Digital thermometer Tympanic thermometer
the heart), can also cause a fever. See Table 1 for a summary of vital sign information.

Vascular Access
The patient’s vascular access is his or her lifeline. Before each treatment starts, check the access to be sure it is working. See Module 5: Vascular Access to learn how to check the access.

General and Emotional Health
Talking with patients, asking them questions, and listening to their answers is another way to gather predialysis information. Patients know themselves best. By talking to and watching them, you can find clues to their general health and emotional well-being. Here are some questions you might ask:

- How have you felt since your last treatment?
- Have you had any trips to the emergency room or outpatient procedures?
- Have you felt any chest pain? Any trouble breathing?
- Are you having any problems eating or digesting your food?
- Have you seen any doctors or started any new medications since your last treatment?

You can also learn about patients just by watching them. For example:

- When the patient walked into the center, did he or she walk as well as on other days?
- Is the patient’s speech normal (not slurred)?
- Does the patient seem confused, agitated, or depressed?
- Is the patient’s skin color normal or is it pale or ashen (gray)?

See Module 2: The Person with Kidney Failure for more information on patients’ health.

Initiation of Dialysis
Once the predialysis tasks are done, the treatment can begin. A number of steps are needed to start the treatment: calculating how much fluid to remove, venipuncture (putting the needles into the patient’s access), blood testing, and starting the machine.

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Vital Sign/Definition
General
Adult Norm Terms
Blood pressure (BP)
- Measurement of BP inside an artery
- Systolic: pressure inside an artery during a beat; top number in a BP measurement
- Diastolic: pressure inside an artery when the heart is at rest; lower number in
a BP measurement
Optimal BP for adults: >120/80
High BP for adults: >140/90
Hypertension: high BP (often with no symptoms)
Hypotension: low BP
Orthostatic hypotension: a drop in BP of 15 mmHg or more upon rising from sitting to standing; causes dizziness and possible fainting
Pulse
The wave of blood in an artery caused by each heart beat 60–100 beats per minute (with regular rhythm)
Tachycardia: fast pulse, >100
Bradycardia: slow pulse, <60
Normal sinus rhythm: normal rate and rhythm
Arrhythmia: irregular pulse and rhythm
Respiration
Taking air into and pushing it out of the lungs 12–16 breaths per minute
Dyspnea: shortness of breath
Apnea: no breathing
Temperature
Difference between body heat produced and heat lost 98.6°F (37°C) for young adults
Afebrile: without fever
Febrile: with fever

Table 1: Vital Signs Fact Sheet
REMOVING FLUID

Removing excess fluid from the blood is a main dialysis task. This process of fluid removal is called ultrafiltration (UF). Fluid moves out of the blood and across the dialyzer membrane due to a pressure difference between the blood and the dialysate (pressure is always higher on the blood side). How fast (and how much) fluid is removed (the UF rate) can be changed by increasing or decreasing the degree of pressure difference. In the past, such pressure differences and ultrafiltration rates (UFRs) were calculated by dialysis technicians. With modern, volumetric dialysis machines, all you need to do is tell the machine how much fluid you want removed from the blood during the treatment and how long the treatment will last. The modern, volumetric dialysis machine will calculate the UFR and determine the correct pressure difference to remove the right amount of fluid during the treatment. To do this, the machine sets the desired pressure difference between the blood side and the dialysate side of the dialyzer by adjusting the dialysate pressure appropriately. This pressure difference is known as the TMP, which stands for transmembrane pressure.21 Appendix 1 on page 202 outlines the calculation for TMP. See Module 4: Hemodialysis Devices to learn more.

It is your job to calculate how much fluid to remove during dialysis. Starting with the desired weight loss (based on the patient’s estimated dry weight and actual pretreatment weight), make adjustments for the patient’s fluid intake during dialysis (see Table 2). Fluid intake includes saline prime (unless this has not been infused into the patient), rinseback (saline used to push the patient’s blood back in the body after a treatment), ice chips, food and drink, and medications. Fluid output during dialysis (e.g., urinating, vomiting) is not usually included. When you enter the total fluid amount (in mL) into the dialysis machine, along with the treatment time, the machine will calculate and set the right TMP and hourly UFR.

Replacing Fluid

Rarely, you may need to give patients normal saline during the treatment to help them reach their goal weight. For example, a patient may come in for a treatment below the prescribed dry weight due to vomiting or diarrhea. Follow your center’s policies and procedures to decide if saline is needed during a treatment and, if so, to figure out how much is needed.

VENIPUNCTURE

To do hemodialysis, an access is needed so blood can be pumped into the dialyzer and then back to the patient. Since in-center treatments are done three times a week at high blood flow rates, the patient’s own veins cannot be used for
access as they are. Instead, a surgeon creates a
dialysis access. For an arteriovenous fistula
(AVF), the surgeon sews a patient’s artery to a
Hemodialysis Procedures and Complications

Desired weight loss in mL

(1 kg = 1,000 mL)

= 2,000 mL

Priming saline = 240 mL

Saline rinseback = 200 mL

Medications = 250 mL

Dietary intake (ice chips, drinks) = 120 mL

Total fluid amount to remove = 2,810 mL

UFR per hour (mL/hr):

2,810 mL ÷ 4 hours (treatment time) = 702.5 mL/hr or 0.7 L/hr

Table 2: Example of Total Fluid Removal Calculation
vein. For a graft, the surgeon links the patient’s vessels with a piece of artificial vein. A fistula is the best access, because it lasts longest and is less likely to become clotted or infected. The access is the patient’s lifeline. Each patient has only about 10 sites on his or her body where an access can be created; when they are used up, the patient must either get a transplant, or switch to peritoneal dialysis to continue living. So, venipuncture (putting needles into the patient’s access) is one of the most vital tasks you will do. With either a fistula or a graft, needles must be placed into the access. Skilled and gentle needle placement prolongs the life of the access. Good blood flow through the needles helps ensure that the patient will receive an adequate treatment, with proper clearances of waste and fluid from the blood. Some patients whose fistula or graft are not yet matured (ready to use) or who do not yet have a fistula or graft must use a catheter (a tube placed in a central vein in the neck, chest, or groin). Catheters must be used with great care to prevent infection. See Module 5: Vascular Access to learn more about venipuncture and the care and use of the different types of vascular access.

LABORATORY TESTS
Blood tests are done to assess how the patient is doing with dialysis and his or her diet limits. You will learn how to draw samples of the patient’s blood from the blood tubing port or the needle tubing, using a needle and syringe or a vacuum adapter.

Drawing Blood Samples
Draw blood samples from the arterial port or arterial needle tubing before you give heparin or saline. In patients with catheters, a small amount of blood needs to be drawn and discarded prior to drawing blood samples for processing. The first blood drawn from a catheter will contain heparin, which may change the results of some blood tests. To draw activated clotting times (ACT, a test of blood clotting) from a catheter, follow your center’s procedure. Most blood tests are drawn before the treatment, except postdialysis BUN (a test of dialysis adequacy), recirculation studies (a test of how much blood is being cleaned during a treatment), and blood cultures (a test for bacteria). All blood tests need a doctor’s order. You must wear gloves, a face shield or mask, and a gown to draw blood. After drawing the blood, use safe needle devices to prevent accidental needle sticks.

Key Points about Laboratory Testing
Learn how to:
- Use aseptic technique and dialysis precautions (see Infection Control on page 168).
- Draw samples from the arterial bloodline injection port or an arterial needle tubing.
Draw blood samples before you give saline or heparin.

Always draw blood into tubes with any anticoagulant in them last.

Gently invert blood tubes back and forth to ensure proper mixing of blood with any additives in the tube. Never shake blood sample tubes vigorously.

Keep blood tubes upright, label them correctly, and handle them properly.

Know for which lab tests the test tube must sit idle for 10-20 minutes before spinning them.

Avoid placing blood sample tubes on warm or hot surfaces (e.g., on top of the dialysis machine).
Most dialysis patients have anemia, a shortage of red blood cells. Blood tests remove even more red blood cells, which can worsen anemia. Draw the smallest amount of blood that the lab in your center will take for each blood test. Use pediatric methods and blood tubes when possible. Follow your center’s policies when drawing blood. Here are three ways that may be used to draw blood samples from a patient’s needle tubing or bloodline:

1. Use a syringe and needle, needleless adapter, or vacutainer to withdraw blood from an injection port on the bloodline and then inject it into a sample tube.
2. Use a Luer-Lok® adapter to draw blood directly into a vacuum sample tube.
3. Attach a syringe to the end of the patient’s needle tubing and draw blood into the syringe. Then put a needle on the syringe and insert the needle into the rubber stopper of the sample tube. Note: remember to clamp the needle tubing before you remove the Luer-Lok adapters or syringes.

After you draw the sample, you will usually attach a syringe to the end of the needle tubing to flush the line with saline and keep the tubing sterile. There are several types of blood sample tubes. Learn which tubes to use for each type of test. You can identify tubes by the color of their rubber caps (e.g., red speckled top, plain red top, lavender top). The color-coding is important, because some tubes have preservatives or solutions needed for a test. Also, it is important to know that vacuum tubes do not fill completely. Do not attempt to overfill the tube by forcing blood into the vacuum tube from a syringe. When the vacuum stops pulling blood into the tube, the tube is full.

Using a Centrifuge
A centrifuge is a machine that uses centrifugal force to separate red blood cells from the serum. It may be your job to “spin down” or centrifuge blood samples. Follow your center’s policies and procedures when using the centrifuge.

Testing Blood Sugar
Diabetes is the most common cause of kidney failure. It is treated with diet, pills, and/or insulin. To assess how well diabetes is controlled, the doctor may order a routine glucose (blood sugar) test. You measure the level of glucose in the blood. Dialysate often contains glucose which helps keep the patient’s glucose levels from becoming too low during the treatment.

MEASURING DIALYSIS ADEQUACY
How do we know if a patient is getting enough, or adequate, dialysis? There are two main lab tests that estimate the adequacy of dialysis given
to a patient during a treatment: urea reduction ratio (URR) and urea kinetic modeling (UKM).22

**Urea Reduction Ratio**

The URR is an estimate of how much urea is removed from a patient's blood during dialysis. Urea, or blood urea nitrogen (BUN), is an easy-to-measure, small molecule waste product of protein breakdown. It indicates how well a treatment is working. If the change in BUN levels from predialysis to postdialysis is too small, the treatment may not be adequate.
How much urea is removed by dialysis is found using blood test results and a mathematical formula. The level of BUN before a treatment is compared to the level after a treatment. So, both predialysis and postdialysis BUN samples are needed (see Appendix 2 on page 203 for URR formula). The URR is the simplest way to estimate the delivered dose of dialysis. But, it does not provide all of the information needed to prescribe a dialysis treatment. It doesn’t tell you, for example, how much extra time a patient with a low URR might need to get adequate dialysis. URR does not account for a patient’s production of urea during dialysis. Also, URR does not tell you how much urea is removed by UF during dialysis. This means URR is less accurate than UKM to estimate dialysis dose in patients who need a large amount of UF.

Urea Kinetic Modeling

UKM is a more in-depth way to estimate the delivered dose of dialysis. It is more complex than the URR, but tells you more about a patient’s treatment needs and is more accurate. UKM can help a doctor predict how much treatment time a patient should have, and determine a protein catabolic rate (PCR, the rate at which the body burns protein) to meet the patient’s needs. UKM also figures in a patient’s size and residual kidney function. The formula used to find the dialysis dose is Kt/V, where:

\[ K = \text{dialyzer urea clearance in mL/min} \]
\[ t = \text{time on dialysis in minutes} \]
\[ V = \text{volume of urea in the patient’s body, in mL} \]

Values for K are based on dialyzer type, and blood and dialysate flow rates. Accurate values for V are hard to find, and require a computer program to estimate. Like URR, a pre- and postdialysis BUN are needed for UKM. Pre- and postdialysis weights are also needed. Kt/V can help you find the delivered dose of dialysis, or can help a doctor set a target value to decide a dialysis prescription. The main advantage of UKM over URR is that it can be used both to measure and to prescribe a treatment. UKM gives the staff a number of options to help determine adequate dialysis and identify problems in delivering an adequate treatment.

Predialysis and Postdialysis BUN Measurements

Predialysis and postdialysis BUN samples are drawn each month so URR and Kt/V can be calculated. Draw the predialysis and postdialysis BUN samples during the same treatment.

Predialysis

Draw predialysis BUN samples just before a treatment, and avoid diluting the sample with saline or heparin. Take the blood sample from the arterial needle before you connect the
arterial blood tubing or flush the needle in patients with a fistula or graft. For patients with catheters, withdraw any heparin and saline from the arterial port, following your center’s protocol. After removing the heparin and saline from inside the catheter lines, connect a new syringe to the arterial lumen to draw the sample for BUN measurement.

Postdialysis
Draw the postdialysis BUN at the end of the ordered treatment time, using your center’s policy:

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1. At the end of the treatment, turn off the dialysate flow. If the machine does not allow the dialysate flow to be turned off, or if this is against your center’s policy, turn dialysate flow down to its lowest setting.
2. Reduce the UFR to 50 mL/hr, the lowest TMP/UFR setting, or off.
3. Turn blood flow down to 100 mL/min for 15 seconds and draw the blood sample, either shutting off the blood pump (stop pump) or leaving it running at 100 mL/min (slow pump).

To keep the blood pump from turning off as the blood flow rate drops, you may need to manually adjust the arterial and venous pressure limits.22

The slow flow/stop pump and the stop pump sampling technique are as follows:
1. To use the stop pump sampling technique:
   n Slow the blood flow rate to 100 mL/min for 15 seconds.
   n Stop the blood pump.
   n Clamp the arterial and venous bloodlines and the arterial needle tubing.
   n Draw blood for the postdialysis BUN from the arterial sampling port closest to the patient with a syringe, or disconnect the arterial bloodline and attach a vacutainer and syringe to the arterial needle tubing to draw the sample.
   n Return the patient’s blood and disconnect the patient per your center’s protocol.
2. Or, to use the slow flow sampling technique:
   n With the blood pump still running at 100 mL/min, draw the blood sample for postdialysis BUN measurement from the arterial sampling port closest to the patient.
   n Stop the blood pump and disconnect the patient per your center’s protocol.

Minimum Delivered and Prescribed Dose of Dialysis
The NKF-KDOQI guidelines use UKM or URR to decide the delivered dose of dialysis. UKM is best, since it is based on patient factors such as body size and residual renal function.22 KDOQI guidelines set standards for the minimum delivered and prescribed doses of dialysis to help ensure that patients get adequate treatment. The minimum delivered dose should be a Kt/V of at least 1.2. This would translate to a URR of about 65%, though the amount of UF a patient needs must be taken into account.22

Because patients do not always get this delivered dose (due to reduced urea clearance, time constraints, or other factors), the minimum recommended prescribed dose is a Kt/V of 1.4 (this translates to a URR of about 70%).22

FACTORS AFFECTING DIALYSIS TREATMENT
It is important to know what affects the
delivered dose or adequacy of treatment. The clearance of wastes through a dialyzer depends on a good blood flow rate, the right dialysate flow rate, and proper anticoagulation to prevent the clotting of dialyzer fibers. How well you do your job can affect all of these factors.

Clearance Factors
Dialyzers vary in size, porosity, and surface area, all of which affect how much dialysis a patient receives during a treatment. Other Hemodialysis Procedures and Complications
Treatment factors can also reduce clearance (K) and the treatment's effectiveness. These include:
- Poor blood flow from the patient's access
- Poor dialyzer function due to insufficient heparin/anticoagulation
- Clotting of the dialyzer's fibers
- Wrong estimates of dialyzer performance
- Wrong blood flow rate settings
- Blood pump calibration errors
- Reduced blood pump speed, such as when the patient has hypotension or muscle cramps
- Wrong dialysate flow rate settings that do not match the physician's orders
- Access recirculation (mixing dialyzed venous blood with undialyzed arterial blood in the patient's access during a treatment)

Time Factors
Factors that affect the patient's time (t) per treatment will also affect adequacy. These may include:
- Stopping a treatment early
- Frequent alarms that stop the blood pump (extracorporeal arterial or venous pressure)
- Frequent alarms that divert dialysate to the drain (alarms that put the machine into bypass)

Losing just 5 minutes from each treatment over a year adds up to 13 hours or more than three treatments. Since even a good conventional dialysis treatment replaces only about 15% of normal kidney function, every minute is needed. When possible, add time at the end of the treatment to make up for a reduced blood flow rate or time lost due to blood pump shut-off or dialysate bypass. If the lost time is significant and the center is too busy to add time, a patient may need to come for an extra treatment.

Patient Well-being
Dialysis should control or reduce the complications of chronic kidney disease. Patient well-being is a way to tell if dialysis is adequate but it is only a late measure. A patient who receives poor dialysis may have few symptoms in the short-term, but may run into severe problems in the long-term and is likely to die sooner.

Poor dialysis can cause uremia (high BUN) which can decrease the patient's appetite. A malnourished patient may lose weight (muscle), have no appetite, and have low BUN and serum albumin levels. Malnutrition raises the risk of patient hospital stays and death. It is wise to measure adequacy with more than one test. Besides looking at the URR or UKM, consider the patient's nutritional status and sense of well-being. These measures serve as a check for the quality of the treatment. They also help alert you to problems and help the doctor tailor the prescription to meet the patient's needs.

STARTING THE
DIALYSIS TREATMENT
The treatment can start after you:

1. Match the dialyzer and dialysate concentrate to the patient.
2. Prime the dialyzer and tubing with normal saline.
3. Check all tubing connections.
n Test and arm all alarms.
n Take the patient’s vital signs and complete predialysis assessments.
n Insert the dialysis needles and tape them in place, or be sure that the catheter is properly flushed and prepared.
n Make sure all monitors are set and are within limits (e.g., arterial and venous pressures, blood leak detector, UF, conductivity, temperature, dialysate flow, blood pump speed, and sodium variation).

After the vascular access has been cannulated and the bloodlines have been connected to the access, start the blood flow slowly. If the patient is to receive the priming solution in the bloodlines, connect both the arterial and venous bloodlines. If the priming solution is to be discarded, connect only the arterial end of the bloodline to the needle to allow priming solutions to drain into the waste receptacle.

Follow your clinic’s policies and procedures. Monitor the patient until the venous line is connected to the access, due to the risk of severe blood loss. If the priming solution is wasted, once the blood has reached the venous chamber, connect the venous line to the access. Once the arterial and venous bloodlines have been connected, slowly increase the blood flow rate to the prescribed rate.

After the treatment has started, document information about the start of the treatment on the treatment flow sheet. Learn what your center requires you to record on the patient’s treatment flow sheet. Before you leave the patient’s chair, recheck to be sure that you have verified all alarms and settings.

Monitoring During Dialysis

During the treatment, you will monitor the patient and the machine. Patient monitoring includes taking vital signs and assessing the patient’s general condition. Machine monitoring includes doing equipment safety checks, monitoring the bloodlines and the machine readings, and checking the alarms when they occur.

PATIENT MONITORING

Vital Signs

You will check the patient’s vital signs during dialysis to ensure a safe and effective treatment. Your center may have you check the patient’s vital signs every half hour, or more often if the patient is having symptoms or is unstable. Report any unusual findings to the nurse.

Hemodialysis Procedures and Complications

Measures to Ensure Safe and Reliable Machine Operation

Learn how to:
- Operate the machine and understand all the dials and displays as described in the manual.
- Test all alarms by hand or automatically before each treatment.
Use only dialysate concentrate that is prescribed for the patient, and have enough ready for the whole treatment.

- Avoid changing the conductivity alarm limits during a treatment.

Key Points to Learn about Dialysis Treatment Monitoring

- How often to check the patient’s vitals signs during treatment
- Signs and symptoms of dialysis-related problems
- Equipment safety checks and how often they are done
- Where to find all of the alarms, how they work, and what to do if an alarm goes off or an emergency occurs
General Patient Condition
You will also learn how patients are tolerating the treatment by watching and listening to them. Watch the patient’s behavior, appearance, response, and symptoms. Teach your patients to recognize and report symptoms so the care team can take action early (see Hemodialysis Complications on page 198). Report any unusual events to the nurse.

Giving Medications
Patients will need some medications before, during, or after a treatment. Drug timing depends on whether a drug will dialyze off, and on center policy and procedure. For example, patients can’t take some blood pressure pills within a few hours before a treatment, because these medications may cause the blood pressure to drop during the treatment. Some drugs, such as volume expanders like hypertonic saline or mannitol, may be given by the nursing staff during a treatment if ordered to help remove fluid or maintain blood pressure. Others, like antibiotics, are given by the nursing staff near the end or after a treatment. This reduces the chance of the drug being removed during dialysis.

TECHNICAL MONITORING
You will learn how and why each monitor and alarm on the hemodialysis machine works, where to find it, and what to do if it should sound. If an alarm sounds or the equipment malfunctions during the treatment, you must act quickly to find the problem. Module 4: Hemodialysis Devices covers monitors and alarms in detail. It will be your job to monitor the extracorporeal circuit, dialysate circuit, and equipment for problems during each treatment (see Figures 10 and 11). These checks help

Figure 10:
Pressure monitoring devices on arterial and venous bloodlines
The extracorporeal circuit has gauges to measure venous pressure and arterial pressure.
Line clamp
Blood pump
Air detector
Arterial bloodline
Arterial pressure gauge (negative, pre-pump pressure)
Arterial pressure gauge (positive, post-pump pressure)
Venous
bloodline
Arterial
(pre-pump)
pressure
Vascular
access
Venous
pressure gauge
(positive,
postdialyzer
pressure)
#1 #2
Sensor device
Sensor device
Line clamp
Line clamp
#2 uses a photocell
to monitor change
in light transmission
#1 uses an ultrasonic sensor
device to monitor change
in sound transmission
Figure 11:
Air detector
ensure patient safety. Check all systems every half hour to hour, per your center’s policy.

ANTICOAGULATION

During a treatment, the patient’s blood comes in contact with the artificial (man-made) dialyzer and lines. This contact can cause blood clots, which could clog the dialyzer and make dialysis difficult or even impossible. Anticoagulants (blood thinners) help prevent clots and keep the patient’s blood flowing freely. Anticoagulants used in dialysis include heparin, saline, or citrate.

Heparin

The anticoagulant of choice in hemodialysis is heparin. Heparin is easy to give, works fast, breaks down quickly in the body, and is removed quickly. The patient’s doctor prescribes the dose of heparin used in a treatment. There are three ways to give heparin before a treatment (see Table 4). Which technique is used will depend on the patient’s needs and your center’s procedure.

Activated clotting time (ACT) is a test of how long it takes for a patient’s blood to clot. Heparin is given to keep the patient’s clotting time at a prescribed limit, such as twice the baseline ACT, during a treatment. The Clinical Laboratory Improvement Amendments Act (CLIA) of 1988 requires human blood to be tested only in certified labs. This law has made it hard to do ACT testing in the dialysis center. Follow your center’s policies and procedures about how to check clotting times.

Learn the signs of heparin or bleeding problems and report any problems to the registered nurse. Check your patients for signs.

Hemodialysis Procedures and Complications

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Routine Continuous Infusion

Inject a bolus (single amount) (e.g., 30-50 U/kg) 2-3 minutes before a treatment starts.

Use the heparin pump on the arterial bloodline to continuously pump heparin during the treatment (e.g., 750-1,250 U/hour).

Stop the heparin pump one hour before the end of the treatment, or per your center’s policy.

Routine Repeated Bolus

Inject a bolus dose of heparin 2-3 minutes before the start of the treatment.

Give bolus doses of heparin throughout the treatment, per center policy.

Tight Heparin

Use for patients who have a slight to moderate risk of bleeding. The bolus dose and infusion rate is lower than with routine continuous infusion.
Inject a bolus (single amount) (10–20 U/kg) 2–3 minutes before a treatment starts.

Use the heparin pump (see Figure 12) on the arterial bloodline to continuously pump heparin during the treatment (500 U/hour).

Stop the heparin pump one hour before the end of the treatment, or per your center’s policy.

Table 4: Heparin Administration Methods

Figure 12:
Heparin pump
To dialyzer
Heparin infusion line
Heparin pump
and symptoms of too much or not enough heparin:

Signs of too much heparin:
- Nose bleeds
- Bleeding in the white part of the eyes
- Ecchymoses (bleeding into the skin)
- Prolonged bleeding from the access site after treatment

Signs of not enough heparin:
- Blood clots in the venous drip chamber or dialyzer
- Very dark-colored blood in the bloodlines
- Shadows or streaks in the dialyzer

Heparin-free Dialysis

Heparin-free dialysis can be done for patients who are at a high risk for bleeding or can't use heparin.

Normal saline, 100 mL, is flushed through the arterial line, predialyzer, every 15-30 minutes.

Heparin-free dialysis is very difficult to maintain. To succeed, a good arterial blood flow rate (>250 mL/min), a dialyzer with a high UF coefficient, and a dialysis machine with UF control are needed.

Regional Citrate

Regional citrate anticoagulation is a rarely-used substitute for heparin-free dialysis. Regional citrate is for patients who have bleeding, are at high risk for bleeding, or who cannot receive heparin. Calcium allows blood to clot. So, another option to thin the blood without heparin is to reduce ionized calcium levels in the blood. This can be done by infusing trisodium citrate into the arterial bloodline, and using a calcium-free dialysate. However, it would be very dangerous to return the patient's blood with low calcium levels. So at the same time that trisodium citrate is infused into the arterial bloodline, calcium chloride is infused into the venous bloodline.

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Table 5: Clinical Complications of Hemodialysis

<table>
<thead>
<tr>
<th>Complication</th>
<th>Causes</th>
<th>Signs/Symptoms</th>
<th>How to Prevent It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air embolism</td>
<td>(air bubbles block a blood vessel)</td>
<td>Chest pain, Trouble breathing, Coughing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A detector is broken or not armed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A leak or loose connection in the extracorporeal circuit before the blood pump.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Empty IV bags on the extracorporeal circuit before the blood pump.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depends on the patient's body position when the air is infused.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>May include:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chest pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trouble breathing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coughing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Blue lips, fingers, toes (cyanosis)
Trouble seeing
Confusion
Arm the air detector throughout a treatment.
Tighten all connections in the extracorporeal circuit.
Check the normal saline level in the IV bag.
Return the patient’s blood with saline, with no air in the bloodlines.
Anaphylaxis (severe allergic reaction)
Ethylene oxide (a new dialyzer germicide) allergy
Reaction to germicide left in the bloodlines
Drug allergy (e.g., to iron dextran, heparin)
Trouble breathing (throat may close up)
Hypotension
Itching
Hives
Feeling anxious
Burning feeling
Unusual swelling
Cardiac arrest
Rinse dialyzers and bloodlines well during equipment preparation.
Avoid drugs the patient has a known allergy to.
<table>
<thead>
<tr>
<th>Complication</th>
<th>Causes</th>
<th>Signs/Symptoms</th>
<th>How to Prevent It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angina</td>
<td>Coronary artery disease, Anemia, Hypotension, Anxiety, Pain or tightness in chest</td>
<td>Patient may be pale, cold, sweating, and have trouble breathing</td>
<td>Monitor blood pressure closely to avoid hypotension. Calculate the fluid goal correctly.</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>Changes in blood pH or electrolyte levels, Hypotension, Heart disease, Irregular pulse</td>
<td>Slow or fast pulse, Patient has palpitations (strong heart beats)</td>
<td>Use the right dialysate concentrate. Manually check the patient's pulse during treatment. Monitor blood pressure.</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>Extreme hypotension, Electrolyte imbalance, especially high potassium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arrhythmias, Heart attack, Air embolism, Severe blood loss, No pulse, No breathing, Loss of consciousness</td>
<td></td>
<td>Check vital signs</td>
</tr>
</tbody>
</table>
during treatment.
- Tell the nurse right away about major vital sign changes and/or the patient complains of chest pain and sweating.
- Cramps
- Removing too much fluid
- Changes in blood chemistry, especially sodium
- Low potassium levels
- Hypotension
- Painful muscle cramps, often in the hands and feet
- Get an accurate weight before a treatment.
- Correctly calculate the fluid goal.
- Use the prescribed dialysate concentrate.
- Encourage patients to follow their salt and fluid limits.

Dialysis disequilibrium syndrome
(brain swelling)
- If BUN is removed much faster from the blood than from the brain, disequilibrium is created and fluid moves into the brain cells.
- This is seen more often in patients who have acute kidney disease or a BUN level >150 mg/dL.
- Headache
- Nausea
- Hypertension
- Restlessness
- Confusion
- Blurred vision
- Seizures
- Monitor the patient during treatment.
- Tell the nurse right away about major vital sign changes.
- In patients with high BUN (>150 mg/ml) a smaller dialyzer and/or slower blood and dialysate flows are preferred. Short, slow dialyses may be prescribed daily for a few treatments.
Table 5: Clinical Complications of Hemodialysis (continued)

<table>
<thead>
<tr>
<th>Complication</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever and/or chills</td>
<td>Infection</td>
</tr>
<tr>
<td>Contaminated dialyzer or bloodlines</td>
<td>(endotoxin exposure)</td>
</tr>
<tr>
<td>Too-cold dialysate</td>
<td></td>
</tr>
<tr>
<td>Fever during dialysis</td>
<td></td>
</tr>
<tr>
<td>Feeling cold</td>
<td></td>
</tr>
<tr>
<td>Feeling cold without a fever</td>
<td>(cold dialysate)</td>
</tr>
<tr>
<td>Redness, swelling, tenderness, warmth, or drainage from access or other sites (e.g., feet, skin wounds)</td>
<td></td>
</tr>
<tr>
<td>Use aseptic technique to set up equipment.</td>
<td></td>
</tr>
<tr>
<td>Use aseptic technique to inserting needles.</td>
<td></td>
</tr>
<tr>
<td>Check vital signs.</td>
<td></td>
</tr>
<tr>
<td>Tell the nurse right away about major vital sign changes.</td>
<td></td>
</tr>
<tr>
<td>Check dialysate temperature before treatment.</td>
<td></td>
</tr>
<tr>
<td>Use the right process to disinfect the dialysis machine and the water components.</td>
<td></td>
</tr>
<tr>
<td>Test water and equipment for bacteria or pyrogens/endotoxins</td>
<td></td>
</tr>
<tr>
<td>First-use syndrome</td>
<td>Reaction to ethylene oxide (used to sterilize new dialyzers)</td>
</tr>
<tr>
<td>Use of polyacrylonitrile (PAN) membranes in patients who take ACE inhibitors (a class of blood pressure pills)</td>
<td></td>
</tr>
<tr>
<td>Symptoms usually occur in the first 15-30 minutes of treatment:</td>
<td></td>
</tr>
<tr>
<td>Itching</td>
<td></td>
</tr>
<tr>
<td>Chest and/or back pain</td>
<td></td>
</tr>
<tr>
<td>Shortness of breath</td>
<td></td>
</tr>
<tr>
<td>Hypotension</td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
<td></td>
</tr>
<tr>
<td>General discomfort</td>
<td></td>
</tr>
<tr>
<td>Rinse the dialyzer well before treatment, per center procedure.</td>
<td></td>
</tr>
<tr>
<td>Use the right dialyzer.</td>
<td></td>
</tr>
<tr>
<td>Heparin overdose</td>
<td>Error in heparin dosing</td>
</tr>
<tr>
<td>Broken heparin pump</td>
<td></td>
</tr>
<tr>
<td>Unusual bleeding around needles</td>
<td></td>
</tr>
</tbody>
</table>
 Longer than normal bleeding from needle sites after treatment

- Draw up heparin doses correctly.
- Use the right type of heparin.
- Monitor the heparin pump during treatment.

Hypertension (high blood pressure)
- Fluid overload
- Patient missing their blood pressure pills

- Anxiety
- Dialysis disequilibrium syndrome
- May have no symptoms
- Headache
- Nervousness
- Calculate the fluid goal correctly.
- Ask patients if they’ve taken their BP pills.
- Encourage patients to follow their fluid limits.

Hypotension (low blood pressure)
- Removing too much fluid
- Taking BP pills before dialysis
- Heart disease
- Low BP reading
- Dizziness
- Tachycardia (rapid pulse)
- Loss of consciousness
- Get an accurate weight before a treatment.
- Calculate the fluid goal correctly.
- Ask patients if they’ve taken their BP pills.
after the dialyzer. This method works very well, but is very complex to monitor, and therefore rarely done in the freestanding dialysis center.26

Hemodialysis Complications

Hemodialysis technology has improved, but there is always a risk of complications during a treatment. Complications can be either clinical (related to patient care) or technical (related to equipment). We will cover both types below.

CLINICAL COMPLICATIONS

Clinical complications that may occur during a treatment are described in Table 5.23,27 Follow your center’s policies and procedures to prevent or react to a complication. Tell the nurse right away if these problems occur.

TECHNICAL COMPLICATIONS

Table 6 describes technical complications that may occur during hemodialysis.23,24 Follow your center’s policies and procedures to prevent or react to a complication. Tell the nurse right away if any of these problems occur.

Postdialysis Procedures

At the end of a treatment, you will have another set of steps to do. These include discontinuing the dialysis treatment, taking the patient’s vital signs and weight, documenting the treatment, and cleaning up the equipment.

DISCONTINUING DIALYSIS

At the end of the treatment, the blood pressure and pulse are taken. This will help you to determine the amount of saline you will need to use to return the patient’s blood. You will draw any postdialysis blood samples that have been ordered by the physician. To end a treatment, you will reduce the blood flow rate and UFR. You will check the patient’s vital signs again. Usually, when the fluid in the venous bloodline

Table 5: Clinical Complications of Hemodialysis (continued)

<table>
<thead>
<tr>
<th>Complication Causes Signs/Symptoms How to Prevent It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruritus (itching)</td>
</tr>
<tr>
<td>Uremia (high BUN)</td>
</tr>
<tr>
<td>High blood</td>
</tr>
<tr>
<td>phosphorus levels</td>
</tr>
<tr>
<td>Calcium phosphate</td>
</tr>
<tr>
<td>crystals under the skin</td>
</tr>
<tr>
<td>Secondary hyperparathyroidism</td>
</tr>
<tr>
<td>Severe itching on and off dialysis</td>
</tr>
<tr>
<td>Red skin</td>
</tr>
<tr>
<td>Crusting on the skin</td>
</tr>
<tr>
<td>Keep skin clean and dry</td>
</tr>
<tr>
<td>Deliver dialysis</td>
</tr>
<tr>
<td>treatment correctly.</td>
</tr>
</tbody>
</table>
- Ask patients if they are taking their phosphate binders.
- Seizures
- Severe hypotension
- Electrolyte imbalance
- Dialysis disequilibrium syndrome
- Seizure disorder (epilepsy)
- Change in level of consciousness
- Jerking movements of the arms and legs
- Monitor BP
- Check that patients with epilepsy are taking their medications.
<table>
<thead>
<tr>
<th>Complication</th>
<th>Causes</th>
<th>Signs/Symptoms</th>
<th>How to Prevent It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air in bloodlines</td>
<td>Underfilling of drip chambers</td>
<td>May see collapse of arterial bloodlines</td>
<td>Keep correct drip chamber levels. Be sure the saline bag is not empty and line stays clamped.</td>
</tr>
<tr>
<td></td>
<td>Empty saline bag</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Loose connections in the extracorporeal circuit</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Dialysis needle taken out while blood pump is on</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air left in extracorporeal circuit after priming</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air bubbles or foaming in the bloodlines</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air in the blood alarm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>May see collapse of arterial bloodlines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clotting</td>
<td>Wrong and/or inadequate anticoagulation</td>
<td>Blood turns very dark</td>
<td>Give heparin as prescribed. Maintain prescribed blood flow rates. Prime the extracorporeal circuit correctly before treatment starts.</td>
</tr>
<tr>
<td></td>
<td>Low blood flow rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air in the extracorporeal circuit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blood turns very dark</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clots in the extracorporeal circuit (see during rinseback)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If clotting in dialyzer, may see a decrease in venous drip chamber pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If clotting in venous chamber, may see an increase in venous drip chamber pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exsanguination</td>
<td>(severe loss of blood)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bloodlines come apart</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taking out dialysis needles with the blood pump on</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Crack in dialyzer casing or improperly fitted header cap
Access rupture
Blood on patient chair, clothes, and/or floor
Hypotension
Seizures
Cardiac arrest
Tighten all extracorporeal connections.
Tape needles securely.
Keep all accesses in view at all times (no blankets over access limbs).
Monitor the extracorporeal circuit per procedure.
Hemolysis (bursting of red blood cells)
Kinked bloodlines
Inadequate water treatment that allows chloramines, copper, zinc, or nitrates into the dialysate
Too-warm dialysate
Formaldehyde in a reused dialyzer
Nausea
Headache
Stomach and back pain
Hypertension or hypotension
Cardiac arrest
Bright red colored blood
Check dialysate conductivity and temperature before treatment.
Test dialysate for chloramines and disinfectants.
Monitor bloodlines for kinks.
Check that blood pump is calibrated for the bloodline header being used.
Power failure
Machine failure
Machine unplugged
Power outage
Machine stops during treatment
No lights on machine
Check that the machine is completely plugged in before treatment.
Be sure the machine has been maintained per center procedure.
is pink, you will stop the saline. Check blood pressure and pulse rate again before the dialysis needles are removed. You will look at the dialyzer after the blood is returned to see how much blood was left clotted in the dialyzer after rinseback (see Figure 13). Learn and follow your center’s policy on discontinuing dialysis.

POSTDIALYSIS PATIENT EVALUATION
After dialysis, you will recheck all the patient’s vital signs (blood pressure, pulse, and temperature) and weight. Blood pressure should be the same as it was at the start of treatment, or lower. Take a sitting and a standing blood pressure to check for orthostatic hypotension (a drop in arm blood pressure when the patient stands up) before you take out the needles. If the patient has hypotension, you can give some normal saline, per your center’s policy. The patient should weigh less after a treatment than before. If the patient has a fever, tell the nurse. Check the patient’s vascular access (see Module 5: Vascular Access) and general condition. Tell the nurse about any changes or abnormal findings before the patient leaves the center.

EQUIPMENT CLEAN-UP
If your center reuses dialyzers, you will prepare the dialyzer for reprocessing after the treatment. In many centers, you will instill heparin (from the infusion pump or a bolus dose) into the normal saline bag. Circulate this saline through the extracorporeal circuit to flush out some of the blood left in the dialyzer. Note: The dialyzer should be completely filled with saline; air will cause any blood that is left to clot. Cap all ports. After each treatment, remove the dialyzer and bloodlines from the hemodialysis machine. Throw away the bloodlines and disposable equipment. A dialyzer that is to be reused should be refrigerated or reprocessed within 10–15 minutes after a treatment to reduce the loss of volume. If your center does not reuse the dialyzer, discard it. Remove and disinfect clamps and other nondisposable items, per center policy, before using them for other patients.

To kill any bacteria, you must disinfect equipment that will be used for another patient. Otherwise, the bacteria could transfer to the next patient who uses it. Clean the outside of the machine with a disinfectant after each treatment. Pay special attention to control knobs and other surfaces that may have been touched and contaminated during the treatment.

Hemodialysis Procedures and Complications

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Good rinseback

A few streaks of blood
Fair rinseback —
several streaks, possibly
in different places
Poor rinseback —
many streaks
Figure 13:
Good, fair, and poor rinsebacks
You must disinfect the dialysate delivery system regularly with heat or chemicals:

Heat disinfection is a 3-cycle process built in to some central dialysate systems and some individual patient machines. During a warm-up cycle, water is heated to 85°C–95°C. Depending on the system, hot water passes through the hydraulic circuit for 20–60 minutes in a recirculation cycle. This disinfects the machine. At the end of the cycle, the hot water is drained and replaced with cool water. The temperature-regulating mechanism resumes normal operation in the normalization cycle.

Chemical disinfection is a 3-cycle (water fill, circulation, rinse) process. The machine runs with disinfectant instead of dialysate. The chemical disinfectant mixes with treated water and follows the dialysate path. The rinse cycle washes out the disinfectant.

Before you start the next treatment, the rinse water must be tested for residual disinfectant.

Conclusion
Dialysis is a complex process with many patient care and technical skills that you need to learn to provide safe patient care. You will work with your preceptor to practice the skills reviewed in this module. Before you work on your own, you will need to be able to show that you can complete all of the skills correctly.
Hemodialysis Procedures and Complications

Appendix 1

CALCULATING TRANSMEMBRANE PRESSURE (TMP)

\[ \text{TMP} = \frac{\text{Total fluid to be removed in mL}}{\text{hours on dialysis}} \]

KUf of dialyzer

\[ \text{KUf} = \text{ultrafiltration coefficient of dialyzer} \]

\[ \text{mL of fluid ultrafiltered by the dialyzer per hour per mmHg of TMP}. \]

Example

Physician’s order:
- Dialyze for 4 hours
- Remove 2 kg
- Dialyzer KUf = 40 (i.e., 40 mL of fluid ultrafiltered by the dialyzer per hour per mmHg of TMP)

Weight to be removed in mL for the 4-hour session = 2,000 mL
Oral intake = 300 mL
Saline rinsed back = 100 mL

Total fluid to be removed in mL for the 4-hour session = 2,400 mL

Total fluid to be removed per hour: 2,400 mL/4 hours = 600 mL

\[ \text{TMP} = \frac{600}{40} = 15 \text{ mmHg} \]

Estimation of dialysate pressure on the dialysate side:

TMP can also be roughly regarded as the difference in pressure between the blood compartment of the dialyzer and the dialysate compartment of the dialyzer (i.e., the blood side pressure minus the dialysate pressure).

Example

If the blood compartment pressure is 120 mmHg (as read on the venous pressure monitor), then the pressure in the dialysate compartment equals: 120 mmHg - 105 mmHg = 15 mmHg. So if you set your machine to remove 600 mL/hr, and the KUf is 40 mL/mmHg/hr, you would expect to have a TMP of 15 mmHg.
Appendix 2

UREA REDUCTION RATIO (URR) AND UREA KINETIC MODELING (UKM) FORMULAS

URR formula:
URR (%) = 100 \left(1 - \frac{\text{BUN}_{\text{post}}}{\text{BUN}_{\text{pre}}}\right)

UKM formula example:
Kt/V = -\ln(R - 0.008t) + (4 - 3.5R)\frac{\text{UF}}{\text{W}}

Where:
- $\ln$ is the natural logarithm
- $R$ is the postdialysis BUN divided by predialysis BUN
- $t$ is the dialysis session length in hours
- $\text{UF}$ is the ultrafiltration volume in liters
- $\text{W}$ is the patient’s postdialysis weight in kilograms
Hemodialysis Procedures and Complications

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Objectives
After completing this module, the learner will be able to:
1. Discuss the history of dialyzer reprocessing.
2. List two reasons why dialysis centers reprocess dialyzers.
3. Explain the steps involved in dialyzer reprocessing.
4. Discuss the hazards to patients and staff that can occur with dialyzer reprocessing.
5. List the required documentation for dialyzer reprocessing.

Module 7 cover photo credit:
Renaclear® Dialyzer Cleaning System reprinted with permission from Minntech Renal Systems, 2005.
Introduction
The dialyzer is a feat of engineering: complex enough to do some of the work of a human kidney, yet simple enough to be massproduced, and reliable enough to be used many times. For medical and non-medical reasons, many dialyzers are reprocessed: cleaned and disinfected to be used again by the same patient instead of being thrown out after a single use. This is called reuse.

Dialyzer reprocessing is regulated by the federal and some state governments. Regulations include the standards and conditions centers must follow so reuse is as safe and effective as possible for both patients and staff.

A reprocessing technician has the immense job of maximizing patient benefits of reuse and reducing the risks. This is done by carefully following all of the guidelines, regulations, and center procedures. This module covers the history of the reasons for reprocessing, the role of regulations and guidelines, and the steps used to reprocess dialyzers.

History of Dialyzer Reprocessing
Dialyzer reprocessing has been around since the late 1960s. At first done by hand, reprocessing is now most often done with a machine. Many factors aided the development and types of reuse equipment; one was the evolution of dialyzers themselves. By the mid-1960s, most patients were treated with Kiil dialyzers (see Figure 1). A Kiil was a sandwich made of layers of membrane sheets held apart by grooved boards of polypropylene plastic. Rubber gaskets and metal clamps held the sandwich together. The Kiil had to be assembled and pressure tested before each use—a slow and complex technique. Often 10%–20% of the time it would fail the pressure test, and the whole process would have to start over with fresh sheets of membrane. In 1967, Dr. Belding Scribner (who helped devise the vascular access) reported that the blood compartment of a Kiil could be filled with a germicide (germ-killing solution), rinsed, and used for the next treatment. The Kiil did not have to be taken apart and rebuilt. This was one of the first examples of dialyzer reprocessing. For Dr. Scribner, the main reason for reusing Kiils was to save home patients the time and trouble of tearing down and rebuilding them. At that time, most of Dr. Scribner’s patients were doing home hemodialysis in his Seattle program.

Figure 1:
Kiil dialyzer
Latches Inside the Kiil, two pairs of membrane sheets (4 sheets) were separated by three grooved polypropylene boards.
By the late 1960s, new coil dialyzers were preferred for reuse. Coils were easier to set up and prime (fill and rinse with normal saline) than Kiils, but too costly for many hospitals to use as disposable or single-use products, as manufacturers suggested. Prior to reuse, they were filled with a disinfecting solution to kill germs and kept in a refrigerator with sterile water in the blood compartment.2 By the late 1970s, disposable parallel plate dialyzers were being reused. The dialyzer could be sealed off with germicide in both the blood and dialysate sides. This reduced the chances of contamination by bacteria.

When hollow fiber dialyzers came on the market in 1970, they proved to be well-suited for reuse. With strong structural integrity, they were easy to rinse. Water pressure could be used to wash fibrin and blood out of the dialyzer fibers. Reused hollow fiber dialyzers performed better than other types. Cell volume (fiber bundle volume) was easy to measure. Since the fiber bundle volume could be measured and used to decide when the dialyzers should be discarded, the hollow fiber dialyzer became the preferred choice for reuse.

From 1964 to 1976, dialyzer reuse evolved; it was studied, changed, refined, tested, and practiced. Researchers looked at how reprocessed coil, parallel plate, and hollow fiber dialyzers differed from new dialyzers in clearance and removal of small molecules. They tried a number of germicides, dwell times, concentrations, and temperatures. In time, they found ways to reliably kill and prevent the growth of bacteria.

Companies built single-station and multistation automated systems for reprocessing. Single-station systems were used for dialysis centers and home hemodialysis. These included the ECHO by Mesa Medical, Inc., and the Renatron® by Renal Systems. A few companies made multistation systems of varying sizes for center use. The ADR-22 by Texas Medical Devices, Seratronics DRS-4, and the Lixivitron 2 by Harco Medical Electronic Devices were four-station systems. The Belro Company built a six-station machine. Computer Dialysis Systems made larger systems; the Compudial KP-1 was 12 stations.

DIALYZER REPROCESSING DEMOGRAPHICS

In 1976, about 18% of U.S. dialysis patients were treated with reused dialyzers. In the 1980s, many studies found that reuse with proper quality control was safe. Machines that made reprocessing easier and more efficient aided growth of the practice. In 1983, dialysis payment from Medicare was changed: centers were paid a fixed sum—the composite rate—per each treatment. The change to a
composite rate may have been the single largest reason for the rapid growth of reuse, which reached a peak in 1997, with 82% of centers using it. In 2002, this dropped to 63%. In 2001, the largest dialysis company in the United States announced a change to single-use dialyzers. Their market share ensures that dialyzer reuse will continue to drop in the United States.

Why Dialyzers Are Reused

The reasons for dialyzer reuse, both medical and non-medical, have changed over time.

Dialyzer Reprocessing
MEDICAL REASONS
FOR DIALYZER REUSE
The main medical reason to reuse dialyzers is to reduce hypersensitivity reactions. A patient may have such a reaction in the first 15-30 minutes of treatment with a new dialyzer. Symptoms include anxiety, itching, and trouble breathing, which can lead to respiratory failure. This is also called first-use syndrome. In rare cases, patients may have an anaphylactic reaction to a new dialyzer; this is a severe, sometimes fatal allergy, which may include hives and respiratory failure. The most severe hypersensitivity reactions are due to ethylene oxide (ETO). ETO is used to sterilize most new dialyzers in the United States. The chance of a reaction is less with a reused dialyzer because the repeated rinsings can lower the levels of ETO. Rinsing new dialyzers can also reduce reactions. The rinsing done for preprocessing and reprocessing can also remove other noxious substances from the dialyzers.
Some centers reuse dialyzers because they want to remove more middle molecules, such as beta-2-microglobulin (ß2m). Reuse makes it possible for these centers to afford the costly high-flux dialyzers that do a better job of removing middle molecules.
SAFETY OF REUSE
In 1997, the National Kidney Foundation’s Council on Dialysis had an expert panel review clinical experience with dialyzer reuse since 1988. The group looked at patient symptoms, death, chemical toxicity, and dialyzer clearance. While the Council did not take a stand for or against reuse, they found no effect of reuse on patient illness or death. It has recently been suggested that there was a patient survival advantage when dialyzer use was switched from reuse to single-use. On the other hand, studies suggesting that patients who reuse dialyzers do not have a higher mortality rate than patients on single-use dialyzers continue to emerge. Many authors believe reuse is safe and can deliver quality care if it is done using recognized reprocessing protocols such as those recommended by the Association for the Advancement of Medical Instrumentation (AAMI) guidelines (as well as dialyzer manufacturers’ instructions).
NON-MEDICAL REASONS
FOR DIALYZER REUSE
The most common non-medical reason for dialyzer reuse is cost. Reusing a dialyzer can reduce the cost per dialysis treatment, even including the staff time that is used. Another argument for reuse is the environmental impact. Throwing out dialyzers can be a major problem and expense. Reusing them reduces the amount of biohazardous waste.
Dialyzer Reprocessing Procedure
Dialyzers should be reprocessed using the AAMI standards and recommendations. The Centers for Medicare and Medicaid Services (CMS) adopted the AAMI guidelines as a Condition for Coverage for dialysis centers, and as federal regulations. The AAMI guidelines cover equipment, cleaning and disinfecting,
labeling, record keeping, supplies, environmental safety, staff qualifications, training, and quality assurance (see Figure 2). All water used for reprocessing must meet AAMI standards.

**TYPES OF DIALYZERS**

In 1996, the Food and Drug Administration (FDA) required that a dialyzer’s label must reflect its commercial marketing and clinical use. Therefore, each dialyzer must be labeled for single or multiple use. Companies who sell dialyzers to centers that reuse them must give instructions for safe and effective reuse. The label must have at least one recommended way to reprocess the dialyzer and scientific documentation that it is safe and effective. Not all dialyzers are approved for use with all germicides used in reprocessing. Only dialyzers that can be reused can be labeled for multiple use. Before you start to prepare a dialyzer for reprocessing, check the label for multiple use.

**AUTOMATED VERSUS MANUAL SYSTEM**

Dialyzer reprocessing can be done with a machine (see Figure 3) or manually (by hand). All the tasks done by the machine can also be done by hand, but the automated system offers better quality control. Use of an automated reprocessing machine is more efficient, more consistent, provides better records, and is safer for patients.

**Preparing for the First Use of a Dialyzer**

**LABELING**

Put the patient’s name on a dialyzer before you use it for the first time. If you have patients with the same or similar last names, the dialyzer label must have a warning or alert. The label should also have extra information such as the first name and middle initial, color code, or medical record number, to prevent mix-ups (see Figure 4). The label will need space for the number of uses, date and time of the last reuse, an identifier for the reprocessing staff member, and results of tests done on the dialyzer.

**Dialyzer Reprocessing**

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Figure 2:

Systems diagram for reprocessing dialyzers

Drawing adapted with permission from AAMI

REJECT DIALYZER REMOVE FROM SERVICE

* This step may be done later but must precede initiation of dialysis.

Initiate dialysis

Germicide/disinfectant test

Germicide/disinfectant rinse

Germicide/disinfectant test
Patient ID check
Inspection
MIN TIME
TIME LIMIT
Storage
Inspection
Germicide/disinfectant fill
Performance test(s) (leak test)
Rinse/pre-clean
First use
Termination of dialysis
Preprocessing (optional)
Re-label
Storage
New dialyzer
Storage
Check
Supplies
Fails specs
Water treatment
Tap water
Labels need to stay readable through reprocessing and dialysis. The label should not cover up the model number, lot number, arrows for direction of blood and/or dialysate flow, or other key data. Labels on dialyzers with clear casings should be small enough that you can see the blood path.

TOTAL CELL VOLUME
Before using a new dialyzer for the first time, you will need to test it for baseline total cell volume (TCV) also called fiber bundle volume (FBV) or a baseline clearance value (e.g., urea, sodium, or ionic clearance). The TCV measures the ability of the dialyzer to transport solutes and ultrafilter at its next use. Compare the baseline TCV or a baseline clearance with the TCV or clearance result after each reprocessing. Check each dialyzer against its own TCV or its own clearance value. There are differences between dialyzers in TCV or clearance value that you will miss if they are only measured in a batch.

Figure 3: Automated reprocessing systems
Drawings adapted with permission from Seratronics and Renal Systems, respectively

Figure 4: Example of a reprocessing label
Drawing adapted with permission from Seratronics
PREPROCESS

Many centers preprocess new dialyzers. Preprocessing removes more residual germicides, such as ETO, or other products of manufacturing, such as spallated particles, bore fluid, cleaning chemicals, phthalates, bisphenols, and other noxious substances that could cause harmful reactions the first time a dialyzer is used. Preprocessing allows for an accurate measure of a dialyzers total cell volume.6

After Dialysis

At the end of a treatment, blood in the dialyzer is rinsed back returned to the patient. It is important to rinse as much of the blood as possible back to the patient. A rinseback that is fair or poor leaves blood in the dialyzer (see Figure 5). Fair or poor rinseback leads to patient blood loss and is a reason to discard a dialyzer. After rinseback, a dialyzer that passes inspection is taken off of the extracorporeal circuit and brought to the reprocessing room.

PRE-CLEANING

The first step in reprocessing is to pre-clean the dialyzer. Pre-cleaning removes some of the blood from the blood compartment. Precleaning may use reverse ultrafiltration; you do this by placing a cap on one of the dialysate ports and sending a controlled supply of water into the other port.17 For some dialyzers, you may need to remove the header (see Figure 6).6 If the header of the dialyzer is removed to allow for cleaning, take special care to rinse and disinfect the area, including the O-rings, before putting the headers back on the dialyzer. Germicides may be used during pre-cleaning.6

PERFORMANCE TESTS

After you rinse and clean the dialyzer, you will need to test its functional and structural integrity. Federal and state regulations require measuring the TCV after each reuse. You will also need to do a leak test; this measures how well the dialyzer can withstand a pressure load, and protects the patient from a dialyzer blood leak. Finally, inspect the dialyzer for cracks, chips, or defects in the plastic housing.18

DIALYZER REJECTION

If a dialyzer fails the performance tests or visual inspection, throw it away. KDOQI guidelines recommend that dialyzers with less than 90% of the original clearance value (whether urea, sodium, or ionic clearance measures are used), or with less than 80% of the original TCV value, should be thrown out.19 Note: Loss of a dialyzers transport capacity does not directly relate to fiber clotting because the (now) greater blood flow velocity in the remaining unclotted fibers will cause a higher diffusion rate inside.
Figure 5:
Good, fair, and poor rinsebacks

- Good rinseback:
  - a few streaks of blood
- Fair rinseback:
  - several streaks, possibly in different places
- Poor rinseback:
  - many streaks
each such fiber. So, when the residual TCV value of a hollow fiber dialyzer is 80% of the original TCV, the relative fall in urea, sodium, or ionic clearance will only be about 10%.15 You will also discard dialyzers that have reached their maximum number of uses (per your center’s policy); fail the leak test; have cracks, chips, or defects in the plastic housing; have been exposed to more than one germicide; or have many discolored fibers.18

**DISINFECTION**

The next step is to disinfect the dialyzer. The automated system fills dialyzers with a germicide or disinfectant (agent that kills pathogenic microorganisms). Dialyzers must be exposed to only one germicide during reprocessing. Use of more than one germicide may damage a dialyzer.20 The four main types of germicides used in the U.S. are peracetic acid, formaldehyde, glutaraldehyde, and heat disinfection with citric acid. Peracetic acid is the most-commonly-used germicide.3 Each germicide has pros and cons (see Table 1).17 To ensure proper disinfection, the germicide must stay in the dialyzer for a certain amount of time. The contact time (amount of time the germicide remains in the dialyzer) differs for each germicide (see Table 1).17

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**Figure 6:**
Parts of hollow fiber dialyzer
- Plastic casing, or housing
- Hollow fibers
- Header
- Translucent polyurethane or polycarbonate (plastic) potting material. If endotoxin leaches into the potting material, it is difficult to remove it.

**Dialyzer reprocessing**
- Blood may clot inside the hollow fibers, making the dialyzer difficult to rinse and clean completely.
- Blood clotting may occur at the ends of the hollow fibers between the potting material and header.

**Germicide**

**Pro Con Contact**

<table>
<thead>
<tr>
<th>Germicide</th>
<th>Time</th>
<th>Pro</th>
<th>Con</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peracetic acid</td>
<td>When diluted, breaks down to biodegradable acetic acid, oxygen, and water</td>
<td>Cost 11 hours</td>
<td>Technician must use a respirator</td>
<td>Quick drench shower needed in</td>
</tr>
</tbody>
</table>
the center  May cause  cancer
- Disposal costs  24 hours
Glutaraldehyde  Cost  Linked with respiratory and skin problems
- Disposal costs  10 hours
Heat disinfection with citric acid
- No staff safety concerns
- No environmental concerns
- Not all dialyzers can be heat disinfected
20 hours

Table 1: Germicide Pros, Cons, and Contact Time
Dialyzer Reprocessing

HANDLING HAZARDOUS MATERIALS
Germicides for reuse kill microorganisms and they can also harm you and your patients. Occupational Safety and Health Administration (OSHA) Standards require centers to tell staff about all hazardous chemicals in the workplace. The center must provide a list of all chemicals and keep it current. One copy of the material safety data sheet (MSDS) for each substance must be kept in a file that you can read. Another must be posted near where a chemical is used, so you can find the information quickly in an emergency. All containers should be labeled clearly to avoid mix-ups.

Your center must train you in its procedures for handling hazardous materials. The center must also encourage you to read its written policies. You should know where policies, emergency procedures, and training materials are kept in your center. A center with more than 10 staff must also keep records of occupational illnesses and injuries. It is the employer's duty to ensure compliance with safety practices and policies. Procedures alone cannot prevent worker injury from toxic substances. Each staff member must learn the steps and follow them. Taking shortcuts with hazardous materials is not a time-saver if it causes an accident. You must protect yourself and others around you by learning how to handle hazardous materials safely.

STORAGE OF REPROCESSED DIALYZERS
Before being stored, the outside of the dialyzer must be wiped or soaked clean with a disinfectant. Don't store reprocessed dialyzers with new ones. Storage conditions should keep deterioration, contamination, and breakage to a minimum.

Reprocessed dialyzers can be stored on wall racks or in carts until they are needed. The storage system should be designed to be easy to clean. Always follow your center's policies and procedures.

Preparing for Next Use
DIALYZER INSPECTION
The first step in getting a dialyzer ready for its next use is looking at it (see Figure 7) to be sure that:

- It is labeled properly.
- No structural damage or tampering has occurred.

Figure 7:
Reprocessed dialyzer
Verify correct patient name.
Hollow fibers should be relatively free of clotted blood.
Dialyzer reprocessing label
Complete and legible label.
There should be no visible damage to the dialyzer.
All caps should be tight with no leakage.
There should be no clots in the header.
Is aesthetic appearance acceptable to patient?
n Ports are capped, and there is no leakage from the ports or other parts of the dialyzer.

n It was stored long enough for the germicide to work, but not so long as to exceed acceptable shelf life.

n The cosmetic appearance is acceptable; it looks clean.

After you look at the dialyzer, use a positive indicator test strip or ampule to confirm that germicide is present and strong enough to work. Looking at the dialyzer cannot tell you how strong or concentrated the disinfectant is. You must test the fluid itself to confirm the presence and strength of germicide.

15 REMOVAL OF GERMICIDE

The next step is to thoroughly rinse the germicide out of the dialyzer before it is used, using the center’s procedure. Then, test the dialyzer to make sure the residual germicide is at or below the manufacturer’s and center’s specifications, using a residual germicide test. It is important to keep fluids flowing in the extracorporeal circuit after you test for removal of the germicide. If not, you will need to retest for germicide before starting the treatment.

If you don’t rinse the dialyzer well enough, the patient could be exposed to the toxic germicide.

PRIOR TO TREATMENT

Just before the start of treatment, two people (staff and/or patient) must check the patient information on the dialyzer to make sure it matches the patient. Record this step on the reprocessing record or dialysis flowsheet, and sign it to show who did the check. Staff members should ensure that the dialyzer has been prepared for use. The dialyzer must be properly labeled, structurally sound (no cracks or leaks, all caps in place, etc.), free of germicide, and clean.

15 Potential Hazards

Dialyzer reprocessing is safe and effective if it is done correctly. If it is done wrong, dialyzer reprocessing poses hazards to patients.

BACTERIA AND ENDOTOXIN

The greatest risk of reuse comes from contamination of a dialyzer with bacteria or endotoxin (toxins on the membranes of certain bacteria). Bacteria and endotoxin may enter the dialyzer from the water used to make dialysate. After a treatment, some bacteria in the dialysate compartment may stay in the dialyzer. If bacteria and endotoxin multiply in the dialyzer and enter the patient’s body, pyrogenic reactions (fever, chills, nausea, vomiting, hypotension, muscle pain) or septicemia (blood infection) could occur. For patients, this can be life-threatening.

Problems with bacterial or endotoxin contamination may occur due to:

n Improperly prepared germicide
n Use of outdated germicide
n Not enough contact time between the dialyzer and germicide
n Improper storage conditions
n Inadequate filling of the dialyzer
Dialyzer housings, support structures, and membranes can adsorb (attract and hold) endotoxin. This makes endotoxin hard to rinse out. So, levels of bacteria and endotoxin in the water used for reprocessing must be kept as low as possible. Bacteria in water used to reprocess dialyzers must not exceed the AAMI standard of 200 colony forming units (CFU).15 The AAMI action level is 50 CFU for bacteria in water used for dialysate.
217 11
The endotoxin level should be <2 endotoxin units/mL (EU/mL) with an action level of 1 EU/mL. If it is found that a patient had a pyrogenic reaction or septicemia due to dialyzer reprocessing, the center must stop reusing dialyzers. Reuse may not restart until the whole reprocessing system has been checked.

CHEMICALS
Reprocessing germicides are toxic if they enter the patient's blood, even in small amounts (see Figure 8). If all of the germicide is not rinsed out before the next treatment, the patient may have burning in the access limb, blurred vision, or numbness in the lips. Death can occur from poisoning. Acute (sudden) toxicity may also occur if dialysis does not start right after an acceptable residual germicide test; waiting may cause a rebound of the germicide in the blood compartment. Small amounts of some germicides that don't cause acute symptoms may still cause long-term problems, such as trouble sleeping and changes in the body's immune system. You must follow center policies and procedures for chemical use exactly to avoid the risks and hazards of chemical use in reprocessing. More importantly, you must test every dialyzer before use to be sure all of the chemicals have been removed.

ALTERED DIALYZER PERFORMANCE
In time, reprocessing and reusing dialyzers reduces and alters their membrane surface area. This can cause poor solute transport and ultrafiltration, so the dialysis prescription is not delivered. Reprocessing dialyzers can change their performance from the manufacturer's specifications in a number of ways. Contact with cleaning agents and germicide can harm the membrane, causing leaks and reducing clearance. During reuse, hollow fibers can clog with blood, or membrane surfaces may be coated with blood products or other material. This can reduce flow and/or the surface area of the dialyzer. A slower flow rate or smaller surface area can reduce clearance as well as the ultrafiltration rate (UFR).

Documentation
Dialyzer reuse is a vital part of hemodialysis in many centers today. While reuse is a medical procedure, the reprocessing is much like a manufacturing process. Centers should follow the good manufacturing practice standards used by dialyzer makers. This means that a lot of documentation is needed (see Table 2). The staff person who documents reprocessing and reuse must be diligent and precise.

Dialyzer Reprocessing

Figure 8: Medical risks of incorrect dialyzer reprocessing
Sleep problems and changes in the immune system caused by exposure to
small amounts of germicide over time
Shortness of breath,
respiratory distress
Burning in the vascular access
Anaphylaxis (severe,
immediate allergic
reaction), which
may include:
   • Hives
   • Rapidly falling
     blood pressure
   • Muscle spasms
     in breathing
     passages,
     GI tract,
or uterus
   • Swelling
     in the
     throat
Quality Assurance and Quality Control
A center must prove it can safely and effectively reprocess dialyzers. Federal regulations require a center that reuses dialyzers to have a program to monitor the system. Quality assurance and quality control are the two parts of the program. The center needs to develop, implement, and evaluate policies and procedures on reuse. All standards, as well as state and federal regulations, must be included in the policies and procedures. Quality assurance provides the proof that policies and procedures have been written and are being implemented. AAMI standards on reprocessing have details on all aspects of a quality assurance program (see Table 3 on page 220).15
Quality control shows that the materials, processes, and final product meet set standards. Examples of quality control for dialyzer reprocessing are TCV measurement, bacterial and endotoxin tests, and tests for the presence or absence of germicide.

Conclusion
Dialyzer reprocessing, done correctly, is safe and effective for patients. If done incorrectly, it can pose a hazard to patients and staff. As a dialysis technician, your role is to follow the center’s policies and procedures on dialyzer reprocessing to ensure patient and staff safety.

Document Description
Dialyzer Reprocessing Manual
A summary of all reuse specifications, policies, procedures, training materials, manuals and methods, and samples of forms and labels
Reprocessing Log Record of every step in the use of a dialyzer from entry in the center to all performance testing, to disposal
Water Quality Record of water treatment system maintenance and operation to meet AAMI standards and the center’s policies and procedures
Complaint Investigation File and Special Incident Report Record of all complaints by patients and staff about dialyzer failures or possible harmful reactions, which includes results of any investigation of the complaints and any actions taken to correct the problem
Environmental Testing Record of testing required by regulatory agencies on any germicides or cleaning agents used in dialyzer reuse
Equipment Maintenance Log of the dates of preventive maintenance, repairs, and results of scheduled testing on all reprocessing equipment
Incoming Materials Log/Material Quality Records Log of incoming materials such as dialyzers, port caps, disinfectants, other reprocessing supplies, and results of any quality control tests
Personnel Health
Monitoring Records
Record of the results of medical exams of workers to monitor exposure to substances that may be toxic, as required by regulatory agencies

Training Records
Record of staff’s completion of a training course in dialyzer reprocessing and proven ability to do reuse correctly

Quality Assurance and Quality Control
Record of the dates and results of all quality assurance and quality control evaluations

Table 2: Dialyzer Reprocessing Documents
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Table 3: Quality Assurance Schedule

Table adapted with permission from the Association for the Advancement of Medical Instrumentation
References


Dialyzer Reprocessing


For more information on reuse and its history, two recent references are available:
Objectives
After completing this module, the learner will be able to:
1. Discuss the purpose of water treatment for dialysis.
2. List the components of a dialysis center’s water treatment system.
3. Discuss the advantages and disadvantages of water softeners, carbon tanks, reverse osmosis, deionization, and ultraviolet irradiation in the treatment of water for dialysis.
4. Describe the method for microbiological testing of the water treatment system.
5. Describe a typical water treatment monitoring schedule.

Water Treatment
Introduction
Dialysate is a fluid used to help remove wastes from patients' blood. Water is used to make dialysate, mix concentrate, and to flush out and reprocess dialyzers. If dialysis water has contaminants (harmful substances), they may enter the blood through the dialyzer and cause disease, injury, or even death to a patient. Healthy people can handle some contaminants in their drinking water; healthy kidneys remove most of them. People with failed kidneys do not have that protection. To be safe, water to be used for dialysis must pass through a water treatment system—a series of devices, each of which takes out certain contaminants. This module covers why and how water is treated before it is used for dialysis. It describes the components of a water treatment system, how the system is monitored, and the common contaminants found in water.

Water Supply
Water is the universal solvent: it will dissolve almost any solute to some extent, in time. As rain water passes through the air toward earth, it picks up impurities like carbon dioxide and sulfur dioxide gases (see Figure 1). These gases dissolve in the water to make weak solutions of carbonic and sulfuric acids—or acid rain. When rain falls onto limestone and other minerals, the acid dissolves the minerals. This process forms calcium carbonate and calcium sulfate. Calcium carbonate is the most common impurity in tap water. Sodium, chloride, fluoride, nitrate salts, and pesticides also dissolve in water. Which contaminants are in the local water supply will depend on nearby minerals and how long the water is in contact with them. The season of the year and type of local industry also affect the local water supply. Fertilizers and pesticides can change levels of some substances in the local water supply in farm regions.

There are two types of water sources: ground water and surface water.
1. Ground water comes from wells and springs. It is often higher in ions (e.g., iron, calcium, magnesium), but lower in microorganisms (e.g., bacteria, viruses, endotoxin).
2. Surface water comes from lakes, ponds, rivers, and reservoirs. Surface water may be high in pesticides, industrial waste, sewage, and microorganisms.1

Drinking water in the United States is regulated by the Environmental Protection Agency (EPA). The EPA passed the Safe Drinking Water Act in 1974. 227 3

Figure 1:
How water collects impurities
Dust
Gases
Impurities
Pump station
Water
Table
Minerals & impurities
Additives
Water
Table
Well
Lake, stream, pond
To be safe for the general public, drinking water is treated to help prevent disease. Chloramine, a mix of chlorine and ammonia, is often used to kill bacteria. Fluoride is used in many places to prevent tooth decay. Alum, an aluminum compound, may be used as a flocculent, which removes solid particles from the water. Some cities also raise water pH (acid/base indicator) to control the levels of metals that can leach (dissolve) out of pipes into the drinking water.1 For people on dialysis, water is more than just a beverage. People with working kidneys may drink 10–14 liters of water per week; most patients are exposed to 270 to 576 liters of water per week as dialysate (see Figure 2).1 Since substances could cross the dialyzer membrane into the patient’s blood, water must be free of contaminants. Tap water has too many contaminants to be used for dialysis as-is. In fact, many of the substances added to make drinking water safe for healthy people are harmful to people on dialysis. To be safe for patients, water must go through a water treatment system. The purpose of water treatment is to prevent harm to the patient and to water treatment equipment. Since dialysis uses so much water, even tiny amounts of contaminants can hurt patients. Patients can suffer acute or chronic problems from water that has not been treated correctly. They may have nausea and vomiting, anemia (a shortage of oxygen-carrying red blood cells), bone disease, hemolysis (breakdown of red blood cells), or high or low blood pressure; they may even die.1,3 Over the years, there have been many sad cases of patient harm and death due to the use of contaminated water for dialysis treatments.3 Water for dialysis should be treated to meet standards set by the Association for the Advancement of Medical Instrumentation (AAMI). AAMI has standards for bacteria, endotoxin (toxins on the membranes of certain bacteria), metals, salts, trace elements, and other substances.4 The Centers for Medicare and Medicaid Services (CMS) adopted the AAMI water standards as part of the Conditions for Coverage for dialysis centers.
Figure 2:
Comparison of drinking water/dialysis water volumes
The average dialysis patient is exposed to about 360 liters of fluid per week.
The average person drinks between 10 and 14 liters of fluid per week.
AAMI standards cover all water and water-related equipment used for reprocessing dialyzers, mixing concentrates, and making dialysate.

Components of a Water Treatment System

It would be convenient if water could pass through one machine and be pure enough to use for dialysis, but in practice, this can’t be done. Instead, a series of treatment components are needed (see Figure 3). Each one removes certain contaminants to make the water safe for use in dialysis. We talk about the placement of each component of the water treatment system in terms used for rivers: upstream and downstream. Feed water (from outside the dialysis center) begins upstream and moves downstream. A component that is upstream would come before one that is downstream. Water must always be kept moving in a water treatment system, because still water allows bacteria to grow. After the last point of use for the water in most centers, a return loop carries the water back through the system. This prevents stagnant spots and reduces the amount of feed water a center needs. Most water treatment systems will have some or all of the components listed in Figure 3. Each center must tailor its system to remove the contaminants in its feed water. They must also consider seasonal changes in local water supply and treatment. One center might have feed water contaminated with bacteria, while another may have feed water with high levels of chloramines and few bacteria. A skilled water treatment engineer should design each water treatment system for dialysis. This

Figure 3:
Sample schematic of water treatment system

UPSTREAM
Hot Thermometer
Backflow prevention device
Blending valve
Cold Carbon filters
Pressure reducing valve
Check valve
3 micron prefiltration
Deionization Multimedia filter
Water softener
Reverse osmosis Ultrafilter Quality monitor DOWNSTREAM Valves leading to dialysis machines End of return loop Check valve
This simplified water treatment system is an example of one way that several water treatment components can be arranged.
engineer must know the impact each component has on the other parts, on the product water, and on the patient. The number and order of devices can be set up to suit the needs of any center.1

FEED WATER COMPONENTS

Backflow Prevention Device
A reduced-pressure, backflow prevention device is needed for all water treatment systems; it stops water from a center’s water treatment system from flowing back into the feed water. This, in turn, keeps any contaminants taken out by the water treatment system from getting into the feed water.1

Temperature Blending Valve
The temperature blending valve mixes hot and cold water to a standard 77°F. The temperature must stay at this level to prevent harm to patients and damage to the reverse osmosis membranes (more on this later in the module). A decrease in temperature from 77°F will decrease the efficiency of a reverse osmosis membrane. There is a 1.5% decrease for every 1°F drop in temperature. A temperature gauge is placed downstream from the temperature blending valve as a monitor.1

Booster Pump
The water treatment system needs constant water flow and pressure. If flow or pressure drop from a center’s water source, a booster pump may be used to increase them. The booster pump is placed downstream from the backflow prevention device and temperature blending valve. Pressure gauges are placed before and after the booster pump.1

PRETREATMENT COMPONENTS

Chemical Injection Systems
The ideal pH of the feed water should be 5.0–8.5. If the pH is higher than 8.5, a chemical injection system may be used to inject a small amount of hydrochloric or sulfuric acid into the feed water. This will lower the water’s pH level. Such systems may also be used to reduce chloramines in feed water by injecting sodium metabisulfite.1

Chemical injection systems have a reservoir to hold the chemicals, a metering pump, and a mixing chamber in the feed water line. The systems must have a way to control the amount of chemicals added to the water.

Sediment Filters
All feed water has particles. Sediment filters strain out particles, solutes, and other substances of a given size (see Figure 4).

Water Treatment 230

Figure 4: Filters of different ratings trap progressively smaller particles
A 5 micron filter will trap particles equal to or larger than 5 microns. Submicron filters will trap particles down to 0.01 micron. Ultrafilters will trap particles down to 0.01 microns, including most microorganisms.
The multimedia filter is the most common sediment filter (see Figure 5). Multimedia filters have layers of different-sized rocks. Water can pass through the filter, but most particles above a certain size are trapped. Each layer is finer than the one before, to trap smaller and smaller particles. As particles are strained out, the filter may clog. When the system is not in use, water should be sent from the bottom of the filter to the top to clean and remix the media. This is called backwashing and flushes particles out of the filter.

Water Softener

Hard water has many minerals. A water softener (see Figure 6) can soften hard water by taking out some of the calcium and magnesium that form scale (solid particles that settle out of the water). Water softeners work by ion exchange: ions of calcium and magnesium are removed and traded for sodium ions, which form sodium chloride. Ion exchange takes place in a bed of tiny round beads made of polystyrene resin. The resin beads are coated with sodium chloride ions. The resin attracts positively charged ions of calcium and magnesium from the hard water. It gives up sodium ions of equal charge. When the resin is saturated with calcium and magnesium, it is exhausted, and must be regenerated (cleaned and saturated again with sodium). Water softeners are regenerated by flushing the resin bed with water and then with brine (very concentrated saline). The resin beads exchange their calcium, magnesium, and other positively charged ions, and are again coated with sodium ions. The unwanted positive ions are then rinsed to the drain.

Figure 5:
Cartridge filter housing
Filter media
Feed water
Trapped sediment
particles A sediment filter, such as this one, acts as a sieve to trap particles of a certain micron size. Feed water enters the filter, passes through the filter media (where particles are trapped), and exits the filter.

Figure 6:
Water softener
Drawing adapted from Keshaviah, Investigation of the Risks and Hazards Associated with Hemodialysis Devices

Inside a water softener, hard water mineral ions (calcium and magnesium, which form scale) are traded for sodium ions in a process called ion exchange. A bed of resin media beads attracts and holds calcium and magnesium ions, and releases
sodium ions into the water. The water that results is called [soft.]
Underbed
media
Resin bed
Salt pellets
Brine tank
Control assembly Drain line
Inlet Outlet
Most centers have permanent water softeners, with their own brine tanks. The brine tank holds salt pellets and water. The salt and water create the solution to regenerate the softener, so centers can regenerate their water softeners onsite. It is vital to prevent your water softener from regenerating during dialysis. If this were to happen, high levels of sodium could cause the reverse osmosis system to alarm because it could not handle that much sodium. Other centers have portable water softeners. These are regenerated off site by a vendor. Regeneration should be done every day or every other day.

Carbon Tanks
Carbon tanks contain granular activated charcoal (GAC). The charcoal adsorbs (attracts and holds) low molecular weight particles from water, much as a magnet attracts iron filings. The water treatment system should have two carbon tanks in series, with one tank feeding the other tank (see Figure 7). The first tank is called the worker; the second is called the polisher.

Carbon tanks are mainly used to remove chlorine, chloramines, pesticides, industrial solvents, and some trace organic substances. The best carbon tanks use GAC, not powdered charcoal. GAC is very porous; its large surface area helps remove contaminants from water. Granular activated charcoal may be made of coconut shells, peach pits, wood, and/or bone. It comes in particle sizes, called mesh sizes; a 12 x 40 or smaller mesh size should be used. The GAC should have an iodine rating (a measure of carbon adsorption) of greater than 900 to provide a large enough surface area. Carbon that is regenerated by the manufacturer should not be used for dialysis.

Feed water must stay in contact with the charcoal long enough to allow chlorine and chloramines to be removed. This time period is called empty bed contact time (EBCT). EBCT is calculated based on the volume of GAC and the water flow rate. At least 10 minutes of EBCT (or 5 minutes in each tank) is needed to reduce chlorine levels to standard levels.

Carbon tanks cannot be disinfected or regenerated. Backwashing moves the carbon around, but does not take out the adsorbed material. The carbon media must be replaced on a regular schedule. When the first tank is exhausted, the second tank is rotated into the first spot, and a new tank is placed in the second spot.

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Figure 7:
Carbon tanks
Drawing adapted from Keshaviah, Investigation of the Risks
and Hazards Associated with Hemodialysis Devices
Like a magnet, the charcoal adsorbs chloramines
Underbed media
Media bed
Sample port
Inlet Outlet
Carbon tanks use charcoal to remove chlorine, chloramines, and organics from water used for dialysis. The water treatment system must be designed so that water stays in contact with each carbon tank media for 5 minutes. It is recommended that two carbon tanks be used in sequence, with sample ports before the first tank, between the first and second tanks, and after the second tank.
Reverse osmosis (RO) is a way to remove solutes from a solution using a membrane and pressure. The RO system contains a water pressure pump and a semipermeable membrane. The RO system is the most fragile and costly part of the water treatment system. One of the tasks of the pretreatment components of the water treatment system is to protect the RO system from damage.

**RO Process**

RO uses hydraulic pressure to remove solutes from water (see Figure 8). Osmosis is movement of water across a semipermeable membrane from an area of lesser solute concentration to an area of greater solute concentration (see Module 3: Principles of Dialysis, to learn more about osmosis). The process goes on until the solute levels on both sides of the membrane are equal. RO forces feed water through a membrane leaving salts and other contaminants behind. The contaminants and some of the water (waste stream or reject stream) are sent to the drain or back to the feed side of the RO system. The purified water is used for dialysis.

**RO System**

**Cartridge prefilter**

A filter is placed just before the RO to remove carbon fines, resin beads, and other debris. Gauges should be placed before and after the prefilter. Prefilters are low-cost and should be changed on a regular basis.

**RO pump and motor assembly**

The RO pump is the loudest part of the water treatment system. The pump is used to raise pressure across the RO membrane.

![Figure 8: Reverse osmosis](image.png)

**Pressure**

**Osmosis**

**Reverse Osmosis**

**Feed**

water

Pure product

water

Pure water

Concentrated salt solution

When a concentrated salt solution and pure water are separated by a semipermeable membrane, pure water will move across the membrane to dilute the salt water, in a process called osmosis. Osmosis will go on until the osmotic pressure is equalized by hydrostatic (hydraulic) pressure exerted by the rising level of concentrated solution. If enough pressure is exerted on the concentrated solution to overcome osmosis, reverse osmosis occurs. Pure water is forced
out of the concentrated solution.
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RO membranes
The membrane is the key part of the RO system. It filters out or rejects metals, salts, and chemicals, as well as bacteria, endotoxins, and viruses. RO can reject 95% to 99% of charged ionic particles (e.g., aluminum). Organic materials (e.g., bacteria) are rejected if their molecular weight is greater than 200. The most common type of RO membranes are thin film composite (TFC) membranes, made of polyamide. TFC membranes have a thin, dense membrane over a thick, porous substructure for strength (see Figure 9); they are spiralwound around a permeate collecting tube (see Figure 10).1 TFC RO membranes have a number of limitations. They must be cleaned and disinfected on a regular schedule. TFC membranes break down when exposed to chlorine and chloramines; carbon tanks must come before the membrane to remove these. Scale can build up and clog the membrane; cleaning is needed every 4 months to strip off scale build-up. Peracetic acid of less than 1% is used to disinfect the membrane once a month. Incoming water temperature, adequate pretreatment, pH, and cleanliness of the RO membrane surface can also affect the membrane. If the RO membrane is not working, water quality or quantity will be reduced.1

DEIONIZATION
Deionization (DI) removes all anions (negatively-charged ions) and cations (positively-charged ions) from water. DI does not remove noncharged particles, like bacteria or endotoxin. Inside the DI tanks (see Figure 11), beds of electrically-charged resin beads attract and hold cations and anions, and exchange them for other ions. Cations in the water are exchanged for hydrogen (H+) ions, and anions are exchanged for hydroxide (OH-) ions. The H+ and OH- ions combine to form very pure product water (H2O).1 There are two types of DI tanks: dual bed and mixed bed. The dual bed tank holds either all cation or all anion resin beads. Mixed-bed tanks contain both cation and anion resin beads. Mixed-bed tanks produce higher quality water than dual bed tanks.1

Figure 9:
RO membrane configuration
Drawing adapted with permission from FilmTec Corporation

Figure 10:
Spiral-wound RO module
Membrane and brine spacer
Product
Brine seal water tube
Brine seal carrier/anti-telescoping device
Waste/
Waste/ 
reject
Feed water
Feed water
Product water
Traditional design, tape-wrapped or fiberglass-wrapped RO element:
Spiral
filter
device
H20
under
pressure
H2O
Repels ions
Mg++
Cl[]
F1[]
Drawing adapted with permission from ANNA
Decreases inorganic
material and temporarily
Reduced amount of ions and blocks bacteria
bacteria in product water
While DI is quite good at taking out unwanted ions, there are some risks to using it:
1. First, if all the hydrogen and hydroxyl ions in a DI tank are exhausted (used up), the resin beads will release the ions that they had removed. So, the treated water may be very acidic (low pH) or alkaline (high pH), or may have high levels of harmful chemicals. DI has caused most of the water treatment related deaths in patients. DI tanks should be sized for greater than the amount of water to be treated. They must be monitored all the time so they can be exchanged before exhaustion occurs.
2. Second, DI does not remove bacteria, and the resin bed can support the growth of bacteria. An ultrafilter, or other way to remove bacteria and endotoxin, is needed after (downstream) the DI tank.
3. Third, portable DI tanks are used in a center but regenerated off-site. It is vital to be sure that resins used for dialysis are not mixed with industrial resins when the tanks are regenerated. Only medical or food-grade resins should be used for dialysis DI tanks. Industrial-grade resins may contain harmful heavy metals and industrial solvents.
4. Finally, a carbon filter should be placed upstream of the DI tanks to remove chlorine. Use of DI systems to treat water containing chlorine/chloramines generates nitrosamines, which can cause cancer in patients treated with the water.

DI is usually an emergency backup to the RO system, and is rarely used as the primary water treatment. Because of the risks, DI tanks used in dialysis must use a temperature-compensated resistivity meter with an alarm that can be heard and seen in the patient care area. The alarm goes off when the water resistivity drops below 1 megohm/cm.

ULTRAVIOLET (UV)
IRRADIATOR
The UV irradiator uses UV light, a form of invisible radiation, to destroy microorganisms. It works by changing the DNA (genetic material) of the bacteria so they die or can’t multiply. UV lights used to prevent bacterial growth have a light wavelength of 254 nanometers. If the UV light is failing, bacteria multiply.

Figure 11: Deionization tanks
Drawing adapted from Keshaviah, Investigation of the Risks and Hazards Associated with Hemodialysis Devices

A deionization (DI) tank, like a water softener, uses resin media beads for ion exchange.
The cation bed removes positively-charged ions and releases hydrogen (H+) ions into the water. The anion bed removes negatively-charged ions and releases hydroxyl (OH\(^-\)) ions. (H\(^+\) and OH\(^-\) ions combine to form H\(_2\)O, pure water.) The mixed bed is used to remove any remaining ions so that water used for dialysis is free of ions that could affect the conductivity of dialysate.

(1) Light\(^-\) resistivity indicator is lit at greater than 50,000 ohm/cm. (2) Light\(^-\) type resistivity indicator is lit at greater than 1 megohm/cm. (3) Temperature compensated resistivity monitor produces audible and visible alarm at less than 1 megohm/cm, and is a requirement per AAMI standards.
can become resistant to UV radiation, and may be able to multiply to harmful levels unless other means are used to control them. UV light equipment uses a mercury vapor lamp that emits light at a certain wavelength, housed inside a quartz sleeve. Feed water flows over the quartz material and is exposed to the UV light. For the UV technique to work, the mercury vapor lamps must be replaced according to the manufacturer's instructions. The quartz sleeve must also be cleaned to stay clear so the water is exposed to the light. The flow of water must also be within the manufacturer's standards. Older systems require monitoring the number of hours used and replacement parameters. In newer systems, the irradiator will have a calibrated UV intensity meter that delivers a minimum dose of radiant energy at 16 milliwatt-sec/cm², and sets off a visual alarm when a new bulb is needed. The UV irradiator may also be placed with the pretreatment components, after the carbon tanks. This will lower the bacteria levels going into the RO system.

SUBMICRON AND ULTRAFILTERS
Submicron filters are membrane filters that reduce the level of bacteria in product water. Ultrafilters (see Figure 12) are membrane filters that remove bacteria and endotoxin. The filters can become contaminated with bacteria, which can enter the product water. Filters should be cleaned and disinfected or replaced when the pressure difference between the inlet and outlet filter gauges is 10 pounds per square inch.

Distribution System
There are two types of RO distribution systems: direct feed and indirect feed. n The direct feed system delivers product water directly from the RO system to the product water loop for distribution. Unused product water is sent back to the RO system. n The indirect feed system uses a storage tank to hold product water and send it to the product water loop for use. Unused product water is returned to the storage tank.

WATER STORAGE
The water storage tank should have a tight-fitting lid and a cone- or bowl-shaped bottom to ensure complete emptying of the tank and easy disinfecting and rinsing. Product water does not contain chlorine or chloramines to prevent the growth of bacteria. The tank needs a recirculation pump, and should be cleaned and disinfected on a regular basis.
Ultrafilter
Membrane housing
Solutes are trapped by tiny pores in the filter membrane.

An ultrafilter is a cartridge housing a semipermeable membrane filter. The membrane removes submicron (very small) solutes, as well as endotoxins and other organic material.
WATER DISTRIBUTION
PIPING SYSTEMS
A continuous loop is the recommended design for a water distribution piping system. Product water goes to a storage tank or the RO system to save water. The loop should not have dead ends or multiple branches, as these raise the risk of contamination. To reduce bacterial growth, the water flow velocity through the distribution system should be kept at a minimum of 3 feet per second for an indirect feed and 1.5 feet per second for a direct feed system. The most common material used in piping systems is polyvinyl chloride (PVC).1

Disinfection of Water Treatment Systems
Water treatment systems need to stay as free from contaminants as possible. Biofilm made by microorganisms is a major problem for water treatment systems. Once biofilm starts to form, it is almost impossible to remove. The entire water treatment system may need to be replaced if biofilm forms.1 The most common type of water treatment system disinfection is chemical (e.g., bleach). Ozone and heat can also be used.

Monitoring a Water Treatment System
Water treatment systems used in dialysis are a key part of the overall care received by people on dialysis. They can also be one of the greatest hazards to patients if they are not working properly. Water treatment monitoring is an area of concern and a chance for quality improvement across the nation. The only way to know if your center’s system is working properly is to set up and follow an effective monitoring program. Each component must be checked to be sure it is working properly (see Figure 13 on page 238). If conditions change (such as feed water being treated differently by your town), you may need to test more often or change the water treatment system.

All dialysis centers should keep in close contact with the local water treatment plant. Each center should send a letter to the plant at least once a year. The letter will remind the plant that a dialysis center is present, and that the center will need updates on the status of water treatment. If water treatment in the area changes, too much of a substance is present, water mains are flushed, or other events related to the water supply occur, the plant needs to alert the center.

Monitoring of the System Components
TEMPERATURE
BLENDING VALVE
To protect the RO membrane and maintain an adequate flow of product water, feed water should be kept at 77°F–82°F (25°C–28°C). If the temperature varies, the amount of 237 13
Product water will vary as well because if the feed water is too hot, it can destroy an RO membrane. The temperature blending valve should be checked each day by measuring the temperature after the valve. The temperature should be within the set range, and should not change much from day to day.2

Water Treatment

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Mon Tues Wed Thu Fri Sat
Date
Gauge Readings
Press. Gauge #1 (psi) (Pre-Mixbed)
  - Mixed Bed
Press. Gauge #2 (psi) (Pre-Softener)
  - Softener
Press. Gauge #3 (psi) (Pre-Carb1)
  - Carbon Tank #1
Press. Gauge #4 (psi) (Pre-Carb2)
  - Carbon Tank #2
Softener Timer Check
Temperature (°F)
Press. Gauge #5 (psi) (Pre-Filter)
Press. Gauge #6 (psi) (Post-Filter)
  - RO Prefilter
Feed Water TDS
Product Water TDS
Percent Rejection
Feed Flow
Permeate Flow
Feed Pressure
Permeate Pressure
Water Tests
Post-Softener Hardness #1
Post-Softener Hardness #2
Logged By (initials):
Chloramines Tests (<0.1 mg/L)
Before 1st patient shift
Before 2nd patient shift
Before 3rd patient shift
Audit (initials):
  .P
  .P
  .P
  .P

Figure 13:
Example of a water treatment system log
Table adapted with permission from AAMI WATER TREATMENT SYSTEM LOG
BACKFLOW
PREVENTION DEVICE
To keep water from flowing backward into the incoming water supply, most cities require that a backflow prevention device must be installed at the start of the water treatment system. The main problem with these devices is that they may reduce water flow and pressure. They must be tested once a year for proper functioning by someone who is licensed to test them.
When the device is installed, if both prepressure and postpressure can be checked, there should not be a drop of greater than 10 pounds per square inch (psi) from the normal operating pressure. If you can only measure postpressure, make sure there is enough pressure and flow. Watch for pressure change over time to see if the device is plugging up. The correct pressure level will vary with each system; you will have to establish a baseline and then monitor for changes. On average, a large RO will need about 30 psi at 10 gallons per minute.

DEPTH FILTRATION
Filters are prone to clogging as they trap particles, which reduces the flow of water. All filters should be checked each day by measuring pressure before and after the filter at normal operating flow rates. If the difference in these two pressures, or delta pressure, is greater than 10 psi more than it was when the filter was new, the filter will need to be replaced or backflushed. If a filter comes with a backflush timer, check the timer setting for correct time; be sure it will only backflush when the center is closed.

WATER SOFTENERS
Water softeners should be monitored by measuring water hardness post-softener at the start and end of each day. Hardness should not exceed 1 grain per gallon (gpg), which equals 17.24 parts per million (ppm). There should be enough salt in the brine tank for regeneration. If the salt level is too high, a salt bridge may occur, where salt hardens at the top and looks full even though there is no salt underneath. The regeneration timer should be checked for correct time, and be set to regenerate when the center is closed.

CARBON TANKS
One of the most vital patient safety tasks each day is checking the carbon tanks for chlorine and chloramines. Each tank must have enough carbon to adsorb the chlorine and chloramines in the amount of time the water is flowing through it. Water must touch the carbon for at least 5 minutes of empty bed contact time (EBCT) in each tank, for a total of 10 minutes for the worker and polisher tanks. EBCT is calculated using the formula: \[ EBCT = \frac{V}{Q} \]
where \( V \) = the volume of carbon (in cubic feet) and \( Q \) = the water flow rate, in gallons per minute (gpm). To calculate the volume of carbon needed, use
the formula: \[ V = \frac{Q \times EBCT}{7.48} \] (this is the number of gallons in one cubic foot of water).\textsuperscript{1,2}

For example, if you have a flow rate of 10 gpm, and you want an EBCT of 5 minutes, your calculation would be:

\[ V = \frac{(10 \times 5)}{7.48} \]

\[ V = 6.69 \]

Therefore, you need a 6.69 cubic foot carbon tank for each working and polishing tank. The water system must be working for at least 15\textsuperscript{20} minutes before you take your first test. If you take your sample when you start up the system.
system, you will be testing water that has been in the tank overnight. This will not give you a representative sample of the carbon tank’s capability at normal flow rates.2

RO DEVICE (OPERATING PARAMETERS)

Each RO device will have its own parameters to tell you if it is working correctly. Water pressure and flow rates are measured in several places. Incoming water pressure needs to be enough to maintain flow through the RO device (this is usually 10 gpm at 30—40 psi, but will vary with each system). Pump pressure is monitored, as this is what pushes water through the membrane. The pressure of the product water is also monitored, and it will vary greatly depending on whether it is a direct or indirect (holding tank) feed system.2

Water flow is also measured in several places using flow meters. Product flow tells you how much purified water is getting through the membrane. Waste flow tells you how much reject water is being flushed down the drain. Direct systems often measure the amount of product water that is recirculated through the system to blend with the incoming water. RO operating parameters should be checked each day for flow and pressure at various sites in the system. Pressure and flow in an RO system are interrelated. For example, if you reduce the RO pump pressure, product water flow will drop and so will waste water flow. If the product water flow drops without a change in pump pressure, the RO membrane may be clogging up. A change in the delta pressure between the pump and reject pressures can mean fouled or torn membranes. So, you will need to know the appropriate baseline values for all pressures and flows, and check out any deviations. Analyze the trends to see even small changes over time.2

Water Treatment

Table 1: Water Treatment Monitoring Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>What to Monitor</th>
<th>What to Look For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backflow Prevention</td>
<td>Device</td>
<td>Pressure drop across the device</td>
</tr>
<tr>
<td></td>
<td>A pressure drop change</td>
<td>of 10 psi from baseline</td>
</tr>
<tr>
<td>Blending Valve</td>
<td>Water temperature</td>
<td>Appropriate water temperature, minimal temperature fluctuation</td>
</tr>
<tr>
<td>Booster Pump</td>
<td>Water pressure</td>
<td>Pump turning on and off at the appropriate pressures</td>
</tr>
<tr>
<td>Acid Feed Pump</td>
<td>pH post-feed pump</td>
<td>pH should be between 7.0 and 8.0</td>
</tr>
<tr>
<td>Depth Filtration</td>
<td>Pressure drop across</td>
<td></td>
</tr>
</tbody>
</table>
Pressure drop of 10 psi or more from normal operating pressures when fresh

Water Softener Post-softener hardness, amount of salt in the brine tank

Hardness not exceeding 1 gpg (17.24 ppm), adequate amount of salt with no salt bridge

Carbon Tank Chlorine and chloramine levels after the worker tank before each patient shift

Chlorine levels within AAMI standards (0.5 ppm chlorine, 0.1 ppm chloramine)

RO Machine Operating Parameters

Water pressure and flow at various locations throughout the system

Changes from normal operating flows and pressures

DI Operating Parameters

Pressure before and after each tank

Pressure drop of 10 psi or more from normal operating pressures when clean

RO Water Quality Product water conductivity, percent rejection, periodic water analysis

Percent rejection greater than 80%, water analysis results within AAMI standards

DI Water Quality Product water resistivity, periodic water analysis

Resistivity greater than 1 megohm/cm, water analysis within AAMI standards

Bacteria and Endotoxin in RO, Holding Tank, and Product Distribution Loop

Water cultures and limulus amoebocyte lysate (LAL)

Culture results less than the action level of 50 CFU/ml, LAL less than the action level of 1 EU/ml

Product Water Flow Velocity

Flow at the end of the loop

Flow rate adequate to maintain a velocity of
greater than 3 ft/sec

Table reprinted from Monitoring Your Dialysis Water Treatment System, with permission from the Northwest Renal Network, Seattle, WA
DI SYSTEMS
(OPERATING PARAMETERS)
DI tanks work by flowing water past small
beads of resin treated with hydrogen and
hydroxyl. DI itself has no moving parts, so the
monitoring is simple and straightforward.
DI tanks should be monitored each day by
measuring pressure before and after the tanks
(see Table 1). When newly installed, there
should not be a pressure drop greater than
10 psi from the normal operating pressure.2

WATER QUALITY
A chemical analysis of your feed water should
be done periodically (see Appendix: Water
Quality Testing Chart). This will tell you about
the contaminants in the incoming water, and
ensure that the water treatment system will be
able to reduce those contaminants to AAMI
levels. AAMI requires testing each year for the
contaminants in Table 2.1

Each day, water quality is also tested indirectly.
This is done by checking conductivity for ROs
and resistivity for DIs. Conductivity tells you
the level of total dissolved solids (TDS) in the
water in parts per million (ppm). By using
the \[\text{percent rejection} = \left(1 - \frac{\text{output conductivity}}{\text{input conductivity}}\right) \times 100\]
formula, you can learn how much of a given solute is
removed by the RO membrane. For example,
input conductivity is 100 ppm, and output
conductivity is 8 ppm. Enter into the formula:
\[\left(1 - \frac{8}{100}\right) \times 100\]
\[= (1-0.08) \times 100\]
\[= 0.92 \times 100\]
Therefore, you have a 92% rejection of total
dissolved solids.

The conductivity monitor should compensate
for temperature to give a consistent reading.
The alarm should be set at a level of percent
rejection that assures AAMI quality water. This
level will depend on your raw water analysis.
Because DI water is more pure than RO water, its
conductivity is too low to check accurately. So, we
monitor the final product water for resistance to the
flow of electricity. This is the inverse, or opposite, of
conductivity. The acceptable limit of resistivity is

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Suggested Maximum Level (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.01</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
</tr>
<tr>
<td>Arsenic, lead, silver</td>
<td>Each 0.005</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.0004</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.001</td>
</tr>
<tr>
<td>Calcium</td>
<td>2.0 (0.1 mEq/L)</td>
</tr>
<tr>
<td>Chloramines</td>
<td>0.1</td>
</tr>
<tr>
<td>Chlorine (free)</td>
<td>0.5</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.014</td>
</tr>
<tr>
<td>Copper, barium, zinc</td>
<td>Each 0.1</td>
</tr>
<tr>
<td>Contaminant</td>
<td>Concentration (mg/L)</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.2</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4.0 (0.3 mEq/L)</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.0002</td>
</tr>
<tr>
<td>Nitrates</td>
<td>2.0</td>
</tr>
<tr>
<td>Potassium</td>
<td>8.0 (0.2 mEq/L)</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.09</td>
</tr>
<tr>
<td>Sodium*</td>
<td>70.0 (3.0 mEq/L)</td>
</tr>
<tr>
<td>Sulfate</td>
<td>100.0</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Table 2: AAMI Standards for Chemical Contaminants in Hemodialysis Water

*230 mg/L (10 mEq/L) where sodium concentration of the concentrate has been reduced to compensate for excess sodium in the water, as long as conductivity of the water is being continuously monitored.
greater than 1 megohm/cm resistance. You will need to understand how the monitor on your center’s DI system works, as they can vary. Most often, the indicators are simply LEDs that tell water quality. Water quality monitoring should be done continuously. Audible and visual alarms must be able to be heard and seen in the patient care area. The percent rejection of an RO system should be maintained at a level that will assure AAMI quality water (>90%). Resistivity of DI water should be greater than 1 megohm/cm.4,5

MICROBIOLOGICAL TESTING

Contamination of water by microorganisms is a serious health concern for patients on dialysis. High levels of bacteria and/or endotoxin can harm patients by causing pyrogenic (fever) reactions. AAMI recommends testing the components of your center’s water treatment system for bacteria and endotoxin at least once a month; more often if problems occur. Water samples should be taken in the worst case scenario. This means cultures should be done just before disinfection of the system.4 You must collect water samples the right way for testing to be accurate. Even small amounts of disinfectant can keep bacteria from growing during a culture. To avoid contaminating a water sample, never clean the sample ports with a disinfectant. If a center insists on disinfecting the ports, it should use alcohol only and allow it to evaporate fully before drawing the culture sample.4 Run water for one minute before you collect the sample in a sterile container.

Test:
- Water used to make reprocessing chemicals
- Water used to rinse and clean dialyzers
- Water from a storage tank, if one is used
- Water leaving the RO unit (and/or deionizer, if used)
- Water at the start, middle, and end of the distribution loop
- Water used to make dialysate (tested at the point it enters the dialysis machine)

Bacteria

Some bacteria help humans, while others (pathogens) cause disease. Bacteria that are harmless on the skin’s surface may become pathogens if they enter the blood. Gram-negative bacteria turn pink and Gram-positive bacteria turn purple, when using Gram’s stain. These bacteria form biofilm and can cling to surfaces like dialysate jugs, pipes, tanks, or feed hoses. Biofilm protects the bacteria from disinfectants, making them hard to remove. With the right pH, food, and a warm temperature, bacteria can multiply very quickly.
If there is a tear in the dialyzer membrane, bacteria can enter the patient’s blood, causing sepsis (blood poisoning). Bacteria can also break down into substances that come into indirect contact with the patient’s blood through the membrane even if it is not torn. When these substances reach the patient, they may cause a pyrogenic reaction: chills, fever, hypotension (low blood pressure), nausea, vomiting, and myalgia (muscle pains). Bacteria in dialysis water must not exceed the AAMI standard of 200 colony forming units.
(CFU) (measure of the number of living bacteria). The AAMI action level for bacteria in water for dialysate is 50 CFU/mL. For ultrapure (sterile, non-pyrogenic) dialysate, the level should be less than 0.1 CFU/mL. An action level is the point when measures must be taken to meet AAMI standards. The center must show that some action (e.g., disinfection, retesting) has been taken to lower the bacteria count if the action level is reached.

Endotoxin

Endotoxin is part of the cell wall of some Gramnegative bacteria. When these bacteria die, endotoxin is released. Endotoxin can cause pyrogenic reactions in dialysis patients. Endotoxin is not alive; it cannot be killed and it is very hard to remove. The endotoxin level should be less than 2 EU/mL (endotoxin units/ml) with an action level of 1 EU/mL. To be considered ultrapure dialysate, the endotoxin level should be less than 0.03 EU/mL.

Caring for Samples

Samples for bacteria testing should be processed within 1-2 hours or refrigerated immediately and processed within 24 hours. Bacteria samples should be tested using the membrane filter technique (Millipore® Samplers) or the spread plate technique. Tryptic soy agar (TSA) is the medium of choice for testing water and dialysate samples. Do not use the calibrated loop, or blood or chocolate agar. Calibrated loops have too small a sample size (either 0.01 or 0.001 cc). Blood and chocolate agars are too nutrient rich for waterborne bacteria; this could cause them to die rather than multiply. Test for endotoxin with a limulus amoebocyte lysate (LAL) test.

Preventing Bacterial Growth

AAMI recommends that water in the product water distribution loop have a flow rate of at least 3 feet per second. This high flow rate provides friction along the wall of the tubing, which keeps bacteria from growing onto the sides of the pipe. To calculate the flow rate, you must install a flow meter at the end of the loop, and know the size of piping used. Water flowing at 10 gpm will move much faster through a 1/2-inch pipe than it will through a 1-inch pipe. A regular program of disinfection (at least monthly) is also needed to prevent bacterial growth.

Chemical Monitoring

A chemical analysis of the water is required at least once a year. The sample should be drawn from a sample port immediately after the RO or DI system. The water treatment system must operate within the AAMI standards at all times. AAMI has set the highest allowable
levels of contaminants that can be in the product water (see Table 2 on page 241). 1

CHLORINE AND

CHLORAMINES

Chlorine and chloramine are used in city water treatment to protect our drinking water from bacterial growth. The chloramine family includes chlorine gas (often used to kill bacteria, fungi, and viruses in drinking water), and chlorine bleach (sodium hypochlorite). Chloramines are made by mixing chlorine and ammonia, and are used by cities when a longer-
acting chlorine is needed. Chloramines can also be formed in nature, when chlorine combines with organic material. Chloramines are strong oxidants: substances that react with oxygen to destroy cell walls, including red blood cells. Patients exposed to high levels of chloramines may develop methemoglobinemia (loss of oxygen-carrying ability of the red blood cells), hemolysis (breakdown of red blood cells), and hemolytic anemia (a shortage of red blood cells due to red blood cell breakdown). The most widely used ways to test water for chlorine/chloramines are colorimeters, color comparators, and test strips. Because these test results are read by comparing colors, the person doing them must pass a color blindness test. The limit for chlorine is 0.5 ppm, and the limit for chloramines is 0.1 ppm. There is no direct test for chloramines, so to measure chloramines you must do two tests: one for total chlorine, and one for free chlorine. The chloramine level is the difference between the two test results. For example, your measured total chlorine is 1.2 ppm and your measured free chlorine is 0.8 ppm:

\[ 1.2 - 0.8 = 0.4 \text{ ppm} \]

Therefore your chloramine level is 0.4 ppm.

It is okay, per AAMI, to test just for total chlorine if the test is sensitive enough to detect low levels and if action is taken for any results greater than 0.1 ppm. If you have a zero reading for total chlorine, there cannot be any chloramines present.2

The importance of careful testing for chlorine/chloramines cannot be stressed enough. Patients exposed to water containing these contaminants will be injured and could die.

SODIUM AND POTASSIUM

Sodium and potassium are electrolytes that must be kept at very precise levels in the blood. Electrolytes send electrical signals along the nerves to the muscles, including the heart. Sodium and potassium are added in precise levels to dialysate to make sure that blood levels of the electrolytes are kept within the normal range. AAMI recommends that water used for dialysis contain no more than 70 mg/L (3.0 mEq/L) of sodium and 8 mg/L (0.2 mEq/L) of potassium.4 Sodium and potassium are removed by RO and/or DI.

CALCIUM AND MAGNESIUM

Hard water contains calcium and magnesium as calcium carbonate and magnesium carbonate. If too much of these minerals reach patients, the result may be hard water syndrome. This can cause nausea, vomiting, muscle weakness, severe headaches, skin flushing, and hyper or hypotension. Calcium crystals can also deposit in the soft tissues of the patient's body over time, causing pain, injury, or death.
Too much calcium or magnesium can also cause scale to form, which can clog equipment and damage the RO membrane. The AAMI standards are no more than 2 mg/L (0.1 mEq/L) of calcium and 4 mg/L (0.3 mEq/L) of magnesium.4

FLUORIDE
Fluorine makes up part of our bones and teeth. A salt of fluorine, called fluoride, is added to drinking water in many areas (up to a level of 1.2 mg/L) as a public health measure to help prevent tooth decay. Levels of fluoride in drinking water may vary from day to day.

Water Treatment

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Water treatment helps protect dialysis patients from accidental exposure to high levels. Many dialysis patients are prone to bone disease. Some patients who have long-term exposure to fluoridated water develop osteosclerosis (hardening of bone and/or bone marrow). Other symptoms of too much fluoride include nausea, vomiting, muscle twitching, hypotension, and seizures. AAMI recommends a fluoride limit in dialysis water of no more than 0.2 mg/L. 3 Fluoride is removed by RO and/or DI.

NITRATES
Nitrates can be found in harmful amounts in water from some wells, due to bacteria or farm fertilizers. Nitrates are dangerous to patients because they can keep red blood cells from using oxygen. This is called methemoglobinemia; a patient with this condition will have cyanosis—bluish skin, lips, gums, and fingernail beds—from the lack of oxygen. They may also have hypotension and nausea. AAMI recommends a nitrate limit in dialysis water of no more than 2 mg/L. 4 Nitrates are removed by RO and/or DI.

SULFATES
Sulfates (salts or esters of sulfuric acid) in levels greater than 200 mg/L can cause nausea, vomiting, and can be linked with metabolic acidosis (high blood acid levels). AAMI recommends a sulfate limit in water used for dialysis of no more than 100 mg/L. 4 Sulfates are removed by RO and/or DI.

ALUMINUM
Aluminum, a common metal in the earth, may occur in the local water supply. Or, it may be added (as alum) to make water clearer by removing algae, sediment, and silt. In healthy people, only small amounts of aluminum are absorbed from the diet; the kidneys remove the excess. When the kidneys fail, aluminum can build up in the brain and bones. Damage to the nervous system and fatal encephalopathy (a defect in brain function) can occur. This is called dialysis dementia; symptoms may include confusion, loss of short-term memory, personality changes, speech problems, muscle spasms, hallucinations, seizures, and intellectual impairment. Long-term exposure to high levels of aluminum has also been linked with aluminum-related bone disease (ARBD). ARBD can cause bone pain, muscle weakness, and fractures. Dialysis water is a key source of toxic aluminum for patients. Ionized (electrically-charged) aluminum can cross the dialyzer membrane and move into the patient’s blood. Dialysis equipment, too, may be a source of aluminum. In 1992, a pump containing aluminum was placed on an acid distribution system. Three patients died and others had
high aluminum levels. Centers should check the design of their water treatment, concentrate, and dialysate delivery systems, and test patients’ blood aluminum levels. Because aluminum builds up in the bodies of dialysis patients, AAMI recommends that aluminum levels in dialysis water be very low, no more than 0.1 mg/L. Aluminum can be removed by RO and/or DI. Since aluminum levels in local water supplies can vary with the season, experts suggest testing water used for dialysis for aluminum more than once a year.
COPPER AND ZINC

Water, especially acidic water, can leach copper out of plumbing pipes. The use of galvanized iron in the water treatment or distribution system can cause high zinc levels in the water. In the patient’s body, too much copper can cause nausea, vomiting, headaches, and chills. More severe problems can include painful pancreatitis (inflammation of the pancreas), metabolic acidosis, liver damage, and fatal hemolysis (breakdown of red blood cells). High zinc levels can cause nausea, vomiting, fever, and anemia.

AAMI recommends an upper limit for copper and zinc in dialysis water of no higher than 0.10 mg/L. Copper and zinc can be removed by RO and/or DI.

ARSENIC, BARIUM, CADMIUM, CHROMIUM, LEAD, MERCURY, AND SELENIUM

Each of these trace metals has been restricted to very low levels by the EPA Safe Drinking Water Act as summarized in Table 3.9. AAMI standards for a number of contaminants are shown in Table 2 on page 241. Arsenic, barium, cadmium, chromium, lead, mercury, and selenium can be removed by RO and/or DI.

Patient Monitoring

As you’ve learned in this module, water quality is monitored to protect patients and to protect equipment so it can protect patients. Failure of one or more parts of the water treatment system can cause serious illness—even death—in patients who are exposed to untreated or improperly treated water. Patient monitoring of water quality should include:

1. Routine blood monitoring—High levels of toxic substances in patients’ blood (e.g., aluminum), or the presence of substances that are not normally found in the blood, need further study. For example, do a number of patients have the same findings? Trouble with anemia management in patients could be related to contaminants in the water. However, most problems with water treatment are not found in routine blood tests.
2. Monitoring patient symptoms—During dialysis, patients may report acute (sudden onset) symptoms. There are many causes for some symptoms, like hypotension, and water quality may be one of them. If two or more patients have similar symptoms at the same time, there may be a problem with a water treatment or delivery system (if a central dialysate delivery system is being used).
<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Maximum Contaminant Level (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0.010</td>
</tr>
<tr>
<td>Barium</td>
<td>2.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.005</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.10</td>
</tr>
<tr>
<td>Lead</td>
<td>0.015</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 3: EPA National Primary Drinking Water Standards
If a water quality problem is suspected, the dialysis machine should be put in bypass, and the water treatment system quickly evaluated. In some cases, treatment will be discontinued. Table 4 lists some patient symptoms and the water contaminants that may cause them.7

**Conclusion**

When maintained and monitored properly, a well-designed water treatment system can reduce the types and amounts of contaminants. Understanding the reasons for water treatment and the type of system in your center is crucial. As a dialysis technician, you play a vital role in making sure that dialysis water is safe for patient use. Every time you check a monitor, record a meter value on a log sheet, or test a component of your center’s water treatment system for bacterial contamination, you are helping to ensure safe, quality patient care.

**Table 4: Symptoms Potentially Related to Water Contamination**

<table>
<thead>
<tr>
<th>Sign or Symptom</th>
<th>Possible Water Contaminant-related Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia</td>
<td>Aluminum, chloramines, copper, zinc</td>
</tr>
<tr>
<td>Bone Disease</td>
<td>Aluminum, fluoride</td>
</tr>
<tr>
<td>Hemolysis</td>
<td>Chloramines, copper, nitrates</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Bacteria, endotoxin, nitrates, calcium, magnesium</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>Low pH, sulfates</td>
</tr>
<tr>
<td>Muscle weakness</td>
<td>Calcium, magnesium</td>
</tr>
<tr>
<td>Nausea and vomiting</td>
<td>Bacteria, calcium, copper, endotoxin, low pH, magnesium, nitrates, sulfates, zinc</td>
</tr>
<tr>
<td>Neurological deterioration</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Fever, chills</td>
<td>Bacteria, endotoxin, copper, zinc</td>
</tr>
<tr>
<td>Severe headaches</td>
<td>Copper</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Calcium, magnesium, copper, sodium</td>
</tr>
<tr>
<td>Liver damage</td>
<td>Copper</td>
</tr>
</tbody>
</table>

247 23
<table>
<thead>
<tr>
<th>Chemical Contaminants &amp; Maximum Allowed (mg/l)</th>
<th>TEST LIMITS</th>
<th>FREQUENCY</th>
<th>SITE METHOD</th>
<th>ACTION IF LIMITS EXCEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.0004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>2 (0.1 mEq/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloramines</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Chlorine</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>70 (3.0 mEq/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>4 (0.3mEq/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>8 (0.2 mEq/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>0.0002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thallium</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>0.0002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(RD62:2001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHLORINE and CHLORAMINES must be tested each shift (FDA Safety Alert, Feb '88)
Monthly after installing H2O treatment system (or after system change) until pattern established.
Quarterly if no H2O treatment system in place
Annually if RO or DI used
(RDS, B5)
CHLORAMINE test sample
should be drawn between
carbon tanks #1 and #2
Obtain samples from
common source where water enters the dialysate supply system
(RDS, 4.2.2)
Chlorine and chloramines must be tested on site to insure accuracy.
Tests kits are commercially available for this purpose
Performed by a laboratory using accepted analytical methods with equipment capable of obtaining accurate results at levels appropriate for dialysis use as opposed to potable water (RD5, 4.2.2)
Employ appropriate water treatment system (deionization, reverse osmosis, water softener, charcoal filter or necessary combinations)
OR
Evaluate current system and supplement as necessary
Bacteria
Water used for dialysate...
(RDS, 3.2.1.1)
Dialysate...
(RDS, 3.2.1.2)
Bicarbonate concentrate...
(RDS, 3.3.1.4)
Water used for dialyzer...
Reprocessing (RD47, 11.2.2)
(RD47, 11.4.1.4)
Maximum Allowed
< 200 CFU/ml
Endotoxin level < 2 EU/ml
< 200 CFU/ml (New RD52)
Endotoxin level < 2 EU/ml
< 200 CFU/ml
<200 CFU/ml &/or 2 EU/ml &/or 1ngLPS/ml
Weekly until result consistently satisfactory . . . then
Not less than monthly . . . and
- after pyrogenic reaction
- after system change
(RDS, B5)
(RD47, 13.2.1)
(RD47, 11.4.1.4)
Obtain water samples at site where H2O enters dialysis machine (RD5, 4.2.1.1)
Obtain dialysate samples at
outflow side of dialyzer
(RD5, 4.2.1.2)

Sites selected randomly, or, as clinical circumstances warrant
H₂O for reuse should be tested @ site where dialyzer rinsed & germicide diluted
(RD47, 7.1.2)

Obtain total viable counts using spread plate or membrane filter techniques. Use TSA agar. Do not use blood agar. Calibrated loop shall not be used. Assay sample within 30 min. of collection, or, refrigerate immediately at 5°C and assay within 24 hrs. Count colonies after 48 hrs of incubation at 35-37°C.
(RD5, 4.2.1.1 & RD5, 4.3.1.4)

Dip sticks are commercially available which allow readings more specific than powers of 10
Action level is 50 CFU/ml
And 1 EU/ml

If action levels are observed in the product water, corrective measures, such as disinfection and retesting, should be promptly taken to reduce the levels into the acceptable range.

Quality Control Device
Deionizer resistivity..
Reverse osmosis..
Audible & Visual Alarms
(temperature compensated)
Resistivity < 1 megohm/cm..
(RD5, 3.2.3.4)

Determines rejection rates &/or resistivity..
Calculated limit based on feedwater analysis & initial rejection characteristics & shall correspond to highest rejection coefficient @ which contaminants reach unsafe limits
(RD5, 3.2.3.5)
Annual test of device accuracy
Daily..
Resistivity light or meter..
Quality control light..
Record reading on light or meter
Record ON or OFF
Initiate appropriate action

* 230mg/L (10mEq/L) where Na concentration of the concentrate has been reduced to compensate for excess Na in water, if conductivity monitored continuously

Reference to corresponding AAMI standards appears in parentheses. RD5 = AAMI Standard for "Hemodialysis Systems" RD47 = AAMI Standard for "Reuse of Hemodialyzers" RD62: 2001 = AANSI/AAMI Standard for "Maximum allowable chemical contaminant levels in water to prepare dialysate"
This chart was originally developed by the Mid-Atlantic Renal Coalition, ESRD Network 5. It has been modified and distributed by the Network of New England, ESRD Network 1, while under CMS Contract #500-03-NW01.
References

Introduction
Across the nation, dialysis technicians are assuming increasing responsibility for the safety and well-being of patients on dialysis. From dialyzer reprocessing to patient care, technician training and experience are a crucial link in providing safe and effective patient care. The purpose of the Core Curriculum for the Dialysis Technician is to provide basic information on the varying duties dialysis technicians may have in a dialysis center. The modules cover both technical and clinical aspects of dialysis treatment. Combining these modules with your center-specific information and a thoughtful, well-planned preceptorship program will help improve dialysis technician training.

The Preceptor Method
WHAT IS A PRECEPTOR?
Each dialysis technician beginning work at a center brings a unique background, education, and set of skills to the workplace. Depending on state law, the trainee may have to meet certain requirements. A new employee may have a high school diploma, a four-year college degree, or anything in between.
To become a productive employee, the new technician will have to learn tasks associated with the job, as well as the routines and personalities that are unique to your center. Helping the new employee to adjust to a new role is the job of a preceptor.
A preceptor is a knowledgeable, experienced staff person who works one-on-one with new employees, overseeing and coordinating their learning process, until they are able to function independently. According to Preceptorships in Nursing Staff Development:

The preceptor is responsible for microplanning: deciding which experiences best fit the novice’s needs, sequencing experiences so that they build on one another, seeking out learning experiences to meet the novice’s needs or goals, and generally planning on a minute-to-minute, hour-to-hour, and day-to-day basis.
In many centers, a trainee will shadow his or her preceptor. The pair will be assigned to all the same shifts for a predetermined period of weeks or months, or until the learning objectives are met. The preceptor will choose patients to care for, to provide the trainee with a balanced learning experience.
There are many roles a preceptor may take. Following are descriptions of the most common ones.
Teacher
The teacher/preceptor is a guide who knows program content, demonstrates proper techniques, and presents new information to the trainee in
an organized, stimulating way that improves understanding. As a teacher, the preceptor helps the student to integrate theory with practice. An assessment of the student’s learning needs helps the teacher/preceptor plan an individualized outline and learning plan. The preceptor observes while the novice attempts new procedures, offering assistance when needed. Careful supervision,
on-the-spot feedback, and objective evaluation help the learner stay on track.

Support Person
The support person/preceptor is a facilitator who helps the student who may be overwhelmed by the sheer volume of new material to master. The preceptor can offer a realistic time frame for the trainee to become more comfortable with new job duties, and provide motivation to continue the learning process. In addition, the preceptor can introduce the new employee to co-workers, and include the novice in workrelated social activities.

Role Model
The role model/preceptor presents an example of appropriate work habits, behavior, and attitudes toward patients and administration. The new employee will be seeking clues about how to best fit into the work place—are other employees conscientious or careless? Do they follow established procedures or take shortcuts? Are they respectful of patients at the work stations and in the break room? A caring preceptor can be a powerful, positive influence on a beginning technician.

Resource Person
The resource person/preceptor is an expert in the day-to-day functioning of the center, the issues facing dialysis patients and healthcare personnel, kidney disease and its effect on patients, and dialysis treatment. As a resource person, the preceptor is available to answer questions and explain policies. The preceptor/resource person does not need to know everything—only where to find the information. Part of the preceptor’s duty as a resource person is to familiarize the student with the reference materials and department manuals that are available.

Mentor
The mentor/preceptor is an established employee who guides the career development of a newer worker, either formally or informally. For example, a staff nurse or experienced dialysis technician might advise a new technician to think ahead to improve knowledge and credibility, and to consider becoming an active member in a professional organization.

WHY USE A PRECEPTOR MODEL?
The preceptor learning model makes sense in today’s dialysis environment because it is a cost effective, practical way to enhance the professionalism of current staff members while boosting the competence of new employees. Preceptorship makes good use of a staff person’s experience to help fill the gap between a novice’s current knowledge and what will be needed to do the job well. The technician-intraining
is not considered to be a full-fledged employee until both the theoretical learning and clinical skills training have been completed. This novice role reduces new-job stress for the trainee, and clears the way for more thorough learning.

An additional advantage for experienced dialysis staff is the opportunity preceptorship offers for professional advancement while continuing to perform patient care duties. With few such opportunities available today, becoming a preceptor can be a welcome way to gain recognition for exceptional performance.

Preceptor Module

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A preceptor program creates a challenging environment for future professional growth. In fact, having a strong preceptorship program in place can help your center attract and retain quality personnel. The obvious value placed on professional competence and continued learning can make your center more attractive to prospective employees. Finally, the atmosphere of professionalism and continued learning that surrounds a thriving preceptorship program is contagious to everyone who works in the center and this can improve the quality of care for patients.

THE PRECEPTOR IN A DIALYSIS SETTING

Feasibility
Is a preceptorship program feasible for your center? In general, a preceptorship program is most cost effective when there will be an ongoing need to train technicians one at a time or in small groups. There are certain considerations as you decide which training model to adopt. The following six are important areas to assess:

Leadership availability
Do you have a motivated leader available to pull the program together, present it to administration, and make it work?

Administrative support
Is your center’s administration open-minded and willing to consider new ways to train employees?

Coordinator time
A coordinator for a preceptorship program is somewhat like a preceptor for preceptors. Is there a willing coordinator who has time to troubleshoot, match up preceptors with trainees, and work out schedules?

Preceptor availability
For a preceptorship program to work, you will need a number of excellent practitioners who are willing to take on the additional responsibility for training and evaluating others. Do you have as many potential preceptors as you’ll need?

Flexibility
Any new training program will require fine-tuning. Can your center adapt to changes and show the necessary sensitivity to new preceptors and trainees?

Economics
Is money available for program development, resource materials, administrative and clerical staff, trainee salaries, and preceptor financial incentives?

Developing Preceptors
If you answer “yes” to the above questions, you’re ready to teach your qualified staff how to be preceptors. While a learn-as-you-go policy may eventually create good preceptors, taking an active approach will yield more consistent and positive results. Workshops or classes in preceptorship are
more formal ways of developing would-be preceptors. Such courses may be available through a hospital in-service department, private companies, colleges and universities, or could even be taught by current employees who have taken the time to research the topic. Self-learning materials are another way to investigate preceptorship. Useful topics might
include background on preceptor and trainee roles, expectations, the adult learner, teaching and learning principles, communication skills, stress and time management, and performance evaluation.

Merging the Clinical and Theoretical

Unfortunately, some dialysis technicians receive only clinical training with no theoretical background. Without knowing the why behind the procedures, it is difficult for these technicians to know whether they are doing things properly. Troubleshooting becomes nearly impossible. Lack of context for a task renders it boring and repetitive which may make dangerous mistakes more likely. Also, technicians who are unable to answer basic questions do not tend to inspire patients' confidence.

A working knowledge of dialysis history, human renal anatomy, physiology, principles of dialysis, devices, vascular access, procedures, reprocessing, and water treatment will improve the technician's ability to care for and communicate with patients.

Planning a Training Program

THE CORE CURRICULUM

How do you get your technician training program off the ground? While it would be convenient if this manual could just tell you to do A, B, C, and D, the reality is that your use of the Core Curriculum must be customized for your specific center. How? The following steps are crucial to the success of a center's preceptor training program.

Assessment

Taking stock of your center's situation is an essential first step to a successful training program. How many new employees will need to be trained? How will you evaluate their skills and education during the hiring process? What resources and personnel are available to you? You must decide what you need before you can plan to meet those needs with a training program.

Prepare one or more questionnaires for current technicians, RNs, and administration to determine what knowledge gaps must be filled and what your priorities will be. Talk informally to patients. The next step is planning your program.

Planning

It is important to carefully set up the structure and personnel for your training program, and determine a realistic budget. If you have chosen a preceptor model, for example, a head nurse or coordinator will be responsible for matching a preceptor to a trainee. The preceptor will follow the novice's entire training, and will evaluate clinical and technical skills.

The preceptor (or supervisor) should arrange to
set aside a file cabinet or drawer or some other space to keep the materials. Each student should have a large folder with his or her name on it in this drawer. Each preceptor can then arrange a pre-training meeting with the trainee. This meeting should cover the program’s purpose, your center’s philosophy, a realistic time framework, goals, and learning objectives.
Preceptor Module
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Learning objectives must be measurable, achievable, written in concrete terms, and understandable by everyone involved (no jargon). Learning objectives may be designed for daily or weekly use. An example of a weekly learning objective might be: By the end of the first week, the trainee should be able to:

- Identify different parts of the machine and describe their functions.
- Define the basic principles of diffusion, osmosis, and filtration.
- Identify the parts of a human kidney on an unlabeled diagram.
- Compare normal kidney functions to those of the dialyzer and delivery system.

The preceptor or supervisor can customize the Core Curriculum for your center by including center-specific materials, procedures, instructions, and other essential information. Each module of the Core Curriculum contains its own concrete learning objectives. (Posttests and posttest answer keys are at the end of this Preceptor Module.) The preceptor determines how appropriate each activity is for the student, and gathers resources ahead of time so that the chosen activities can take place.

Implementation
Now that your plan is in place, it can be put into action. Using the Core Curriculum, the preceptor can tailor the educational experience to the knowledge level of the trainee and to the job skills that will be required. Throughout the use of the Core Curriculum, the preceptor is available to answer questions, clarify concepts, and check the results of the posttests. At the same time, the preceptor designs clinical learning activities to complement the lessons in the Core Curriculum. Constant assessment and feedback allow the novice to gradually function independently at a high level.

During the implementation phase of a technician training program, it is important to make sure that your preceptors or trainee supervisors have enough time for their new roles. If possible, an RN acting as a preceptor should not also be charge nurse. In addition to shadowing the preceptor's shift, the schedule ideally should allow time for the preceptor and novice to have weekly planning meetings and feedback sessions.

Periodically throughout each module and at the end of each module, the preceptor should record all appropriate information about the student's progress. The record should include feedback to and from the student. An even more thorough picture of the student's progress will emerge if the preceptor includes anecdotal observations along with the more formal learning assessments.

Evaluation
A training program can be evaluated on several
levels. You will need ongoing feedback to know not only how your trainee is doing, but also how well the training program is functioning to bring the new employee up to speed. According to M. Knowles in The Adult Learner: A Neglected Species, among the different types of evaluation are:  

- **Reaction evaluation** — a paper-and-pencil test of how well participants liked the program.  
- **Learning evaluation** — posttests to determine how well the facts were learned.
n Behavior evaluation—observation of behavior or self-ratings can disclose whether the training is effective.

n Results evaluation—an institutional determination of the benefits to the organization, such as cost savings, improved quality of care, or better staff retention.

n Re-diagnosis—determining further areas of learning needs, and areas for potential growth.

If a number of trainees are consistently unable to understand a certain portion of the theoretical background, for example, it may be necessary to rework the way that section is taught.

The evaluation component of your training program allows your center to undertake the type of continuous quality improvement that is the basis for the Core Curriculum. Fine-tuning and troubleshooting the program according to the feedback you receive encourages flexibility and continued professional growth.

OTHER TRAINING MODELS

If a full-fledged preceptor program is beyond the needs or resources of your center, other training models are available that may offer some of the same benefits—if they are handled conscientiously. Either of these models could potentially be molded into a classic preceptor program over time when your center’s circumstances are more favorable.

Independent Study/ Clinical Orientation

Trainees may complete the Core Curriculum modules by themselves, and then shadow a clinically competent buddy who is responsible for teaching skills and procedures.

Staff time will be required to decide which modules are to be used and in what order, and to answer questions. Even so, the lack of formal structure inherent in a loosely-woven training program such as this can increase the stress felt by novices, potentially reducing their learning levels. If this type of plan is used, it would be helpful if a supervisor could set up weekly planning meetings with the trainee to evaluate his or her progress and allow questions to be answered. The fewer staff people the trainee must answer to, the better. Too many opinions about how to perform every procedure can be confusing.

The important training component which could be lost under this system is progress evaluation of the novice. An effort must be made by the head nurse or chief technician to follow the trainee’s progress, and provide the feedback he or she needs to develop confidence in a new and demanding role.

Group Study/ Clinical Orientation

Theoretical and background information can be taught to small groups of trainees, using the Core
Curriculum and additional center-specific materials. This model has the advantage of a knowledgeable staff person available to answer questions and present materials. However, the disadvantage of this model is the difficulty involved in tailoring a novice’s training when all students must be given the same information at the same time. The inability to adjust for different levels of prior knowledge and different job descriptions in the center may lead to some trainees being bored, while others are left behind and don’t understand the material.

Preceptor Module

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Student evaluation in the classroom can be done quite easily, but it will be necessary to make arrangements to evaluate each novice's clinical skills. This could, perhaps, be done by the classroom instructor in conjunction with a clinical orientation buddy.

**CORE CURRICULUM MODULES**

Eight core modules form the basis of the training series. Each module is a self-sufficient topic, containing objectives, suggested practice areas with relevant informational background, and evaluation material. In addition, there is a separate reference module, which includes a glossary of terms. The eight Core Curriculum training modules include:

- **Module 1: Today's Dialysis Environment: An Overview**
  Most beginning technicians lack an overall sense of the context of dialysis. Why is dialysis needed? By whom? How does it work? When did it begin? This introductory module covers many of the basic concepts of dialysis. Most important, the student learns that allowing patients with chronic kidney disease to lead lives as normal as possible is the goal of all dialysis treatment. This module introduces the history of dialysis, history of the Medicare End-Stage Renal Disease program, and career options. Much of this information is covered in greater depth in additional modules.

- **Module 2: The Person with Chronic Kidney Disease**
  Although many of the aspects of dialysis treatment involve equipment and technical devices, every student must learn that his or her actions directly affect the recipient of care—the patient. With an understanding of the patient's experience, the student will be better able to communicate with patients, and recognize symptoms and potential problems early. This module of the Core Curriculum helps the student learn what happens to the patient who requires dialysis treatment. The module explains normal kidney function and the causes, signs, and symptoms of chronic kidney disease. Because there are important nutritional, psychological, and financial concerns for people with chronic kidney disease, a dietitian has contributed a section on diet, and a social worker has outlined available services. An overview of hemodialysis, peritoneal dialysis, and renal transplant is presented, including medications, potential complications, and expected goals of treatment.

- **Module 3: Principles of Dialysis**
  How does dialysis remove excess fluid and waste from the patient's body? The Principles
of Dialyismaodule considers fluid and solute movement at the cellular level. A thorough grounding in the physiological principles that make dialysis possible will help the technician understand the reasons behind the orders given for the patient’s dialysis treatment. This module helps the student understand the basic principles behind dialysis and how dialysis replaces some functions of damaged kidneys. To understand some of the concepts of dialysis, it is helpful to understand how the human body works. This module compares...
the functions of dialysis to the functions of the kidneys in the human body. This module also shows how the principles of dialysis relate to methods for achieving appropriate clearance.

Module 4: Hemodialysis Devices

Impressive technical advances over the past half century have combined to make dialysis an increasingly safe, effective, and efficient treatment for patients with renal failure. A dialyzer, dialysate, and a delivery system are the three key components of hemodialysis treatment. Each component of the hemodialysis system raises complex safety and monitoring issues that are covered in this module. These issues include safe handling and mixing of dialysate, and the function of each alarm on the delivery system and extracorporeal circuit. The technician learns that the most important safety monitor is an alert, conscientious staff person.

This module provides information about dialysis devices, including different types of dialyzers, dialysate fluid, and delivery systems. By carefully following center procedures and learning from this module, the new technician will master the use of each device, and be able to assist in the safe delivery of the hemodialysis treatment.

Module 5: Vascular Access

Despite significant advances since the first reusable vascular access in 1959, this patient life-line remains the greatest challenge to the success of dialysis. Complications such as thrombosis, stenosis, and infection can lead to hospitalization, surgery, illness, and even death. Without a good working access, patients do not receive adequate dialysis treatments, which affects their health, their work, and their family lives. The importance of good technician training and care for a vascular access cannot be underestimated.

This module provides information about each type of vascular access, and advantages and disadvantages for each type. Good management and care of the access are emphasized, as are patient teaching and complications. Knowledge and an appreciation for the value of a good vascular access are the best gifts a dialysis technician can bring to patient care.

Module 6: Hemodialysis Procedures and Complications

Every center has developed preferred methods for performing dialysis-related tasks. The specific techniques used at a given center for individual steps in a procedure should be passed on to the
new technician by a preceptor or teacher who can demonstrate step-by-step processes. The Hemodialysis Procedures and Complications module helps the student to understand the procedures he or she will need to learn. It breaks the numerous complex tasks that make up a dialysis treatment into manageable pieces. The module is organized to cover the process of dialysis, from set-up through clean-up. Topics covered in the module include predialysis procedures, initiation of dialysis, monitoring during dialysis, heparinization, discontinuing the dialysis treatment, postdialysis procedures, and determining adequate dialysis.
The module also includes information about potential medical and technical complications during dialysis, general practice, infection control, laboratory tests, and documentation.

Module 7: Dialyzer Reprocessing

Economic savings and improved patient care converge in the reprocessing of dialyzers at least for many patients. On the one hand, the biocompatibility of dialyzers is enhanced by reprocessing, making dialysis more comfortable and less symptomatic. On the other hand, residual bacteria, endotoxin, or germicide can be hazardous for patients.

In this module, the technician learns about the history, basic theory, procedures, and benefits-versus-risks to patients of reprocessed dialyzers. Risk management, and AAMI/CMS safety regulations are also covered. Practical guidelines for handling, labeling, reprocessing, inspecting, and storing dialyzers are provided, as well as quality assurance and quality control policies.

Module 8: Water Treatment

The large volume of water used in dialysis means that dialysis water quality is vitally important to patient safety. The student must understand why water quality must be maintained, and be able to monitor the variety of filters and other devices used to remove microorganisms, sediment, heavy metals, chemicals, and ions before drinking water can be used for dialysis.

This module of the Core Curriculum presents the dialysis technician with information about why and how water is treated before being used for dialysis-related purposes. It covers the types of contaminants commonly found in water; how contaminants can affect patients; water treatment system components; and monitoring of the water treatment system.

INDIVIDUALIZING THE CURRICULUM

The preceptor can individualize technician training according to the center's priorities by varying the order of the Curriculum modules and the overall outline of the trainee's orientation program. Each module is a self-contained center that can be used alone or in sequence with the others.

Certain key concepts and illustrations are repeated in several modules to help the student understand how these concepts apply to different contexts.

RESOURCES

To make the best use of the Core Curriculum and related modules, each dialysis center should be prepared to provide trainees with the following library resources.

Reference Materials
Dialysis center references should include an English language and a medical dictionary, a medical terminology text, drug references, literature from equipment manufacturers, FDA manuals, and American Association of Medical Instrumentation (AAMI) materials.

Textbooks
Recent texts (published within the past five years) should be available covering all aspects of clinical and technical information on kidney disease and dialysis.

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Medical Journals
Periodical literature helps practitioners keep up with new information in the field:
- Advances in Chronic Kidney Disease
- American Journal of Kidney Diseases
- American Society for Artificial Internal Organs (ASAIO) Journal
- Clinical Journal of the American Society of Nephrology
- Dialysis and Transplantation
- Hemodialysis International
- Journal of the American Medical Association
- Journal of the American Society of Nephrology
- Kidney International
- Nephrology News & Issues
- Nephrology Nursing Journal
- New England Journal of Medicine
- Peritoneal Dialysis International
- Seminars in Dialysis
- Professional and patient organization journals and newsletters:
  - American Association of Kidney Patients
  - American Society of Nephrology
  - Board of Nephrology Examiners
  - National Association of Nephrology Technologists
  - National Kidney Foundation
  - National Renal Administrators Association
  - Renal Physicians Association

Additional Materials
Films, videos, slide shows, and other non-printed information help round out the collection.
Obtaining Resource Materials
Given the budget constraints that all dialysis centers must work under, it may take creativity and time to build up a respectable library of educational materials. Merely making it known that you are seeking these resources may bring some of them to you. Here are several suggestions of ways to acquire materials:
- Center subscriptions to journals or periodicals
- Copies of journals or periodicals donated by staff members
- Journals obtained by staff members who join professional organizations
- Textbooks purchased with vendor or donor funds
- Free pamphlets, videos, slides, or tapes from vendors

The library you put together will be a valuable resource for existing staff members. The Internet is also an excellent resource.

PRECEPTING THE ADULT LEARNER
Most dialysis technician trainees will, as a rule, be interested in learning the material you are helping them to master. After all, their jobs will
depend on it and so will the safety of the patients cared for directly or indirectly by the trainee. As an adult, the technician trainee is self-directed and self-motivated, and the information you will be providing is immediately relevant to his or her life.
Preceptor Module
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A problem-centered approach, staying on task, is most useful for the adult learner. Too much background information can be confusing and may even interfere with transmission of the main message. Relevance is a powerful concept in adult education. Consider, for a moment, how information about home remodeling suddenly becomes interesting when you are planning a home improvement project, or how you look for travel information when vacation time is near. Adults actively seek out information that is relevant to their current life situation. To help a trainee learn, be sure the information you provide is what he or she needs to know.

Adult learners share other characteristics that can make your role as preceptor more clear-cut. With a lifetime of experiences to call upon, adults have a broad background of information that can serve as a framework for new information. When you present new material, help the student to see how it compares to other information he or she already knows.

Additional factors influence adult learning. They may include the following:

Self-concept
Adults are usually seen by society and each other as workers, not learners, but this view can be changed by the preceptor. A positive educational experience with a preceptor can build the student’s self-confidence.

Environment
A comfortable physical setting encourages learning. It is difficult, for example, to concentrate on learning when the chair wobbles, the room is ice-cold, and there is constant noise and activity. A comfortable psychological atmosphere also helps the learning process. An open, non-judgmental, non-authoritarian setting encourages adult learners to participate.

Age
An individual’s life experience, maturation, and previous accomplishments influence his or her motivation to learn.

Motivation
Internal motivation arises from an interest of the learner, and is stronger than external motivation, which comes from outside the individual (for example, traffic school attendance mandated after a ticket). Asking a trainee about personal reasons for wanting to learn the information can help you understand exactly how important mastery of the material is to him or her.

Education and Learning Style
Previous educational attainments and reading levels influence a learner’s comfort level with the whole idea of learning a new body of information. Learning style is an individual’s general way of relating to new information by
relating it to previous knowledge, by observing,
by theorizing, or by active experimentation and
participation. A preceptor who is careful to
observe the learning style of a trainee can
present information in the best way to improve
understanding.

ADULT LEARNING
PRINCIPLES
The following learning principles from
Preceptorships in Nursing Staff Development are
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Feedback following performance of a newly learned task can make the behavior more or less likely to recur. For example, if you try out a new recipe, you'd be more likely to repeat it if you hear good things about it (positive reinforcement) than if you hear unpleasant comments (negative reinforcement).

Goals and Feedback

Setting and meeting individually-set goals can contribute to the student's satisfaction and increase his or her internal motivation. Discussing goals and learning objectives and how they will be measured at the beginning of a new section helps clarify what must be learned from the new materials.

Readiness

Individual maturity, time available for learning tasks, and previous experiences all contribute to a student's readiness to learn new material. For example, teaching must begin at a different level for a technician who is unfamiliar with the functions of a kidney versus one with a background in anatomy and physiology. The first student must begin at a basic level, while the student with a strong anatomy/physiology background may be ready to begin dialysis concepts after a brief refresher.

Assessment

Self-observation by the learner as well as external feedback from the preceptor help identify progress and learning needs. The student's self-assessment, direct observation by the preceptor, and objective measurements (such as tests) should be combined to provide a complete picture of the trainee's performance. Assessment should be followed by identification of specific areas for improvement.

LEARNING CONTRACTS

Younger adults, perhaps just out of high school, may not be as self-motivated as you'd like. One way to increase a less-mature trainee's ownership of the responsibility to learn new material is to sit down with the trainee and complete a learning contract (see example on page 269). According to M. Knowles in *The Adult Learner: A Neglected Species*, a learning contract specifies what is to be learned, how long it will take, what resources will be available, and how mastery of the information will be measured. Both the trainee and the preceptor or supervisor sign the contract. Use of a learning contract can also reassure the trainee that he or she is in fact there to learn, and not merely to relieve the regular staff of low-level, repetitive tasks. For the learning contract to be effective, it is
necessary to first have preset, concrete learning objectives for your training program. Before putting the contract to use, it would be helpful to have a number of staff members look it over to see if the objectives are clear, or if anything is missing.

Strategies for Effective Preceptorship

THE TEACHING PROCESS
A preceptor cannot force anyone to learn.
Instead, teaching is a process of facilitating learning by taking certain steps that encourage progress. Ongoing assessment, planning, and evaluation help you tailor the learning experience to meet the student’s educational needs. Being prepared can reduce your anxiety, and allow you to take advantage of spontaneous teachable moments that may arise throughout the course of a shift. Devoting some thought however brief to learning objectives and methods also improves lesson organization and use of time. Beware of overstructuring and planning every minute, however, or you may lose the interest of your student.

Lessons themselves and any written handouts should be brief and to the point. Formal presentations should be limited to no more than 20 minutes, and should actively involve the student in participation or discussion.

COMMUNICATING SKILLFULLY

As a health professional, you are clearly and accurately transmitting crucial information every day; misunderstanding a lab value or a prescription could be disastrous. The same care must be taken to be sure that you and your trainee understand each other. The following list of communication methods can help you think about your use of important learning tools.

Language
You speak English, your student speaks English or do you? Many healthcare professionals quickly become unaware of the technical medical terms, abbreviations, and jargon they use each day. Ms. Smith needs her meds QID, we need to record her I and O and vitals before the end of the shift, and send a crit, BUN, and creat to the lab. Do not assume that a trainee understands these terms; make an effort to explain them at every opportunity.

Observation
Communication is more than words. Eye contact and body language are additional forms; even the way individuals dress influences how they perceive, and are perceived by, others. Picking up on some of the nonverbal messages your trainee is sending can help bring issues out into the open that might not otherwise be dealt with.

Silence
Sometimes a preceptor’s silence can help a trainee concentrate on a task, work through a solution, or just think about what was said. A trainee’s silence could indicate that he or she is uncomfortable, quietly observing, bored, or does not understand the material. Skillful assessment by the preceptor can identify the reason for the trainee’s silence and deal with the issue.
Listening and Empathy
The ability to listen with focused attention and fully understand a message is a powerful tool. Called active listening, the technique involves reflecting, or restating the speaker’s message in different words, paying careful attention to the emotional content. Empathy is also important when dealing with students’ fears or feelings of inadequacy. Let your students know that you, the preceptor, once had the same concerns they are feeling. Stress that with more experience and training, their confidence and knowledge will grow.
Strategies for Improving Communication

Table 1 lists several techniques you can use to make your communication with your trainee better.

ONE-ON-ONE: THE PRECEPTOR/TRAINEE RELATIONSHIP

A preceptor and trainee are subject to the same interpersonal differences as any other relationship. In theory, a head nurse or coordinator should choose a preceptor for a trainee after careful consideration of the personalities involved. In practice, there may not be time or available, qualified personnel to make this possible. In general, however, an atmosphere of openness and mutual respect will go a long way toward easing the path of preceptorship for both partners.

Preceptorships in Nursing Staff Development has valuable insights into the preceptor/trainee relationship and its potential pitfalls. Some aspects of this relationship have been found to be quite predictable across a variety of situations, including:

Preceptor Module 266

<table>
<thead>
<tr>
<th>Technique Effect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask direct questions</td>
<td>Gives preceptor more information.</td>
</tr>
<tr>
<td>Ask open-ended questions</td>
<td>Questions that cannot be answered “yes” or “no” encourage free exchange and an atmosphere of willing communication.</td>
</tr>
<tr>
<td>Make small talk</td>
<td>A moment or two reduces anxiety and tension and paves the way for more in-depth talk. (Overuse could be seen as avoidance.)</td>
</tr>
<tr>
<td>Confront</td>
<td>To be effective, confrontation must be followed by cooperative problem solving. (What can we do to help you?)</td>
</tr>
<tr>
<td>Clarify</td>
<td>Summarizing what you think was said, or asking, “did you mean...” can improve understanding on both sides.</td>
</tr>
<tr>
<td>Compare</td>
<td>Drawing comparisons between situations can help relate past knowledge to current situations, and allows trainees to find solutions on their own.</td>
</tr>
<tr>
<td>Reflect/paraphrase</td>
<td>Restating trainees’ phrases in your own words helps them feel they are in a supportive environment where they can speak freely. It also encourages further thought.</td>
</tr>
<tr>
<td>Acknowledge feelings</td>
<td>Promotes further communication.</td>
</tr>
<tr>
<td>Express doubt</td>
<td>Carefully worded expressions of doubt, like “is that the way you believe it works?” can advocate critical thinking without criticizing the thinker, and encourage an atmosphere of tolerance.</td>
</tr>
<tr>
<td>Verbalize the implied</td>
<td>Clarifying motives and hidden messages can bring feelings out into the open where they can be dealt with.</td>
</tr>
<tr>
<td>Encourage</td>
<td>Positive feedback and encouragement help motivate the learner. Statements like, “yes, go on,” indicate that the learning environment will be supportive.</td>
</tr>
<tr>
<td>Be specific</td>
<td>Concentrating on specific examples and areas for improvement minimizes confusion.</td>
</tr>
</tbody>
</table>

Table 1: Strategies for Improving Communication
Reality Shock
Many new employees find that the day-to-day situations they encounter on the job fail to meet their expectations. At first, a trainee tends to experience a honeymoon phase: patients, co-workers, and the job itself are all better than expected. This is followed by a period of depression—the real world doesn’t match up to the ideal goals set in training. Employees who make it past this phase enter a recovery stage, regaining their sense of balance. Finally, resolution is an integration of ideal and realworld values into a workable solution.

Trust
For optimal training to occur, the trainee and preceptor must be able to trust each other. Being honest, consistent, dependable, and respecting privacy and confidentiality help trust to grow.

Acceptance
The preceptor and trainee must be willing to accept each other as individuals, regardless of the differences between their personal values. Openness, tolerance, and acceptance contribute to a quality learning environment.

Preceptor Pitfalls
Helping a trainee to be fully functional in the workplace is not always an easy task. At times the student’s own agenda or other issues may interfere with the educational goals you have worked out together.

Anxiety
New employee anxiety can be contagious to you, adding to your concerns about your own performance and leading you to second-guess your methods. Try to keep your own feelings separate from those of your student, who is understandably nervous about the new job responsibilities.

Avoidance
Students may try to divert attention from subject matter that intimidates them. A sudden surplus of off-the-topic questions or nonessential tasks that must be performed are cues to redirect attention to the original task, or seek the reasons for the avoidance behavior.

One-way thinking
One-way thinking can limit problem-solving ability for both preceptor and student. If a student devises a different way to perform a task, think carefully before immediately assuming that your own way is better. Many problems can be solved in a variety of ways, and a trainee with a fresh perspective may indeed have something to offer.

Indecisiveness
This problem is common among new employees, who may feel reluctant to apply the new information they are learning. Instead
of making decisions for the trainees, ask for their recommendations and the reasons for them. Ask questions to direct the line of thought carefully. It is better for a student to attempt to act now, under your supervision, than to rely on your decisions and be unable to function alone later.

Letting Go:
the Fledgling Trainee
You\'ve accomplished your goal. The raw trainee you worked with has become a responsible

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addition to your center, able to perform his or her assigned duties independently and seek out information when needed. The preceptor/student relationship is over, and the preceptor becomes a consultant instead. 
Like many preceptors, you may find it surprisingly difficult to let go of a trainee when the time comes. Loss of the student’s constant companionship and the continuing appreciation for your vast knowledge and experience can make a shift seem flat and empty. You may find yourself disagreeing that the trainees know enough to be on their own; after all, you’ve been evaluating their progress and you know exactly how much more they need to learn. At some level you may even be concerned that your student’s job performance will be a reflection on you as a preceptor; if the trainee fails, do you fail, too? No one can tell you that you have to accept the end of a preceptor relationship, but if you are aware that it can be an uncertain time, you can reward yourself and take other steps to help you cope. Most importantly, when you are part of a successful preceptor relationship leading to a conscientious, alert technician, you are helping your center and your patients.

EVALUATING YOUR TRAINING PROGRAM
How do you know whether your technician training is effective? Certainly one way to tell is the caliber of technicians you are turning out. Another way to fine-tune your program and demonstrate its progress is to do periodic evaluations. Generally, most evaluations are done to answer two questions:
1. How well is the program doing?
2. How can it be improved?
To tell how your program is performing, it must be compared against a set of measurable criteria that you develop. These outcome criteria should be understandable by everyone, achievable, and consistent with the resources and philosophy of your center. Your review of the results can help you recommend improvements in the preceptorship program, making it a solid contributor to continually improving patient care.
Preceptor Module 268
Sample Learning Contract

Learner’s Name: ____________________________________________

Center: ___________________________ Dates of orientation: __________

Type of orientation: __________________________________________

This learning contract is a method by which the learner and the preceptor mutually identify a plan for orientation. By signing this contract, both document commitment to actively participate in this program.

Learner: I have read the program format and objectives of the Core Curriculum for the Dialysis Technician.

1. I agree to complete _____ selected learning modules.
2. I agree to actively participate in _____ days of clinical orientation.
3. I understand that I will be expected to verbalize and/or demonstrate the required knowledge and skills for __________________________ to show competence in the curriculum materials.
4. I understand my training period will cover _____ weeks and will be evaluated by a preceptor and testing.

_____________________________ ________________
Learner Date

Preceptor: I am familiar with the format and objectives of the Core Curriculum for the Dialysis Technician.

1. I agree to provide resources necessary to facilitate the learner’s attainment of required knowledge and skills.
2. I agree to provide _____ days of clinical orientation.
3. I will observe and verify the knowledge and skills required of the learner.
4. I will reverify skills annually.

_____________________________ ________________
Preceptor Date
Sample Student Evaluation
DIALYSIS TECHNICIAN EDUCATION PROGRAM
Please take a few minutes to complete the attached evaluations of your dialysis center and your preceptor.
The results will be used to help improve the quality of clinical training instruction. All information will be kept strictly confidential.

Evaluation of the Dialysis Center
Dialysis Center: ____________________________________________
Dates: From __________________________ to __________________________

1. Evaluate the dialysis center in terms of meeting your training needs.
   ____ Excellent. Opportunities to practice needed skills were always available.
   ____ Above average. Opportunities to practice needed skills were usually available.
   ____ Average. Opportunities to practice needed skills were sometimes available.
   ____ Below average. Opportunities to practice needed skills were seldom available.
   ____ Poor. Opportunities to practice needed skills were never available.
   Comments:

2. Evaluate the availability of staff for instruction and supervision:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
   Comments:

3. Evaluate the overall quality of the instruction by the staff:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
   Comments:

Preceptor Module
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4. How much direct physician contact did you have during this rotation:
   ____ Very much
   ____ Much
   ____ Some
   ____ Little
   ____ None
Comments:
5. Evaluate the dialysis center in terms of providing teaching activities that helped you learn:
   ____ Excellent. Rich and varied opportunities were available.
   ____ Above average. Several opportunities were available.
   ____ Average. Occasional opportunities were available.
   ____ Below average. Few opportunities were available.
   ____ Poor. No opportunities for enrichment were available.
Comments:
6. How could the educational opportunities be improved?
Evaluation of the Preceptor
Instructor’s Name: __________________________________________________
Dates of rotation: From ______________________ to ______________________
1. Rate the preceptor’s ability to teach technical skills for dialysis:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
Comments:
2. Rate the preceptor’s ability to integrate materials into dialysis practice:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
Comments:
3. Rate the preceptor’s ability to teach problem solving skills:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
   Comments:
4. Rate the availability of the preceptor for skills practice and testing:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
   Comments:
5. Rate the objectivity of the preceptor during skills testing:
   ____ Very fair
   ____ Fair
   ____ Unfair
   ____ Very unfair
   Comments:
6. Evaluate the preceptor’s creativity and motivation as a clinical teacher:
   ____ Excellent
   ____ Above average
   ____ Average
   ____ Below average
   ____ Poor
   Comments:
7. How could the preceptor improve as a clinical educator?

Adapted with permission from Madison Area Technical College, Respiratory Therapy Program,
Madison, WI.
Preceptor Module
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Module 1 Posttest
1. What are the two main types of dialysis:
   a. Continuous renal replacement therapy
   and peritoneal dialysis
   b. Hemodialysis and peritoneal dialysis
   c. Hemofiltration and peritoneal dialysis
   d. Hemodialysis and continuous renal replacement therapy
2. Which of these developments in dialysis history came first:
   a. Dr. Kolff’s rotating drum device
   b. Shunt
   c. Dr. Kolff’s coil dialyzer
   d. Arteriovenous fistula
3. How are clinics paid by Medicare for dialysis treatment:
   a. Separate billing
   b. Contract pricing
   c. Composite rate
   d. Fee-for-service
4. Which of the following is covered by the standards of the Association for the Advancement of Medical Instrumentation (AAMI):
   a. Dialyzer reprocessing
   b. Clinical performance measures
   c. Hemodialysis machine maintenance
   d. Safety of hemodialysis machines
5. Which of the following is a step of the CQI process:
   a. Implement the PDCA cycle.
   b. Write a long article about the problem.
   c. Develop a hypothesis.
   d. Consult an expert.
6. Which of the following actions shows that you have a conscientious manner:
   a. Running through the dialysis clinic
   b. Getting to work on time
   c. Talking about patients in front of other patients
   d. Talking about your personal problems in front of patients
7. Which of the following is an example of a boundary that should be kept between you and your patients:
   a. It is okay to ask a patient for a date.
   b. You may take gifts, money, or tips from patients.
   c. You can borrow money from patients.
   d. You should not invite patients to your home.
8. What is the minimum number of months of experience you need to take a certification exam:
   a. 3
   b. 6
   c. 9
   d. 12
Module 2 Posttest

1. The functional unit of the kidney, or the structure in the kidney that does the work, is the:
   a. Medulla
   b. Cortex
   c. Calyx
   d. Nephron

2. A nephron is made up of:
   a. A glomerulus and a tubule
   b. The nephrons and a capsule
   c. The loop of Henle and the capillary ball
   d. The bladder and the ureter

3. The leading cause of chronic kidney disease for adults in the United States is:
   a. Hypertension
   b. Glomerulonephritis
   c. Diabetes
   d. Urinary obstruction

4. The endocrine functions of the kidney include:
   a. Regulating growth hormone and making thyroid hormone
   b. Making erythropoietin and the active form of vitamin D
   c. Making estrogen and testosterone
   d. Regulating body temperature and sleep rhythms

5. The primary cause of the anemia of ESRD is:
   a. Erythropoietin deficiency
   b. Calcium deficiency
   c. Iron deficiency
   d. Cholecalciferol deficiency

6. Which of the following are hemodialysis treatment options:
   a. CAPD, nocturnal, short daily
   b. CCPD and transplantation
   c. In-center, nocturnal, short daily
   d. Short daily, CAPD

7. Which is the best definition for dry weight:
   a. Postdialysis weight at which all or most excess fluid has been removed
   b. Weight gained between treatments
   c. Predialysis weight
   d. Amount of weight to be removed during treatment

8. What is the Health Insurance Portability and Accountability Act (HIPAA)?
   a. A law about how to treat patients
   b. A law that created rules about how to document dialysis treatments
   c. A law that created national rules about the security and privacy of health data
   d. Standards on how to manage healthcare information

Preceptor Module
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9. Mrs. M., a 72-year-old widow, asks to have her treatment shortened by 20 minutes today so she can get home and watch her favorite soap opera. You explain that:
   a. This will be okay because a few minutes here and there don’t make any difference
   b. Center policy does not permit patients to discontinue treatment early
   c. It is very important to get the prescribed time, every dialysis treatment, to avoid medical complications
   d. She can leave, but she must sign a release
10. Which of the following medical problems may occur due to chronic kidney disease (choose all that apply):
   a. Anemia
   b. Indigestion
   c. Sleeping problems
   d. Pericarditis
11. Kidney failure is a chronic illness that causes many changes for the person with the disease and his or her family and friends. The dialysis team member with special training in helping people adjust to these changes is the:
   a. Nurse
   b. Physician
   c. Social worker
   d. Technician
22755
Module 3 Posttest

1. A solution is a mixture of:
   a. Water and blood
   b. Dialysate
   c. A solvent and a solute
   d. Water and sodium

2. A semipermeable membrane is a filter that:
   a. Allows only certain sized particles to cross
   b. Prevents fungal contamination
   c. Can distinguish between particles
   d. Is biocompatible, non toxic, and hypoallergenic

3. Diffusion is movement of particles:
   a. By filtration through a biocompatible membrane
   b. From an area of higher concentration to an area of lower concentration
   c. Into a vacuum created when fluids are forced through a membrane
   d. Into a space made by solutions moving in countercurrent flow

4. Negative pressure is pressure created when:
   a. Larger amounts of filtration exist in a closed space
   b. Fluids separated by a membrane flow in the same direction
   c. Larger molecules drag smaller molecules across a membrane
   d. Fluid is pulled through a restriction

5. During dialysis, ultrafiltration occurs when:
   a. Water is removed from blood because there is a pressure gradient across a membrane.
   b. Phosphorus is removed from blood because dialysate is low on phosphorus.
   c. A higher concentration of sodium causes water to move from body compartments into the dialysate.
   d. A suction device is applied to the venous trap and a Harvard Clamp is applied to the arterial side of the blood set.

6. Which of the following best describes the intravascular fluid compartment?
   a. Fluid inside the cells
   b. Blood inside the blood vessels
   c. Fluid between cells
   d. Fluids inside and between cells

7. During dialysis, levels of waste in the blood should:
   a. Remain the same
   b. Decrease
   c. Increase
   d. Fluctuate

8. Which of the following factors affects the rate of diffusion:
   a. Pressure gradient
   b. Flow rate
c. Hydraulic pressure  
d. Surface area of the membrane
Module 4 Posttest
1. Which of the following is not a dialyzer characteristic:
   a. Capacity
   b. Clearance
   c. Biocompatibility
   d. Molecular weight cutoff
2. Which of the following is a way to remove solutes:
   a. Convection
   b. Suction
   c. Surface area
   d. Irradiation
3. Name the two compartments of the dialyzer:
   a. Conventional and high flux
   b. Convection and adsorption
   c. Blood and dialysate
   d. Hollow fiber and flat plate
4. Dialysate is the fluid that helps remove waste products from the body. It contains a number of substances. Choose the group below that might be prescribed for a dialysate solution:
   a. Bicarbonate, sodium, potassium
   b. Magnesium, creatinine, calcium
   c. Chloride, glucose, urea
   d. Beta-2-microglobulin, calcium, sodium
5. What is the purpose of a proportioning system?
   a. Monitors the dialysate flow rate
   b. Monitors for blood leaks
   c. Checks the conductivity of the dialysate
   d. Make dialysate by mixing fresh concentrate with fixed amounts of treated water
6. Dialysate conductivity measures:
   a. The total electrical charge of a solution
   b. The total number of thermistors in a solution
   c. The total number of mL per solution
   d. The total number of gradients in a solution
7. What condition occurs due to dialysate that is too hot:
   a. Hypersensitivity reaction
   b. Hemolysis
   c. Pyrogenic reaction
   d. Septicemia
8. What are the two types of ultrafiltration systems:
   a. Volumetric UF control and flow control
   b. Flow rate and UFR
   c. TMP and UFR
   d. Proportioning system and flow control
22777
9. Which of the following is not a component of the extracorporeal circuit:
   a. Blood leak detector
   b. Blood pump
   c. Heparin infusion line
   d. Drip chamber

10. Which of the following best describes the transducer protector:
   a. Pump that moves blood through the extracorporeal circuit
   b. Device inside the machine that converts air pressure into an electronic signal
   c. Tubing that carries blood from the patient’s access to the dialyzer and back to the access
   d. System that removes water from the blood

11. Although dialysate delivery systems have back-up monitoring systems, it is critical that:
   a. The monitoring systems be checked and calibrated on a schedule recommended by the manufacturer
   b. Conductivity and pH be verified by independent meters before each dialysis treatment and whenever the dialysate is changed
   c. All alarm systems be tested prior to each dialysis treatment
   d. All of the above

12. Choose the group below that contains the dialysate delivery system monitors:
   a. Temperature, venous pressure, flow rate
   b. Blood and dialysate flow rates
   c. Conductivity, pH, flow rate
   d. Blood leak, pH, arterial pressure

13. Which of the following is a negative pressure:
   a. Venous
   b. Venous and arterial
   c. Arterial
   d. Predialyzer pressure
Module 5 Posttest

1. Mrs. Phyllis R. is a 40-year-old woman whose kidneys are failing due to hypertension. She does not have diabetes or cardiac problems. If her blood vessels are in good condition, what type of access is preferable?
   a. A femoral catheter
   b. A forearm loop graft
   c. An arteriovenous fistula
   d. A cuffed, tunneled catheter

2. When assessing a fistula or graft, which of the following needs to be listened for prior to starting dialysis:
   a. Bruit
   b. Stenosis
   c. Thrill
   d. Steal syndrome

3. Which of the following are possible complications of flipping the needle in AVF cannulation (choose as many as apply):
   a. Stenosis
   b. Infiltration
   c. Steal syndrome
   d. Stretching the needle hole
   e. Tearing the lining of the vessel

4. Which direction should the venous needle be placed:
   a. Antegrade
   b. Next to the anastomosis
   c. Retrograde
   d. Into the flow of blood

5. Which of the following is the reason for rotating needle sites on a fistula:
   a. Prevent infiltration
   b. Prevent stenosis
   c. Prevent steal syndrome
   d. Prevent aneurysms

6. Infiltration refers to which of the following definitions:
   a. A pocket of blood inside the blood vessel
   b. A needle tip that punctures a vessel and goes out the other side, so blood escapes into the tissues
   c. The colonization of bacteria in a graft anastomosis
   d. Mixing of already dialyzed blood with arterial blood in the patient’s access

7. Which of the following is a long-term complication of fistulae:
   a. Infiltration
   b. Thrombosis
   c. Bruit
   d. Recirculation

8. When assessing a fistula or graft, which of the following need to be felt prior to starting dialysis:
   a. Pulse and deep access
   b. Bruit and deep access
   c. Bruit and pulse
   d. Pulse and thrill
9. Which of the following is the complication that can happen to grafts if the needle sites are not rotated:
   a. Stenosis
   b. Pseudoaneurysm
   c. Steal syndrome
   d. Infiltration
10. Which of the following will help prevent infection in catheters:
   a. Wash hands and change gloves prior to touching the catheter
   b. Palpate the skin along the catheter from the blood vessel down to the exit site looking for drainage at the exit site
   c. Change the catheter dressing
   d. Assess the catheter blood flow
11. Which of the following is a step in the port/catheter predialysis assessment:
   a. Cleansing the catheter site
   b. Connecting the catheter to the bloodlines
   c. Assessing the blood flow rate through the catheter
   d. Assessing the ease of heparin removal and saline flushing before connecting the bloodlines
Module 6 Posttest

1. The instrument used for measuring blood pressure is called a:
   a. Sphygmomanometer
   b. Spirometer
   c. Bronchoscope
   d. Tachometer

2. A rapid pulse of 104 beats/min would indicate that the patient has:
   a. Bradycardia
   b. Tachycardia
   c. An arrhythmia
   d. Atrial flutter

3. The normal range of resting respirations in an adult is:
   a. 12 to 20 breaths/min
   b. 20 to 40 breaths/min
   c. 30 to 50 breaths/min
   d. 30 to 50 breaths/min

4. For which of the following situations would you use the stand-and-pivot technique to transfer a patient:
   a. Patient is brought into the dialysis clinic on a stretcher
   b. Patient can bear weight once standing, but has trouble getting up from the dialysis chair
   c. Patient can get out the dialysis chair without any problems
   d. Patient is complaining of dizziness and nausea

5. Which of the following methods kills bacteria, but will not destroy all of them completely?
   a. Asepsis
   b. Disinfection
   c. Exposure to chemical sterilants
   d. Open-flame irradiation

6. What is the most important activity that you can perform to prevent the spread of infectious disease in the dialysis clinic:
   a. Wearing a mask
   b. Wearing gloves
   c. Wearing protective equipment
   d. Handwashing

7. Which of the following should be done to prevent needle sticks (choose all that apply)?
   a. Recapping needles
   b. Throwing used needles into puncture-resistant, color-coded containers
   c. Break or bend the needle
   d. Leaving needles on the medicine carts

8. The purpose of priming the extracorporeal circuit with saline during setup is:
   a. To remove air and germicide before initiating treatment
   b. To be certain fibers are thoroughly filled with germicide before initiating dialysis
   c. To assess ultrafiltration capacity of the dialyzers and check for leaks
d. To maintain fiber noncompliance until the dialysis begins
23811
9. Mrs. Smith’s dry weight is 62 kg. Her pretreatment weight when she came in for treatment on Monday was 67 kg. For her treatment the priming saline amount is 240 mL, the rinseback amount is 200 mL, fluid from medications is 100 mL, and she is not allowed any fluids during treatment. What is the total amount of fluid weight to be removed during her treatment?
   a. 5,000 mL  
   b. 5,230 mL  
   c. 5,540 mL  
   d. 5,820 mL

10. Based on Mrs. Smith’s total amount of fluid to be removed, what is the ultrafiltration rate per hour (mL/hr) for her 4-hour treatment?
   a. 1,220 mL/hr  
   b. 1,385 mL/hr  
   c. 1,440 mL/hr  
   d. 1,500 mL/hr

11. A medication used to prevent blood from clotting in the extracorporeal circuit is:
   a. Mannitol  
   b. Heparin  
   c. Hypertonic saline  
   d. Lidocaine

12. Which of the following is used to prevent air in the bloodlines:
   a. Maintain prescribed blood flow rates  
   b. Tighten all connections  
   c. Monitor patient’s blood pressure  
   d. Allow the normal saline bag to empty

13. Which of the following is a cause of hypotension during and after dialysis treatments?
   a. Uremia  
   b. Patient forgetting to take their blood pressure pills  
   c. Fluid overload  
   d. Removing too much fluid
1. Dialyzers are reprocessed mainly because:
   a. Reprocessing reduces the cost of dialysis treatments
   b. Reprocessing shortens the dialysis treatment
   c. Reprocessing is safer for staff
   d. Reprocessing reduces the amount of plastic in landfills
2. Which organization sets the standards and recommendations for dialyzer reprocessing:
   a. FDA
   b. CDC
   c. AAMI
   d. CMS
3. Which of the following tests must be performed on new dialyzers:
   a. Hgb (hemoglobin)
   b. TIBC (total iron binding capacity)
   c. CBC (complete blood count)
   d. TCV (total cell volume)
4. What are the steps for dialyzer reprocessing after a dialysis treatment:
   a. Pre-cleaning, performance tests, dialyzer rejection, disinfection
   b. Labeling, TCV, performance tests, disinfection
   c. Pre-cleaning, TCV, dialyzer rejection, disinfection
   d. Preprocessing, TCV, performance tests, disinfection
5. Which of the following is a germicide used for dialyzer reprocessing:
   a. Alcohol
   b. Hydrogen peroxide
   c. Peracetic acid
   d. Acetone
6. Which of the following is the definition of [contact time]:
   a. Amount of time the germicide is rinsed through the dialyzer
   b. Amount of time between dialyzer uses
   c. Amount of time the germicide remains in the dialyzer
   d. Time it takes to reprocess the dialyzer
7. AAMI standards recommend quality control activities before a reprocessed dialyzer is used on a patient. Who must check the dialyzer to verify quality control information:
   a. The patient, only as long as he or she is sighted
   b. Two people, one of whom should be the patient
   c. The medical director and the charge nurse
   d. Two registered nurses and a patient care technician
8. Which of the following is a problem in dialyzer reprocessing that may cause bacteria or endotoxin contamination of the dialyzer:
   a. Use of proper storage conditions
   b. Correct contact time used
c. Use of heat and citric acid

d. Improperly prepared germicide

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9. Which of the following best describes the Dialyzer Reprocessing Manual:
   a. Record of the dates and results of all quality assurance and quality control evaluations for the center
   b. Summary of all reuse specifications, policies, procedures, training materials, manuals and methods, and samples of forms and labels
   c. Log of the dates of preventive maintenance, repairs, and results of scheduled testing on all hemodialysis equipment
   d. Record of testing required by regulatory agencies on any germicides or cleaning agents used in dialyzer reuse

10. Which of the following are two criteria for rejecting a reprocessed dialyzer:
    a. Less than 80% of original fiber bundle volume, aesthetic appearance
    b. Label incomplete, dialyzer not heparinized
    c. Patient preference, access is recirculating
    d. HIV status, hyperkalemia present
Module 8 Posttest

1. Water used for dialysate must be treated because dialysis patients:
   a. Have strict fluid restrictions and drink only pure water
   b. Drink large amounts of water despite their restrictions
   c. Are exposed to large volumes of water during dialysis
   d. Are able to excrete contaminants in dialysate during dialysis

2. Choose the substance which may be added to municipal drinking water supplies to make the water clearer:
   a. Bleach
   b. Zinc
   c. Potassium
   d. Alum

3. The water softener performs the following activity:
   a. Removes calcium and magnesium from water
   b. Removes chlorine and chloramines from water
   c. Adds calcium and magnesium water
   d. Kills bacteria in the water

4. Which of the following is a limitation of a reverse osmosis (RO) system?
   a. Removes bacteria and endotoxin
   b. Removes solutes from the water
   c. Thin film composite membranes break down when exposed to chlorine and chloramines
   d. Produces purified water

5. Which is the most common way that water treatment systems are disinfected:
   a. Heat
   b. Ozone
   c. Chemical
   d. Minerals

6. Contamination of water by bacteria/endotoxins may cause one of these reactions:
   a. Blurred vision
   b. Bone disease
   c. Pyrogenic
   d. Double vision

7. How often should the RO operating parameters be checked:
   a. Weekly
   b. Hourly
   c. Monthly
   d. Daily

8. Which of the following is an acceptable level of post softener hardness:
   a. 0.8 grain per gallon
   b. 1.1 grain per gallon
   c. 1.5 grain per gallon
   d. 2.0 grain per gallon
9. According to AAMI standards, bacteriologic testing for water and dialysate should take place:
   a. Daily
   b. Weekly
   c. Monthly
   d. Yearly
10. According to the AAMI standards, the total microbial count of dialysate shall not exceed:
    a. 200 CFU/mL
    b. 400 CFU/mL
    c. 800 CFU/mL
    d. 1,000 CFU/mL
11. According to AAMI standards, the total endotoxin count of dialysate shall not exceed:
    a. 1 EU/mL
    b. 2 EU/mL
    c. 3 EU/mL
    d. 4 EU/mL
12. How frequently should the carbon tanks be checked for chlorine and chloramines:
    a. Each shift
    b. Weekly
    c. Monthly
    d. Annually
13. Large amounts of aluminum in water used for dialysate could cause:
    a. Fever/chills
    b. Liver problems
    c. Bone disease
    d. Diarrhea
Module 8 Posttest (continued)
Module 1
1. b
2. a
3. c
4. a
5. a
6. b
7. d
8. b

Module 2
1. d
2. a
3. c
4. b
5. a
6. c
7. a
8. c
9. c
10. a, c, d
11. c

Module 3
1. c
2. a
3. b
4. d
5. a
6. b
7. b
8. d

Module 4
1. a
2. a
3. c
4. a
5. d
6. a
7. b
8. a
9. a
10. b
11. d
12. c
13. c

Module 5
1. c
2. a
3. b, d, e
4. a
5. d
6. b
7. b
8. d
9. b
10. a
11. d

Module 6
1. a
2. b
3. a
4. b
5. b
6. d
7. b
8. a
9. c
Posttest Answer Key
Preceptor Manual

References

Preceptorship Resources

Module 7
1. a
2. c
3. d
4. a
5. c
6. c
7. b
8. d
9. b
10. a
11. b
12. b
13. d

Module 8
1. c
2. d
3. a
4. c
5. c
6. c
7. d
8. a
9. c
10. a
11. b
12. a
13. c

Preceptor Module
ABSCESS
An abscess is an infection under the skin that looks like a blister or pimple filled with fluid or pus. If fistula needles are inserted into or near an abscess, infection of the fistula or graft or other tissues may occur.

ACCESS
An access (vascular access) is a route into the bloodstream that allows enough blood flow for hemodialysis. For permanent access, a surgeon connects a vein to an artery. This can be done directly (fistula) or with a piece of synthetic tubing (graft). For temporary vascular access, a catheter may be placed in a large central vein, such as the internal jugular vein in the neck. (See also: Arteriovenous Fistula, Catheter, Graft.)

ACID
An acid is a substance with a pH below 7.0 that is capable of donating a hydrogen ion (H+). In the human body, acids are created when protein and other substances are broken down by cell metabolism. (See also: Buffer.)

ACQUIRED IMMUNODEFICIENCY SYNDROME (AIDS)
See: Human Immunodeficiency Virus (HIV).

ACUTE KIDNEY FAILURE
Acute kidney failure (or acute renal failure) is kidney failure with a sudden onset. It is most often caused by an illness, injury, or toxin that stresses the kidneys. In some cases, patients who survive acute kidney failure recover their kidney function with the temporary support of dialysis. Some patients die or develop chronic kidney failure.

ADEQUACY
See: Hemodialysis Adequacy, Peritoneal Dialysis Adequacy.

ADSORB
Adsorb means to attract and hold on a surface. The dialyzer membrane adsorbs blood proteins to
the walls of the hollow fibers during a treatment. This can make reused dialyzers more biocompatible (like the body) than new ones if bleach is not used to remove the protein coating.

ADVANCE DIRECTIVES
Advance directives outline a patient’s wishes for medical treatment in case he or she becomes too ill to make such decisions. A living will is an example of an advance directive. The patient’s family and other members of the healthcare team should be told of the patient’s wishes when an advance directive has been prepared and given a copy to keep.

AFFERENT
Afferent means toward an organ.

AIR DETECTOR
The air detector (or foam detector) checks blood in the venous line of the extra corporeal circuit for air. Air in a patient’s bloodstream can interfere with blood flow or heartbeat, causing death. If the detector finds air, an alarm will sound, the blood pump will stop, and the venous bloodline will clamp to keep air from reaching the patient.

AIR EMBOLISM
An air embolism occurs when air bubbles enter the bloodstream and are carried in to a vessel small enough to be blocked by the air. The air embolus in the vessel acts like a clot, blocking the flow of blood. Dialysis machines have an air detector on the venous bloodline to help prevent this problem, which can be fatal.

ALBUMIN
Albumin is a blood protein. Low serum albumin levels (<3.5 g/dL) may mean that a patient is undernourished. Malnutrition is common in hemodialysis patients, and increases their risk of death.

ALKALINE
See: Base.

ALUM
Alum is an aluminum compound often added to city water supplies to remove sediment and make the water clearer. Aluminum can build up in the bodies and brains of dialysis patients. Aluminum in the water used for dialysis must be kept at low levels by treating the water used to make dialysate. (See also: Encephalopathy, Flocculant.)

Reference Module 294
ALUMINUM-RELATED BONE DISEASE (ARBD)
ARBD is a bone disease caused by long-term exposure to aluminum. Aluminum builds up in the tissues at the point where new bone forms, and can be seen on x-ray. Sources of aluminum include water used for dialysate, medications, and aluminum cookware. Aluminum-based phosphate binders are also a source, but are rarely used today. Symptoms of ARBD can include deep bone pain, muscle weakness, and fractures.

AMYLOIDOSIS
Amyloidosis is the build-up of a protein called beta-2-microglobulin (ß2m) in the soft tissues, bones, and joints. In dialysis patients, these deposits can cause arthritis-like joint pain and/or bone pain. High-flux dialysis membranes and/or nocturnal hemodialysis remove more ß2m, which may help prevent or treat this disorder.

ANAPHYLACTIC REACTION
An anaphylactic reaction (anaphylaxis) is a rapid, severe immune response to an allergen. Hives, itching, or wheezing may be present. Anaphylactic shock may occur, causing hypotension, cardiac arrhythmia or arrest, spasms of the breathing passages, and swelling of the throat. This problem can be fatal.

ANASTOMOSIS
An anastomosis is a surgical connection. In a vascular access, the anastomosis is the spot where a vein and artery are joined to form a fistula, or where the artificial vein is joined to the patient’s artery and vein for a graft. Dialysis needles should not be inserted into the area of the anastomosis.

ANEMIA
Anemia is a shortage of oxygen-carrying red blood cells. It causes severe fatigue, heart problems, trouble concentrating, reduced immune function, and many other problems. Anemia is common in chronic kidney disease due to less erythropoietin, iron deficiency, and loss of blood through tests and hemodialysis treatments. (See also: Hematocrit, Hemoglobin.)

ANESTHETIC
An anesthetic is a drug that numbs the body to reduce pain. Local anesthetics can be injected into a certain spot (such as the skin around a puncture site before needle insertion). Or, gels or creams can be applied to the skin to prevent pain at that site.
ANEURYSM
An aneurysm is a ballooning or bulging of a weak spot in a blood vessel. Because severe bleeding can occur if an aneurysm ruptures, great care must be taken with a patient who has one. Aneurysms can occur if needles are inserted too often into the same small area of a fistula.

ANGIOPLASTY
Angioplasty is a procedure to open a narrowed blood vessel (stenosis). In dialysis patients, angioplasty may be used for vascular access repair. A small balloon is threaded through the vessel into the access and gently inflated to push the walls of the vessel open. (See also: Stenosis.)

ANION
An anion is a negatively charged ion.

ANNA
American Nephrology Nurses Association

ANTEGRADE
Antegrade means forward moving; in dialysis, it means in the direction of blood flow. The venous needle should always be placed antegrade. The arterial needle may be placed either antegrade or retrograde. (See also: Retrograde.)

ANTICOAGULANT
An anticoagulant is a blood-thinning drug used to keep clots from forming. Anticoagulants, such as heparin, are used to prevent clotting in the extracorporeal circuit during hemodialysis.

ANTIDIURETIC HORMONE (ADH)
Antidiuretic hormone (ADH; vasopressin) is released by the pituitary gland in the brain. ADH helps prevent excess fluid loss by signaling healthy kidneys to reabsorb water. ADH also signals the blood vessels to constrict (tighten).

ANTISEPTICS
Antiseptics are products that slow or stop the growth of bacteria and viruses. They are used to kill microorganisms to prevent infection and the spread of disease.

APICAL PULSE
The apical pulse is felt on the chest wall directly over the heart.

Reference Module
APNEA
Apnea is a temporary period when breathing stops.

ARRHYTHMIA
An arrhythmia is an irregularity of the heartbeat. It may be felt as an extra pulse or heard directly over the heart.

ARTERIAL PRESSURE
In hemodialysis, arterial pressure is measured in the extracorporeal circuit between the arterial needle and the dialyzer. Pre-pump arterial pressure is measured from the patient’s access to the blood pump. Post-pump arterial pressure is measured after the blood pump and before the dialyzer.

ARTERIAL PRESSURE MONITOR
A pressure sensor monitors pre-pump arterial pressure in the extracorporeal circuit between the patient’s access and the blood pump. A post-pump arterial pressure monitor measures pressure between the blood pump and the dialyzer. If the pressure reading is outside of set limits, an alarm will sound and the blood pump will stop. (See also: Extracorporeal Circuit.)

ARTERIALIZE
When a fistula is created, strong arterial blood flow causes the vein to arterialize: it dilates (widens), thickens, and becomes more muscular, like an artery.

ARTERIOVENOUS (AV) FISTULA
In dialysis, an arteriovenous fistula (AVF) is a surgical connection between an artery and a vein beneath the skin of an arm or leg to provide access to the blood. The force of blood flowing from the artery makes the vein larger and thicker. After an AVF matures, it can be punctured repeatedly with dialysis needles and will provide the rapid blood flow rates needed for dialysis. (Plural: Fistulae.)

ARTERIOLE
An arteriole is a small artery.

ARTERY
A blood vessel that carries blood away from the heart at high pressure. Arteries deliver oxygenated blood to every part of the body.
ARTIFICIAL
Artificial means man-made, often in imitation of something found in nature. The dialyzer is called an artificial kidney because it is a man-made filter that imitates the function of the human kidney. A piece of artificial vein is used to create a dialysis graft.

ASCITES
Ascites is a build-up of fluid in the abdomen caused by liver damage, heart failure, malnutrition, or infection. Special ultrafiltration and other methods (i.e., abdominal drainage) may be needed to remove the excess fluid.

ASEPSIS
Asepsis is the absence of pathogens. Asepsis in dialysis is achieved by disinfection, equipment maintenance, and using aseptic technique for invasive procedures such as inserting dialysis needles.

ASEPTIC
Aseptic means sterile or germ-free.

ASEPTIC TECHNIQUE
Aseptic technique is a series of steps used to maintain a germ-free environment. Steps in aseptic technique include washing hands before touching items in sterile packages; touching sterile objects only to other sterile objects; cleaning blood ports or the patient’s skin with disinfectant before inserting a needle; and discarding any sterile supplies in wet, damaged, or torn packages. Peritoneal dialysis exchanges must be done using aseptic technique to prevent infection.

ASSOCIATION FOR THE ADVANCEMENT OF MEDICAL INSTRUMENTATION (AAMI)
AAMI develops voluntary standards for aspects of dialysis, including water treatment and dialyzer reprocessing. The AAMI Guidelines have been adopted by the Centers for Medicare and Medicaid Services (CMS).

AUSCULTATE
Auscultate means to listen with a stethoscope. Auscultation of a patient’s vascular access is used to help diagnose problems like stenosis or thrombosis that can change the normal sound of the bruit. (See also: Bruit.)

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AUTOMATED PERITONEAL DIALYSIS (APD)
See: Continuous Cycling Peritoneal Dialysis (CCPD).
ß2m
See: Amyloidosis.
BACKFILTRATION
Backfiltration is movement of dialysate across the dialyzer membrane and into the patient's blood. It can be caused by a change in the pressure or concentration gradient between the dialysate and the blood. Backfiltration may be more likely with high-flux dialyzer membranes, which have larger pores, and thus are more permeable. Backfiltration can harm patients because endotoxin in the nonsterile dialysate can enter the bloodstream, causing infection and fever.
BACKWASHING
Backwashing means forcing water backwards through a filter. This technique can be used to remove particles from clogged sediment filters in a water treatment system.
BACTEREMIA
See: Sepsis.
BACTERIA
Bacteria are microscopic, single-celled organisms that can cause disease. Bacteria are classified as Gram-positive or Gram-negative by the color they turn on a standard laboratory test called a Gram's stain. (See also: Endotoxin.)
BASE
Bases are chemicals capable of accepting a hydrogen ion (H+). A substance with a pH of greater than 7.0 is considered to be a base, or alkaline. In the body, bicarbonate is a base. (See also: Buffer, pH.)
BETA-2-MICROGLOBULIN (ß2m)
See: Amyloidosis.
BICARBONATE
Bicarbonate is a buffer used by the body to neutralize acids that form when the body breaks down protein and other foods. It is reabsorbed by healthy kidneys. Dialysis patients often have low levels of bicarbonate because their kidneys do not reabsorb enough. Thus, they cannot neutralize acids well. Bicarbonate is used in dialysate to help restore levels of bicarbonate in the body. Bicarbonate dialysate
has two main disadvantages: it supports bacterial growth and it requires two concentrates (acid and bicarbonate) to prevent formation of scale (calcium carbonate or magnesium) that can interfere with the equipment operation. (See also: Buffer.)

BINDERS
See: Phosphate Binders.

BIOCOMPATIBLE
Biocompatible means like the human body. A biocompatible dialyzer membrane is less likely to cause patient symptoms or trigger adverse immune responses caused by a foreign invader. Synthetic membranes (such as polysulfone) are more biocompatible than cellulose membranes. Cellulose membranes can become more biocompatible after reuse; a coating of blood protein builds up that keeps the patient’s blood from touching the foreign membrane.

BLOOD LEAK
A blood leak occurs when the delicate semipermeable membrane of the dialyzer tears, letting blood leak into the dialysate. Severe blood leaks can cause major blood loss during treatment. Any blood leak will expose patients directly to the dialysate.

BLOOD LEAK DETECTOR
The blood leak detector is an alarm system on the hemodialysis delivery system. It monitors used dialysate for blood that would indicate a leak in the dialyzer membrane. The detector shines a beam of light through the dialysate and into a photocell. A break in the light beam caused by blood cells triggers an alarm that stops the blood pump and clamps the venous line. This prevents further blood loss and contamination of the patient’s blood with dialysate. (See also: Hemodialysis Delivery System.)

BLOODLINES
See: Blood tubing.

BLOOD PUMP
The blood pump is part of the hemodialysis delivery system. It pushes the patient’s blood through the extracorporeal circuit at a fixed rate of speed. During hemodialysis, the blood tubing is threaded between the pump head and rollers. The rollers move blood through the extracorporeal circuit and back to the patient. (See also: Pump Occlusion.)

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**BLOOD PUMP SEGMENT**

The blood pump segment is a durable, larger diameter section of the arterial blood tubing that is threaded through the roller mechanism of the blood pump. (See also: Pump Occlusion.)

**BLOOD TUBING**

Blood tubing is the part of the extracorporeal circuit that carries blood from the patient’s vascular access through the arterial needle, to the dialyzer, and back to the patient through the venous needle. There are two segments of blood tubing: arterial (often color-coded red) and venous (often color-coded blue). Components of the blood tubing include patient connectors, dialyzer connectors, drip chamber/bubble trap, blood pump segment, and heparin and saline infusion lines.

**BLOOD UREA NITROGEN (BUN)**

Urea is a waste product of protein metabolism; it is measured as blood urea nitrogen (BUN). Failed kidneys cannot remove urea, which builds up in the body between treatments. BUN is easy and lowcost to measure, so it is used as a stand-in for other wastes that are harder to identify or measure. BUN levels are the basis of the urea reduction ratio and urea kinetic modeling methods used to assess the adequacy of dialysis. (See also: Hemodialysis Adequacy, Urea Kinetic Modeling, Urea Reduction Ratio, Uremia.)

**BOLUS**

A bolus is a single, relatively large amount of something. In dialysis, heparin can be given by bolus: the full prescribed dose is given all at once.

**BONE DISEASE**

See: Renal Osteodystrophy, Secondary Hyperparathyroidism.

**BONENT**

Board of Nephrology Examiners Nursing & Technology. This group offers an exam to become a Certified Hemodialysis Technologist/Technician (CHT).

**BRACHIAL PULSE**

The brachial pulse is the pulse felt in the crease of the elbow at the brachial artery.

**BRACHIOCEPHALIC FISTULA**

A brachiocephalic fistula is the most common type of AV fistula of the upper arm. It is created by surgically joining the brachial artery and the cephalic vein.
BRINE
Brine is concentrated saline solution. In dialysis water treatment, brine is used to flush the resin bed of a water softener. This recharges the softener with sodium chloride ions which are then exchanged with calcium and magnesium to soften the water.

BRUIT
A bruit is a buzzing or swooshing sound caused by the high-pressure flow of blood through a patient's AV fistula or graft. The bruit can be heard through a stethoscope at the anastomosis, and for some distance along the access. A high-pitched bruit may mean there is stenosis of the access.

BUBBLE TRAP
See: Drip Chamber.

BUFFER
A buffer is a substance that maintains the pH of a solution at a constant level, even when an acid or base is added. Bicarbonate is the buffer used in dialysis to maintain the pH of dialysate. (See also: Acid, Base, Bicarbonate.)

BUN
See: Blood Urea Nitrogen.

BUTTONHOLE TECHNIQUE
In the buttonhole (constant-site) cannulation technique, dialysis needles are placed in a fistula (not a graft) into the same holes at the same angle. Over 3–4 weeks, this creates pierced earring-like tracks that guide the needles to the right spots. The patient or the same staff person should place the needles. Once the tracks are formed, special blunt needles are used to avoid cutting new tracks. Buttonhole cannulation is quick to do, less likely to infiltrate, and largely painless for the patient. (See also: Needle Site Rotation.)

BYPASS
Bypass is a safety feature of the hemodialysis delivery system that cuts off the flow of fresh dialysate to the dialyzer and shunts it to the drain. Bypass prevents unsafe dialysate (wrong conductivity, temperature, pH, or dialysate) from reaching the patient and causing harm. (See also: Hemodialysis Delivery System.)

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CALCIUM
Calcium is an element that exists as a cation (positively charged ion). In the body, calcium is an electrolyte needed for nerve and muscle function and to form normal bone. It is partly bound to protein in the blood. Too much or too little calcium in dialysate can cause severe complications or death for patients. Patient blood levels of calcium are checked monthly. Calcium in a dialysate feed water supply can combine with other substances to form scale that can clog dialysis equipment. (See also: Electrolyte, Hypercalcemia, Hypocalcemia.)

CANNULA
See: Shunt.

CANNULATE
To cannulate means to put dialysis needles into a fistula or graft. (See also: Buttonhole Technique, Needle Site Rotation.)

CAPD
See: Continuous Ambulatory Peritoneal Dialysis.

CAPILLARIES
Capillaries are the body’s smallest blood vessels, where oxygenated blood crosses from arteries to veins. Capillaries are smaller than a human hair; blood cells must line up single file to pass through. Unlike arteries and veins, capillary walls are semipermeable: they allow oxygen, nutrients, and waste products to pass through. In the kidneys, each glomerulus is a tiny ball of capillaries that filters out wastes from the blood.

CARBON TANK
Carbon tanks are water treatment devices that contain granular, activated carbon that adsorbs low molecular weight particles from water. Carbon tanks are mainly used to remove chlorine, chloramines, pesticides, industrial solvents, and some trace organic substances from water used for dialysis.

CARDIAC ARREST
Cardiac arrest occurs when the heart stops beating. Cardiac arrest can be a lethal side effect of some dialysis problems, such as too-warm dialysate, wrong dialysate concentration, hemolysis, severe blood loss, or a large amount of air in the bloodstream. Hyperkalemia (high blood potassium levels) can also cause cardiac arrest.
CARDIAC OUTPUT
Cardiac output is the amount of blood passing through the heart in a certain period of time. Having an AV fistula or graft causes a 10% increase in cardiac output. This causes a 10% increase in the size of the heart. Patients who cannot tolerate this increase in cardiac output are not able to have AV fistulae or grafts.

CATABOLISM
Catabolism is a chemical process in which substances (e.g., proteins) are broken down into simpler substances in the body, producing wastes. These wastes (e.g., urea) are removed by healthy kidneys. In dialysis patients, they must be removed during the treatment.

CATHETER
A catheter is a plastic tube. In hemodialysis, a catheter can be placed in a large, central vein for temporary or longer-term access. In peritoneal dialysis, a catheter is surgically placed in the abdomen to allow fresh dialysate to be infused into the peritoneum and used dialysate to be drained.

CATION
A cation is a positively charged ion. In water treatment, cations can be removed by ion exchange or reverse osmosis to ensure safe water for dialysate and dialyzer reprocessing. (See also: Anion, Deionization Tank, Ion.)

CBNT
See: Certified in Biomedical Nephrology Technology.

CCHT
See: Certified Clinical Hemodialysis Technician.

CCNT
See: Certified in Clinical Nephrology Technology.

CCPD
See: Continuous Cycling Peritoneal Dialysis.

CELLULOSE
Cellulose is a fiber that forms the cell walls of plants. Cellulose acetate was the first material used as a dialyzer membrane by Dr. Willem Kolff in 1942. It was also the first material used for reverse osmosis membranes for water treatment. To form a membrane, cellulose can be dissolved in a solution.

Reference Module
304
containing copper salts and ammonium, then spun into sheets or hollow fibers. Cellulose dialyzer membranes are the most likely to cause first-use syndrome, because they are not biocompatible. (See also: First-use Syndrome.)

CENTRAL VENOUS STENOSIS
Central venous stenosis is narrowing of a central vein. This problem can damage vessels in the arm on the affected side so a patient can’t have a vascular access. With only about 10 access sites in the body, it is vital to preserve as many as possible. Due to the risk of central venous stenosis, the subclavian vein is not recommended by the KDOQI guidelines as a hemodialysis catheter site. The internal jugular (IJ) is suggested instead.

CERTIFIED CLINICAL HEMODIALYSIS TECHNICIAN (CCHT)
The 2-year CCHT certification is offered by the Nephrology Nursing Certification Committee.

CERTIFIED IN BIOMEDICAL NEPHROLOGY TECHNOLOGY (CBNT)
The CBNT certification is offered by the National Nephrology Certification Organization, Inc. (NNCO).

CERTIFIED IN CLINICAL NEPHROLOGY TECHNOLOGY (CCNT)
The CCNT certification is offered by the National Nephrology Certification Organization, Inc. (NNCO).

CEU
See: Colony-forming Units.

CHLORAMINE
Chloramine is a mix of chlorine and ammonia, or chlorine and organic material. Ammonia may be added to city water to boost the germ-killing power of chlorine. Chloramine is an oxidant; it destroys microorganisms by breaking down their cell walls. Chloramines in dialysis water can cause a serious condition called hemolysis (rupture of red blood cells). Carbon tanks are used to remove chloramines from water used for dialysis.

CHLORIDE
Chloride is a salt concentrate needed in dialysate and in the human body. Chloride combines with other elements to form sodium chloride, potassium chloride, magnesium chloride, and calcium chloride.
CHLORINE
The element chlorine is a greenish-yellow gas that can cause severe irritation to the lungs if inhaled. It is combined with other ingredients (such as in sodium hypochlorite bleach) to disinfect surfaces. Chlorine may also be added to city water supplies to destroy microorganisms. Carbon tanks are used to remove chlorine and chloramines from water used for hemodialysis and dialyzer reuse.

CHRONIC
Chronic means long-term.

CHRONIC KIDNEY DISEASE (CKD)
Chronic kidney disease is a long, usually slow, progressive loss of nephrons and thus kidney function. CKD can take many years to develop. It is divided into stages based on the glomerular filtration rate (GFR). See Module 2, Table 1 on page 27 for definition of stages. (See also: End-stage Renal Disease.)

CLEARANCE (K)
Clearance is the amount of blood (in mL) that is completely cleared of a solute in one minute of dialysis at a given blood and dialysate flow rate. Dialyzer clearance affects treatment adequacy. Manufacturers test dialyzers with solutions other than blood (in vitro), so clearance of a dialyzer during treatment (in vivo) can vary from the manufacturer's stated clearance. (See also: Hemodialysis Adequacy.)

CLINICAL PRACTICE GUIDELINES
Clinical practice guidelines are recommendations to improve patient outcomes based on a thorough review of the medical research and/or expert opinion. The National Kidney Foundation (NKF) DOQI Clinical Practice Guidelines were recommendations for patient care written by panels of experts who review medical studies. The NKF-Kidney Disease Outcomes Quality Initiative (KDOQI) updated the guidelines for key areas of nephrology, including anemia, hemodialysis adequacy, peritoneal dialysis adequacy, vascular access, heart disease, high blood pressure, bone disease, nutrition, chronic kidney disease, and managing lipid disorders. The goal of the KDOQI clinical practice guidelines is to improve patient outcomes.

CMS
Centers for Medicare and Medicaid Services. (See also: Medicare ESRD Program.)

COEFFICIENT OF ULTRAFILTRATION (Kuf)
The Kuf is the fixed amount of fluid a dialyzer will remove from the patient's blood per hour at a specified pressure. Kuf is also called the ultrafiltration factor (UFF) or ultrafiltration rate (UFR). It is
expressed as milliliters (mL) per hour (hr) of water removed for each millimeter (mm) of mercury (Hg) of transmembrane pressure (TMP), or mL/hr/mmHg TMP. The higher the KUf, the more fluid per mL of pressure will be removed. High-flux and high-efficiency dialyzers have higher KUf's than conventional dialyzers. Any KUf above 8 requires volumetric control hemodialysis systems to precisely control the amount of fluid removed.

COLONY-FORMING UNIT (CFU)
The number of CFUs in a water or dialysate sample is a measure of the number of living bacteria.

COMPLEMENT ACTIVATION
Complement is a group of proteins in the blood serum that work to remove pathogens from the body. Complement activation occurs when this system is exposed to a pathogen.

CONCENTRATE
In dialysis, concentrate is one of two salt solutions (acid and bicarbonate) that are mixed together to form dialysate.

CONCENTRATION
Concentration is the amount of solute dissolved in a measure of fluid. A highly concentrated solution has more solutes and less fluid. A less concentrated (more dilute) solution has less solute and more fluid. One task of healthy kidneys is to control the concentration of urine, so that the proper amounts of fluid and other substances are retained in the body. In dialysis, the concentration of each of substance in dialysate must be correct, to ensure a safe and effective treatment.

CONCENTRATION GRADIENT
See: Gradient.

CONDUCTIVE SOLUTE TRANSFER
See: Diffusion.

CONDUCTIVITY
Conductivity is the ability of a fluid to transfer electrical charge. It is a measure of ions in solution. A conductivity meter measures the electrolyte composition of dialysate to be sure it is within safe limits. (See also: Electrolyte.)
CONDUCTIVITY MONITOR
The conductivity monitor checks conductivity of the dialysate to be sure it is correct. If the level is wrong, an alarm is triggered, and the machine goes into bypass so dialysate is sent to the drain.

CONGESTIVE HEART FAILURE (CHF)
Congestive heart failure occurs when the heart cannot pump out the blood it receives. Excess fluid backs up into the lungs. Fluid overload from too much fluid intake or not enough fluid removal at dialysis may lead to CHF in dialysis patients.

CONSTANT-SITE CANNULATION
See: Buttonhole Technique.

CONTINUOUS AMBULATORY PERITONEAL DIALYSIS (CAPD)
CAPD is peritoneal dialysis with manual exchanges of dialysate done four or five times each day. CAPD exchanges can be done at home or work, and the patient can go about his or her day. Each exchange takes about 30 minutes. CAPD is continuous, so large amounts of wastes do not build up between treatments. This means the diet and fluids can be less restricted for CAPD than for hemodialysis. Because the patient can dialyze on his or her preferred schedule, this treatment is work-friendly. (See also: Exchange, Peritoneal Dialysis.)

CONTINUOUS CYCLING PERITONEAL DIALYSIS (CCPD)
CCPD, also called automated peritoneal dialysis (APD), is PD using a cycler machine to do multiple exchanges of dialysate, often at night while the patient sleeps. Because the patient can dialyze at night, leaving days free, this treatment is work-friendly. (See also: Exchange, Peritoneal Dialysis.)

CONTINUOUS QUALITY IMPROVEMENT (CQI)
CQI is a way to improve care by choosing an area that needs to be improved, analyzing the process of care, finding root causes, and then making and using a plan of change.

CONTINUOUS RENAL REPLACEMENT THERAPY (CRRT)
CRRT is a slow, ongoing form of dialysis that uses the patient’s heart or a blood pump to move blood through an extracorporeal circuit. Usually CRRT is done for many hours to gently remove extra fluid and some wastes in patients who are too ill or unstable for standard hemodialysis. A cartridge with a semipermeable membrane (like a dialyzer) is used.

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CONVECTION
See: Solvent Drag.

CONVECTIVE SOLUTE TRANSFER
See: Solvent Drag.

CONVENTIONAL DIALYSIS
Conventional dialysis uses a dialyzer with an in vivo KUf below 6 to remove wastes and excess fluid from patients with kidney failure. Treatments are done three times a week, most often for three hours or more.

CONVENTIONAL HOME HEMODIALYSIS
Dialysis treatments are done three days a week by the patient and a partner at home. The patient and partner are trained for several weeks to use the dialysis machine, cannulate the access, do the treatments, draw blood tests, keep records, and report problems. Because the patient can dialyze on his or her preferred schedule, this treatment is work-friendly.

COUNTERCURRENT FLOW
Countercurrent flow in a dialyzer occurs when blood moves in one direction and dialysate flows in the opposite direction. This allows for the most efficient dialysis, because it keeps the blood in constant contact with fresh dialysate.

CQI
See: Continuous Quality Improvement.

CREATININE
Creatinine is a waste product of muscle use that is removed by healthy kidneys. Larger people with more muscle normally have higher creatinine levels in their blood. Higher than normal creatinine levels may mean kidney disease.

CREATININE CLEARANCE
Creatinine clearance is a urine test that measures how well the kidneys remove creatinine from the blood in a certain time period. As kidney disease worsens, creatinine clearance will fall to 10% of normal or less.
CRENATION
Crenation is shriveling of blood cells that occurs if the blood cells are expose
d to a solution that is more
centrated than blood. For example, crenation may occur if dialysate with too
much concentrate is
used (hypertonic solution). If crenation occurs, the blood will appear dark red.
The condition can be
fatal.
CUFFED TUNNELED CATHETERS
Cuffed tunneled catheters, used for dialysis access, are placed in a blood vesse
l through a tunnel created
under the skin. Inside the tunnel, tissue grows into an attached cuff. The cuff
makes the catheter more
stable and acts as a physical barrier against bacteria.
CYANOSIS
Cyanosis is bluish-colored skin, lips, gums, and fingernail beds from lack of ox
gen. It may be present
in patients with methemoglobinemia, caused by exposure to dialysate water that c
ontains nitrates.
DEHYDRATION
Dehydration occurs when the body does not have enough water. It may be caused by
diarrhea, vomiting,
excess sweating, or excess fluid removal at dialysis. A dehydrated patient may h
ave low blood
pressure, sunken eyes, listlessness (lack of interest in surroundings), and poor
skin tone. (See also:
Hypotension.)
DEIONIZATION TANK
Part of a water treatment system, a deionization tank uses beds of resin beads t
o remove unwanted ions
from water used for dialysis. The unwanted ions are exchanged for hydrogen (H+)
and hydroxide (OH)
ions to form water (H2O).
DELIVERY SYSTEM
See: Hemodialysis Delivery System.
DIABETIC NEPHROPATHY
Diabetic nephropathy is kidney disease that results from diabetes. Type 2 diabet
es, a shortage of or
resistance to insulin, is the leading cause of kidney failure in the United Stat
es. In type 1 diabetes, the
immune system destroys the pancreas cells that make insulin. Diabetes is a disea
se of the blood vessels;
it causes heart disease and nerve damage. Along with nephropathy, diabetes is th
e leading cause of
blindness and loss of limb.
Reference Module
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DIALYSATE
Dialysate is a precise mixture of treated water and chemicals. It is used in dialysis to create a concentration gradient so wastes can be removed from the blood. Sodium, calcium, magnesium, chloride, potassium, glucose, and bicarbonate are usually included, in levels like those of normal blood. The concentrations must be very precise, and the dialysate must be mixed properly, or patients can be harmed. (See also: Gradient.)

DIALYSATE DELIVERY SYSTEM
See: Hemodialysis Delivery System.

DIALYSIS
Dialysis is a process of removing wastes and excess fluid from the blood of people whose kidneys have failed. It may be done using a dialyzer (hemodialysis) or the patient’s peritoneum (peritoneal dialysis) as a filter. (See also: Hemodialysis, Peritoneal Dialysis.)

DIALYSIS ADEQUACY
See: Hemodialysis Adequacy, Peritoneal Dialysis Adequacy.

DIALYSIS CHAIN
See: Large Dialysis Organization.

DIALYSIS DEMENTIA
See: Encephalopathy.

DIALYSIS DISEQUILIBRIUM SYNDROME
Dialysis disequilibrium syndrome is a condition in which rapid or drastic changes in the patient’s extracellular fluid affect the brain. Urea transfers more slowly from the brain tissue to the blood, so fluid is drawn into the brain, causing swelling. This syndrome occurs most often in acute renal failure, or when BUN values are very high. (See also: Blood Urea Nitrogen.)

DIALYZER
The dialyzer, or artificial kidney, is a semipermeable membrane inside a plastic cylinder. Dialyzers are used in hemodialysis to filter out wastes and fluid from the blood of patients with kidney failure. Ports on the cylinder permit blood and dialysate to flow in and out. The membrane keeps blood and dialysate apart, but allows an exchange of certain solutes and fluid to occur. (See also: Hollow Fiber Dialyzer, Semipermeable Membrane.)
DIALYZER REPROCESSING
See: Reprocessing.

DIASTOLIC
Diastolic blood pressure is the pressure of blood against the arteries when the heart rate is at rest (between beats). It is the bottom number of a blood pressure reading. (See also: Systolic.)

DIFFUSION
Diffusion is movement of dissolved particles across a semipermeable membrane from an area of higher solute concentration to an area of lower solute concentration. The process goes on until the concentration of solutes on both sides of the membrane are equal. In dialysis, diffusion works to remove wastes from the blood. The dialyzer membrane or peritoneum in peritoneal dialysis keeps blood and dialysate apart. Dialysate has no wastes, so wastes in the blood diffuse across the membrane into the dialysate. The rate of diffusion depends on the concentration difference between fluids (gradient), dialysate temperature, membrane pore size, and waste particle size. Diffusion is also called conductive solute transfer.

DISEQUILIBRIUM SYNDROME
See: Dialysis Disequilibrium Syndrome.

DISINFECTANT
A disinfectant is a chemical or process (e.g., heat) that destroys or slows the growth of harmful microbes. To work, disinfectants need time, and must stay moist and in contact with a surface. Common equipment disinfectants include heat, bleach, formaldehyde, glutaraldehyde, Renalin®, citric acid, and Amuchina®. Disinfectants are also used to clean water treatment ports before taking a water sample, and to wipe off surfaces in the dialysis center.

DISTAL
Distal means far. In anatomy, distal is far from the center of the body. The hands and feet are distal extremities.

DIURETIC
A diuretic is a drug that increases the amount of urine produced. Some diuretics can cause hypokalemia because they promote the loss of potassium in the urine. Diuretics are the first line of treatment for high blood pressure, and may be used for kidney patients before they start dialysis. Once the kidneys stop making urine, diuretics are no longer effective. (See also: Hypokalemia.)

Reference Module 312
DOCUMENTATION

Documentation is information about a patient’s care written in the permanent medical record or chart. It is vital to track the patient’s progress, provide a means to follow up each patient’s response to treatment, and ensure continuity of care. A patient’s chart is legal evidence of the care he or she received.

DRIP CHAMBER

An arterial or venous drip chamber monitors arterial or venous pressure in the extracorporeal circuit. A bubble trap inside the drip chamber collects any air that enters the blood tubing.

DRY ULTRAFILTRATION

See: Isolated Ultrafiltration.

DRY WEIGHT

Dry weight is the patient’s weight without excess fluid. When dry weight is reached, there are no signs of fluid overload or dehydration; breathing is normal, with no signs of fluid in the lungs; and blood pressure is normal for the patient (not too high nor too low). Target weight is the goal weight for a given treatment, and is usually determined by the dry weight.

DWELL TIME

In hemodialysis, dwell time is the length of time a disinfectant must stay in a dialyzer to ensure disinfection while reprocessing. If a disinfectant is used on the hemodialysis delivery system, it must dwell in the fluid pathways long enough to kill bacteria, then be rinsed. In peritoneal dialysis, dwell time is the length of time dialysate stays in the patient’s abdomen before it is drained and replaced with fresh.

DYSPNEA

Dyspnea means trouble breathing or shortness of breath. It can be a symptom of anemia, fluid overload, lung or heart problems, or other dialysis problems such as an air embolism.

ECCHYMOSIS

An ecchymosis is a bruise or bleeding under the skin. In dialysis patients, an ecchymosis can be a sign that too much heparin has been given or that not enough pressure was placed on the needle site after the needles were removed.

EDEMA

Edema is water retention with swelling in body tissues. It occurs as a result of fluid overload or other conditions, such as congestive heart failure. This swelling may be seen in the patient’s eyelids, ankles, feet,
Pitting edema is present when a finger pushed against the skin of the ankle leaves a dent. This should be reported to the nurse. (See also: Dry Weight, Pulmonary Edema.)

**Efferent**

Efferent means away from an organ.

**Electrolyte**

An electrolyte is a compound that breaks apart into ions (electrically charged particles) when dissolved in water. Electrolytes send electrical signals along the nerves to the muscles, including the heart. In the body, healthy kidneys keep electrolytes in balance. Sodium, potassium, magnesium, chloride, and calcium are electrolytes; each is added to dialysate in precise amounts.

**Embolus**

See: Air Embolism.

**Empty Bed Contact Time (EBCT)**

Empty bed contact time is the amount of time that feed water must stay in contact with the charcoal bed in a carbon tank during water treatment to remove chlorine and chloramines.

**Encephalopathy**

Encephalopathy is a change in brain function that can be fatal. Symptoms include confusion, short term memory loss, personality changes, speech problems, muscle spasms, hallucinations, seizures, and impaired thinking. One cause of encephalopathy is chronic exposure to high levels of aluminum. Sources of aluminum include dialysate water, antacids, and cookware.

**Endocrine Function**

Endocrine function, making hormones, is one of the tasks of healthy kidneys. Kidneys make hormones that adjust blood pressure (angiotensin) and signal the bone marrow to make red blood cells (erythropoietin). Healthy kidneys also convert vitamin D into an activated form that the body can use to absorb calcium to maintain healthy bones (calcitriol).

**Endotoxin**

Endotoxin (lipopolysaccharide) is a toxic part of the cell walls of some bacteria. Living bacteria can shed endotoxin, and it is released when the bacteria die. Endotoxin is not alive; disinfectants cannot kill it. If endotoxin enters a patient’s body, it can cause pyrogenic (fever) reactions. Endotoxin is a concern in water treatment and dialyzer reprocessing. It is controlled by reducing the number of bacteria in the water or removing it with an ultrafilter. (See also: Pyrogenic Reaction.)
END-STAGE RENAL DISEASE (ESRD)

ESRD is a legal term for complete and irreversible loss of kidney function. This is the last stage (stage 5) of chronic kidney failure, when dialysis or a transplant are needed for the patient to live. Patients have ESRD when their glomerular filtration rate has dropped to <15, about 10% of normal. (See also: Chronic Kidney Disease, Glomerular Filtration Rate.)

EQUILIBRIUM

Equilibrium is a state of balance. For example, diffusion and osmosis both continue until equilibrium has been reached: until the levels of solutes or fluid are equal on both sides of a semipermeable membrane.

ERYTHROPOIETIN (EPO)

Erythropoietin is a hormone made by healthy kidneys that signals the bone marrow to produce red blood cells.

See: End-stage Renal Disease.

ESRD NETWORKS

The ESRD Networks were established by the U.S. government in 1978 to oversee dialysis centers and ensure that patients receive high quality care. The Networks collect data, implement quality improvement, encourage rehabilitation, establish a grievance procedure for patients, and provide resource materials to ESRD staff and patients. There are 18 regional ESRD Networks in the United States.

ETHYLENE OXIDE (ETO)

ETO is a gas used by some manufacturers to sterilize new dialyzers. Patients who are hypersensitive to ETO may have first-use syndrome if a new dialyzer is not properly rinsed of ETO.

EXCHANGE

In peritoneal dialysis, an exchange occurs each time used dialysate is replaced with fresh dialysate after a dwell period. Exchanges may be done by hand or by using a cycler machine. (See also: Continuous Ambulatory Peritoneal Dialysis, Continuous Cycling Peritoneal Dialysis.)

EXCRETORY FUNCTION

To excrete means to eliminate from the body. The excretory function of healthy kidneys acts to rid the body of wastes and excess fluid as urine. Urine contains excess water and a high concentration of waste products.
EXSANGUINATION
Exsanguination is a severe loss of blood that may be fatal. Common causes of exsanguination at dialysis that can be prevented include needle dislodgment, bloodline separation, access rupture, or a cracked dialyzer casing.

EXTRACELLULAR
Extracellular means outside the cells. About one third of the fluid in the body is extracellular, or between the cells and in the blood vessels. Fluid must move into the blood vessels to be removed by dialysis. The sodium level in dialysate helps ensure movement of fluid into the blood vessels so it can be removed during a treatment.

EXTRACORPOREAL
Extracorporeal means outside the body. Hemodialysis is an extracorporeal therapy; it takes place outside the body.

EXTRACORPOREAL CIRCUIT
The extracorporeal circuit is the arterial bloodline, dialyzer, venous bloodline, and extracorporeal circuit monitors. It is an extension of the patient’s blood vessels outside of the body, bringing blood from the access to the dialyzer and back to the patient. (See also: Blood Tubing, Dialyzer.)

EXTRACORPOREAL CIRCUIT MONITORS
Extracorporeal circuit monitors include a blood flow monitor, arterial or venous pressure monitors (measured at drip chambers), an air detector, and a blood leak detector. They shut off the blood pump and clamp the venous bloodline if pressure limits are exceeded, air gets into the venous bloodline, or blood is detected in the spent dialysate. (See also: Air Detector, Arterial Pressure, Blood Leak Detector, Venous Pressure.)

EXTRASKELETAL CALCIFICATION
Extraskeletal calcification occurs when calcium phosphate crystals form in blood vessels or soft tissues. Though rare, it can cause gangrene, loss of limb, and death. Patients whose blood (serum) levels of calcium and phosphorus are high are at a higher risk for extraskeletal calcification. Mottled, painful, purplish skin is a symptom of extraskeletal calcification that must be reported right away to the nurse or nephrologist.

FEED WATER
Feed water is untreated tap water before it passes through a water treatment system. Feed water must pass through all of the components of a water treatment system before it is used for dialysis.

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316
FEMORAL CATHETER
A femoral catheter is a temporary vascular access placed in the femoral vein in the groin. The femoral vein is easy to reach and preserves blood vessels in the upper body for permanent vascular access. However, the site is very prone to infection and limits patient mobility. It is most often used for critically ill or bedridden patients.

FERRITIN
Ferritin is an iron storage protein complex in body tissues; it is measured with a blood test. Ferritin stores are needed as a building block for red blood cell production. KDOQI anemia guidelines recommend that dialysis patients' ferritin levels be between 100 and 800 ng/mL. Most patients need intravenous iron to keep their ferritin levels in the target range.

FIBER BUNDLE VOLUME (FBV)
Fiber bundle volume, also called total cell volume (TCV), is a measure of the volume of fluid the hollow fibers in a dialyzer can hold. FBV is measured before a dialyzer is used and again after each reprocessing, because reprocessing a dialyzer can reduce FBV.

FIBRIN SHEATH
A fibrin sheath is a collection of blood clotting fibers that build up on the outside of a catheter lumen. The fibers can form a cap that blocks the end of a catheter and reduces blood flow.

FIBROSIS
Fibrosis is overgrowth of scar tissue. Fibrosis can develop in a fistula as a result of repeated needle punctures for dialysis. Scar tissue builds up, narrowing the lumen of the vessel and reducing blood flow.

FILTERS
Filters are devices that remove particles, solutes, and other substances by not passing them through holes of various sizes.

FILTRATION
Filtration is the process of passing a fluid through a filter. In dialysis, filtration forces a fluid out of the patient's blood and across the dialyzer membrane by using pressure.
FIRST-USE SYNDROME

First-use syndrome is a group of symptoms that occur shortly after starting a treatment with a new dialyzer. Symptoms may include nervousness, chest pain, back pain, palpitations (skipped or missed heartbeats), or itching. First-use syndrome may be caused by ethylene oxide gas or manufacturing residues in the dialyzer. Preprocessing a dialyzer may help by removing ethylene oxide and residues.

FISTULA
See: Arteriovenous Fistula.

FLOCCULANT
A floculant is a chemical added to drinking water to remove solid particles from the water to make it clearer. Alum is one substance that may be used as a floculant.

FLOW
A flow is a stream. Blood flow to each organ in the body is based on the amount and pressure of blood delivered by the heart, and the resistance the blood meets in the blood vessels. Blood flow in the extracorporeal circuit is based on the blood pump setting, resistance in the extracorporeal circuit, and capacity of the access.

FLOW RATE
Flow rate is the amount of fluid that flows through the tubing in a given period of time.

FLOW VELOCITY
Flow velocity is the speed at which the fluid moves through a given length of tubing.

FLUID MOVEMENT
See: Osmosis.

FLUSH
See: Priming.

FOOD AND DRUG ADMINISTRATION (FDA)
The FDA is a federal office that regulates the release and marketing of medications and medical devices, including dialyzers and devices used for reprocessing.

Reference Module
318
FORMALDEHYDE
Formaldehyde is a poisonous, colorless, foul-smelling gas. In its liquid form (37% gas in water), it is called aqueous formaldehyde or Formalin®; it is an effective germicide used to disinfect dialysate delivery systems or reprocess dialyzers. The liquid form is volatile; it changes into a vapor that can penetrate and disinfect even small spaces. Formaldehyde is a suspected cancer-causing agent; centers must follow OSHA safety rules to prevent injury to patients or staff.

FORMALIN®
Formalin is a trademark name for a 37% solution of formaldehyde.

FREE CHLORINE
Free chlorine is chlorine that is not chemically bound to other substances. (See also: Chloramine.)

GAUGE
A gauge is a standard of measurement for needle sizes.

GLOMERULAR FILTRATION RATE (GFR)
GFR is the volume of blood filtered by the glomerulus each minute, in mL/min. A normal GFR is about 120 to 130 mL/min. Chronic kidney disease is divided into stages based on the level of GFR. See Module 2, Table 1 on page 27 for definition of stages. (See also: End-stage Renal Disease.)

GLOMERULONEPHRITIS
Glomerulonephritis is an inflammation that damages the glomeruli of the kidneys. It can be slow and progressive or rapid in onset, and may occur as an immune response to a streptococcal infection. Hypertension often occurs with it.

GLOMERULOSCLEROSIS
Glomerulosclerosis is a hardening of the glomeruli.

GLOMERULUS
A glomerulus is a tangled ball of capillaries held together by a membrane called a Bowman’s capsule in the nephron of the kidney. Water and small molecular weight particles are forced through filtration slits in each glomerulus by the pressure of the beating heart. The resulting solution is called glomerular filtrate. (Plural: Glomeruli.)
A gradient is a difference. A concentration gradient is a difference in the concentration of solutes between two fluids separated by a semipermeable membrane. In dialysis, the fluids are blood and dialysate. They are separated by the dialyzer membrane, or by the peritoneum in peritoneal dialysis.

To graft is to join one thing surgically to another. In hemodialysis, a graft is a piece of artificial vessel that is used to create a vascular access. One end of the graft is connected to the patient’s artery, the other to the vein.

Gram-negative bacteria are a class of bacteria that turn pink in a standard laboratory Gram’s stain. They live in water and form an electrically charged biofilm (slime) that lets them cling to surfaces like dialysate jugs or hoses. Biofilm protects the bacteria from disinfectants, making them difficult to remove. For example, Achromobacter is a Gram-negative bacteria that can contaminate the dialysis water supply or dialysate. Acinetobacter, Aeromonas, Alcaligenes, Flavobacterium, Moraxella, Pseudomonas, and Serratia are other types of Gram-negative bacteria.

Gram-positive bacteria turn blue to black in a standard laboratory Gram’s stain. Staphylococci are Gram-positive bacteria that cause most access infections.

Heat disinfection is an alternative to chemicals used to reprocess some types of dialyzers and equipment. The use of heat prevents patient and staff exposure to chemicals. Cellulose dialyzer membranes degrade in heat, and cannot be disinfected in this way.

A Hemastix is a reagent strip that reacts to the presence of blood. When the blood leak detector indicates that there is blood in the used dialysate but the blood cannot be seen, a Hemastix strip should be used to check the presence of blood and the extent of the leak.

Hematocrit (Hct) is a measure of red cells in the blood. It is stated as a percentage of red blood cells per total blood volume. Routine checks of Hct levels were used to assess anemia in the past. (See also: Hemoglobin.)
HEMATOMA
A hematoma is a painful, hard, black and blue collection of blood under the skin, caused when blood leaks out of a vessel into surrounding tissues. Hematomas can form when dialysis needles are placed, infiltrated, or removed. A hematoma can compress the access vessel, making a clot more likely. (See also: Infiltration.)

HEMOCONCENTRATION
Hemoconcentration is dehydration of the blood. This can occur in the extracorporeal circuit if ultrafiltration goes on after the blood pump is turned off. Also, recirculation in the access can lead to this problem. Hemoconcentration can lead to blood clotting, which can damage the patient’s access.

HEMODIALYSIS
Hemodialysis cleans the blood of excess water and wastes by passing it through an artificial kidney, or dialyzer. Water and wastes move out of the patient’s blood through the semipermeable dialyzer membrane and into dialysate. The patient’s blood is brought to the dialyzer and back to the body through tubing connected to needles placed in a vascular access. Alarms and monitors help prevent patient injury and ensure a safe treatment. Hemodialysis is the most common treatment for patients with endstage renal disease. It can be done in a dialysis center or at home, during the day or at night while the patient sleeps.

HEMODIALYSIS ADEQUACY
Hemodialysis adequacy is measurement of the dialysis dose to ensure that patients receive at least the minimum amount of treatment needed for survival. The KDOQI guidelines provide recommended standards for adequacy, and ways to attain them. Hemodialysis adequacy is measured with urea kinetic modeling or the urea reduction ratio. KDOQI guidelines for hemodialysis adequacy recommend a minimum delivered Kt/V of at least 1.2 (prescribed Kt/V of 1.4) or a minimum delivered URR of about 65% (prescribed URR of about 70%) for adequate dialysis. (See also: Urea Kinetic Modeling, Urea Reduction Ratio.)

HEMODIALYSIS DELIVERY SYSTEM
The delivery system is a machine that consists of a blood pump, dialysate delivery system, and safety monitors. The blood pump moves blood from the patient’s access through the dialyzer and back to the patient. The machine makes dialysate by mixing treated water with dialysate concentrate. Safety alarms monitor blood and dialysate flow, dialysate temperature, conductivity, venous and arterial pressure, blood-in-dialysate leaks, and, often, the patient’s blood pressure.
HEMODIALYSIS INFECTION CONTROL PRECAUTIONS
The U.S. Centers for Disease Control (CDC) recommended ways to prevent bloodborne infections in hemodialysis patients in 2001. These guidelines are more strict than the Standard Precautions often used in hospitals. They include handwashing between patient contacts, before and after invasive procedures (like cannulation), before touching a wound (including a needle site) or any body substance or mucous membrane, after taking off gloves, between tasks and procedures on the same patient, and when entering or leaving the center. Handwashing should be done for at least 15 seconds, covering all surfaces of the hands and fingers. Protective equipment (gloves, gown, face shield, and protective eyewear) is to be used for staff protection and to keep clothes clean. Precautions must also be taken to avoid needle stick injuries.

HEMODIALYZER
See: Dialyzer.

HEMOGLOBIN
Hemoglobin (Hgb) is the red, oxygen-carrying pigment of red blood cells. Measuring hemoglobin levels is a way to diagnose anemia. Routinely checking Hgb levels allows the care team to follow the patient’s response to anemia treatment and alerts them to any chronic blood loss. (See also: Anemia.)

HEMOLYSIS
Lysis is cell rupture; hemolysis is the rupture of red blood cells. This is a life-threatening condition that requires immediate care from a doctor. Hemolysis may be caused by hyponatremia (low blood sodium); dialysate that is too hot or too dilute (hypotonic); chloramines, copper, or nitrates in dialysate water; formaldehyde or bleach in the dialysate; low dialysate conductivity; too-high pre-pump arterial pressure; incompatible blood transfusions; kinked blood tubing; some drugs; and certain diseases.

HEMOLYTIC ANEMIA
Hemolytic anemia is a shortage of red blood cells due to hemolysis.

HEMOTHORAX
A hemothorax is a collection of blood in the chest that keeps the lungs from fully expanding. This causes dyspnea (trouble breathing). Hemothorax can occur if a blood vessel is accidentally punctured when a hemodialysis catheter is placed.

HEPARIN
Heparin is a blood thinner (anticoagulant) used during dialysis so blood will flow freely through the extracorporeal circuit. It can be given intermittently (periodically) or continuously. Continuous Reference Module 322
infusion uses a pump to slowly inject heparin into the extracorporeal circuit at a prescribed rate during a treatment.

**HEPARIN INFUSION LINE**
The heparin infusion line is a small tube that extends from the blood tubing. It allows heparin to be given during dialysis. The heparin infusion line is most often found on the arterial blood tubing segment just before the dialyzer.

**HEPARIN PUMP**
A heparin infusion pump consists of a syringe holder, a piston, and an electric motor. It is used to continuously deliver precise amounts of heparin during dialysis. The heparin pump is connected to the heparin infusion line, which is part of the extracorporeal blood tubing. Most dialysis machines have a heparin delivery system, although stand-alone heparin pumps are still in use in some settings.

**HEPATITIS**
Hepatitis is inflammation of the liver caused by a virus that can be found in several forms, including hepatitis viruses A, B (HBV), or C (HCV). Hepatitis B and C are spread through contact with infected blood or other body fluids, and are a concern for dialysis patients and staff. Hepatitis virus infections can cause long-term, permanent liver damage or death. Vaccination against the hepatitis B virus should be offered to all dialysis staff and patients. Standard precautions should be followed to prevent the spread of hepatitis and other infections.

**HIGH-EFFICIENCY DIALYSIS**
High-efficiency dialysis uses dialyzers that can remove more small solutes (e.g., urea) than conventional membranes. Larger-gauge needles and blood flow rates from 300 to 500 mL/min are most often used. Ultrafiltration control is required by the federal government when dialysis is done with a dialyzer KUF above 8. (See also: Coefficient of Ultrafiltration.)

**HIGH-FLUX DIALYSIS**
High-flux dialysis uses a membrane that is permeable to a broad range of molecular weight solutes, including higher molecular weight solutes. KUF values for high-flux dialysis are higher than 8 and require ultrafiltration control. High-flux dialyzers can remove larger amounts of fluid as well as large substances such as beta-2-microglobulin.

**HIGH-OUTPUT CARDIAC FAILURE**
High-output cardiac failure occurs when the patient’s heart cannot work hard enough to pump out the extra blood sent to it by an AV fistula or graft. (See also: Cardiac Output.)
HIPAA

HIPAA is the Health Insurance Portability and Accountability Act. This Act requires that patients’ medical information be kept confidential.

HOLLOW FIBER DIALYZER

The hollow fiber dialyzer contains thousands of tiny hollow fibers (semipermeable membranes) held in place at each end by clay-like potting material. The hollow fiber and potting material are encased in a hard plastic cylinder. During dialysis, blood flows through the hollow tubes and dialysate flows around them. The hollow fiber dialyzer allows for well-controlled and predictable diffusion and ultrafiltration, and is the only type of dialyzer on the market in the United States.

HOMEOSTASIS

Homeostasis is the constant balance that is kept in the internal environment of the body. Healthy kidneys help maintain fluid balance, acid/base balance, hormone balance, and electrolyte balance, all key aspects of homeostasis.

HORMONES

Hormones are chemical messages made in one organ or gland that act on another part of the body. Healthy kidneys make a hormone (erythropoietin) that signals the bone marrow to make red blood cells and other hormones that control blood pressure and use of calcium in the body.

HUMAN IMMUNODEFICIENCY VIRUS (HIV)

HIV is a virus that disables the body’s immune system by destroying white blood cells that fight disease (T-lymphocytes). HIV is transmitted through blood, semen, vaginal secretions, peritoneal fluids, and breast milk. Over time, people who have HIV can develop acquired immunodeficiency syndrome (AIDS). Damage to the immune system caused by AIDS leaves the body open to infections and cancers that usually do not occur in people with healthy immune systems. While treatments are available, prevention is the best approach. Follow Standard Precautions to prevent the spread of HIV in the dialysis center. (See also: Hemodialysis Infection Control Precautions, Infection Control, Opportunistic Illnesses.)

HYDRAULIC PRESSURE

Hydraulic pressure is water pressure created naturally (such as from gravity) or artificially (such as from a pump). Hydraulic pressure affects the amount of water that is removed from the patient during dialysis.

Reference Module

324
HYDROPHOBIC
Hydrophobic means water-repellent.

HYPER
The prefix hyper means beyond, above, more, or too much. For example, hyperactivity is an above normal activity level.

HYPERCALCEMIA
Hypercalcemia means too much calcium (an electrolyte) in the blood. Symptoms of hypercalcemia can include muscle weakness, fatigue, constipation, loss of appetite, abdominal cramps, nausea and vomiting, and coma. (See also: Electrolyte, Extraskeletal Calcification.)

HYPERGLYCEMIA
Hyperglycemia means high blood sugar levels. Thirst may be a symptom of hyperglycemia in a patient who has diabetes.

HYPERKALEMIA
Hyperkalemia means too much potassium (an electrolyte) in the blood. Hyperkalemia causes symptoms of muscle weakness, and can lead to cardiac arrhythmia, cardiac arrest, or death. Hyperkalemia can occur if a dialysis patient eats too many high potassium foods; if tissue breaks down due to surgery, bleeding, hemolysis, or fever; or if dialysate with too much potassium is used. These conditions cause potassium to be released from cells into the bloodstream. (See also: Electrolyte.)

HYPERMAGNESEMIA
Hypermagnesemia means too much magnesium (an electrolyte) in the blood. Magnesium is needed for muscle and nerve function. Symptoms of hypermagnesemia include poor nerve transmission, hypotension, slower breathing, and sleepiness. Severe hypermagnesemia can cause cardiac arrest. (See also: Electrolyte.)

HYPERNATREMIA
Hypernatremia means too much sodium (an electrolyte) in the blood. Excess sodium in the blood causes water to move out of the cells including red blood cells. It can cause headaches, hypertension, and crenation. (See also: Electrolyte.)

HYPERPHOSPHATEMIA
Hyperphosphatemia means too much phosphorus in the blood. It is most often found in patients who are eating a lot of protein and/or dairy foods, not taking enough phosphate binders, or not taking
binders with their meals. Phosphorus is a component of bones, and is key in energy transfer between cells. On its own, hyperphosphatemia can cause severe itching in the short term, and bone damage in the long term. Hyperphosphatemia with hypercalcemia can cause fractures, bone pain, and deposits of sharp calcium phosphate crystals in soft tissues. (See also: Extraskeletal Calcification.)

**HYPERPLASIA**

Hyperplasia is overgrowth of cells. Clotting in the middle of a vascular access graft is often caused by clumps of platelets that build up on areas of hyperplasia.

**HYPERSENSITIVITY**

Hypersensitivity is above normal sensitivity or allergy. Hypersensitivity reactions may occur most often with cuprophane (cellulose) dialyzers. This can cause anaphylaxis in some patients. (See also: Anaphylactic Reaction.)

**HYPERTENSION**

Hypertension is high blood pressure. Hypertension can be a cause or result of kidney failure; it is the second most common cause of kidney disease in the United States. Hypertension can damage the kidneys, heart, blood vessels, eyes, and other organs, and raise the risk of a stroke. Patients on in-center hemodialysis often must take more than one blood pressure drug to control hypertension.

**HYPO**

The prefix [hypo] means below, beneath, or too little. For example, a hypodermic needle is a needle that is inserted beneath the skin.

**HYPOCALCEMIA**

Hypocalcemia means not enough calcium (an electrolyte) in the blood. Hypocalcemia can cause tetany—spasms and twitching of the muscles—or seizures. Low blood calcium can occur in kidney disease due to the loss of calcitriol production by the failing kidneys. Calcitriol allows the body to absorb calcium from the diet. (See also: Electrolyte.)

**HYPOGLYCEMIA**

Hypoglycemia means below normal levels of sugar in the blood. In a patient with diabetes, this can cause hunger, nervousness, shaking, weakness, sweating, dizziness, sleepiness, confusion, or trouble speaking. The treatment is a fast-acting carbohydrate (e.g., juice). Reference Module
HYPOKALEMIA
Hypokalemia means below normal levels of potassium (an electrolyte) in the blood. This is rare in dialysis patients, but can occur if there is not enough potassium in the diet or in the dialysate. Hypokalemia can also be caused by a loss of potassium due to vomiting, diarrhea, use of potassium exchange resins, and use of diuretics that increase the loss of potassium in the urine (if the patient makes urine). (See also: Electrolyte.)

HYPONATREMIA
Hyponatremia means below normal levels of sodium (an electrolyte) in the blood. Without enough sodium, water moves out of the extracellular space and into cells, which can cause hypotension and hemolysis. Symptoms can include muscle cramping, restlessness, anxiety, pain in the access, headache, and nausea. (See also: Electrolyte.)

HYPOPHOSPHATEMIA
Hypophosphatemia means below normal levels of phosphorus in the blood. This is rare in dialysis patients, because phosphorus is found in most foods. It may occur if a patient has a poor diet and takes too many phosphate binders. Low levels of phosphorus can suggest malnutrition. Hypophosphatemia can cause cardiac arrhythmia or muscle weakness.

HYPOTENSION
Hypotension is low blood pressure. In dialysis patients, hypotension occurs most often when too much fluid is removed during dialysis, or when patients take too many blood pressure drugs. Symptoms include severe muscle cramps; headache; feeling warm, restless, dizzy, faint, or nauseated; or having visual disturbances. The Trendelenburg position (raising the feet higher than the heart) and giving fluids (i.e., normal saline) help return blood pressure to normal.

HYPOTONIC DIALYSATE
Hypotonic dialysate is dialysate that is diluted with too much water, which can lead to hemolysis (bursting of red blood cells).

IN-CENTER HEMODIALYSIS
In-center hemodialysis treatments are done in a hospital or dialysis center. Dialysis staff perform the treatments, although some patients may take their own vital signs, place their own needles, and monitor their own treatments. In-center treatments are most often done three days per week for about 3-4 hours. Some centers also offer nocturnal in-center hemodialysis, which is done for eight hours, three nights per week. The patients sleep at the center; this is a work-friendly treatment because it leaves patients days free.
INFECTION
An infection is a condition that occurs when the body is invaded by a disease-producing organism (e.g., bacteria).

INFECTION CONTROL
Infection control is a series of steps taken to prevent the spread of infection. Using aseptic technique for invasive procedures, disinfecting equipment after use, washing hands, and wearing protective equipment are all part of infection control. (See also: Hemodialysis Infection Control Precautions.)

INFILTRATION
Infiltration is abnormal leakage of a substance into body tissues. In dialysis patients, infiltration of blood into the tissues around the vascular access can occur if the needle punctures the back of the vessel wall. To prevent infiltration, perform needle insertion carefully. Use of the buttonhole technique for cannulation can reduce the risk of infiltration.

INFLAMMATION
Inflammation is tissue swelling in reaction to injury, infection, or surgery.

INSTILL
To instill is to place into or cause to enter. Heparin is instilled into each lumen of a catheter to prevent clotting in a dialysis catheter between treatments. Dialysate fluid is instilled into the peritoneum for peritoneal dialysis.

INTERDIALYTIC
Interdialytic means between dialysis treatments.

INTERMITTENT
Intermittent means periodically or not continuously. Heparin can be given intermittently during dialysis.

INTERNAL JUGULAR (IJ) CATHETER
Dialysis catheters may be placed in the internal jugular vein in the neck. This site is less likely to cause central venous stenosis than placement in the subclavian vein. (See also: Central Venous Stenosis.)

INTERSTITIAL SPACE
Interstitial space is the space between the cells or organ tissues.

Reference Module 328
INTIMA
The intima is the smooth lining of the inner surfaces of arteries and veins. The intima is covered with a thin, fragile layer of cells that allows blood to flow through the vessel easily. In a fistula or graft, overgrowth (hyperplasia) of the intima cells at the anastomosis can cause stenosis (narrowing), which makes blood clots more likely.

INTRACELLULAR
Intracellular means within the cells. Two thirds of fluid in the body is inside the cells. Sodium causes fluid to move across cell membranes between the intracellular and extracellular spaces.

INTRADERMAL
Intradermal means within the skin. Local anesthetics may be injected intradermally.

INTRAMUSCULAR
Intramuscular means within a muscle.

INTRAVASCULAR
Intravascular means within blood vessels.

INTRAVENOUS
Intravenous means within a vein. Many medications are injected intravenously.

IN VITRO
In vitro is a Latin phrase that means in an artificial environment. Dialyzer clearance is measured in vitro by the manufacturer, using non-blood fluids (i.e., saline). Actual dialyzer clearance may vary from the manufacturers' specifications.

IN VIVO
In vivo is a Latin phrase that means within a plant or animal. Tests performed on a dialyzer while a patient is being treated are considered in vivo.

ION
An ion is an electrically-charged particle. Ions can carry a positive charge (cation) or a negative charge (anion).
ION EXCHANGE
Ion exchange occurs inside a deionizer for water treatment. Unwanted ions are traded for hydrogen and hydroxyl ions to create pure water.

IRON DEFICIENCY
Iron deficiency is a lack of iron in the body to make red blood cells. Without iron, the bone marrow can’t make red blood cells, even if erythropoietin is present. Low levels of iron can cause a form of anemia.

ISCHEMIA
Ischemia is a lack of oxygen in the tissues, due to reduced blood flow. It can be painful. For example, ischemia of the heart can cause angina pain. Steal syndrome (ischemia of the hand) may cause hand pain during exercise; a cold, clammy feeling; and, in extreme cases, painful, non-healing skin ulcers. Limb ischemia can be caused by placement or complications of some vascular accesses, and, in severe cases, can lead to loss of a limb.

ISOLATED ULTRAFILTRATION (IU)
IU removes water, but not solutes. It uses the extracorporeal circuit and dialyzer without dialysate. IU is also called dry ultrafiltration, sequential ultrafiltration, or pure ultrafiltration. Isolated ultrafiltration can be done before, after, or without dialysis. The main advantage of IU is that fluid removal is better tolerated than with standard dialysis.

KDIGO
KDIGO stands for Kidney Disease: Improving Global Outcomes. It is a program started by the National Kidney Foundation (NKF) in 2003 to improve care and outcomes of kidney patients around the world by writing and implementing clinical practice guidelines.

KDOQI
KDOQI stands for Kidney Disease Outcomes Quality Initiative. (See also: Clinical Practice Guidelines.)

KIDNEY TRANSPLANT
A kidney transplant replaces the failed kidneys with a single healthy kidney from a donor. Only one healthy kidney is needed to live. It is possible to receive a kidney from a relative, spouse, friend, or deceased donor. Blood type and other tissue factors are used to match a recipient after a medical work-up has been done.

Reference Module
Kt/V
See: Urea Kinetic Modeling.

KUf
See: Coefficient of Ultrafiltration.

LARGE DIALYSIS ORGANIZATION (LDO)
An LDO is a corporation that owns many centers, often in different parts of the
country (dialysis chain).
Each year, LDOs grow in size as they buy independent, hospital-based, and smalle
r chains.

LEACH
Leaching occurs when a fluid passes through a substance and dissolves part of th
at substance. In water
treatment, copper, lead, or galvanized steel should not be used after the blendi
ng valve because water
can leach copper or zinc from the pipes.

LEAK TESTING
See: Pressure Testing.

LOADING DOSE
A loading dose is a dose of medication that creates a certain blood level in the
body. A loading dose of
heparin may be given after both needles are in place but before a treatment begi
ns, to allow the heparin
to flow through the patient’s bloodstream.

LOCAL INFECTION
A local infection is an infection only in one area such as in a fistula or graft a
nd its surrounding tissues.

LUMEN
The lumen is the inside diameter of a blood vessel or tube (i.e., catheter or ne
edle). In stenosis, the
lumen of the vascular access becomes narrower, which limits blood flow.

LYSE
To lyse is to dissolve. One option for treating a blood clot in a vascular acces
s is to use a drug that will
lyse the clot.
MAGNESIUM
Magnesium is a metallic mineral. It is found in the body as an electrolyte in the intracellular fluid; a small trace of magnesium in body fluids is vital to the nervous system.

MEDICARE ESRD PROGRAM
The Medicare ESRD Program was established by the U.S. Congress in 1972. The program gave Medicare benefits to patients with kidney failure who were entitled to Social Security benefits. The ESRD program pays for 80% of the allowable cost of dialysis treatment for eligible patients.

MEMBRANE COMPLIANCE
Membrane compliance is the ability of a membrane to change shape or volume due to pressure.

MEMBRANE FILTERS
Membrane filters are water treatment cartridges; they contain thin membranes with pores of a specified size. Membrane filters remove small particles and some solutes.

METABOLIC ACIDOSIS
Metabolic acidosis occurs when the acid/base balance of body fluid and tissues shifts toward acid due to a build-up of acid in the body. It is common in dialysis patients because their kidneys no longer reabsorb as much bicarbonate—a blood buffer that stabilizes blood pH. For this reason, bicarbonate is used as a buffer for dialysate.

METABOLISM
Metabolism is the sum of chemical processes that involves breaking down some substances and creating other substances.

METABOLIZE
To metabolize is to break down into a simpler substance.

METASTATIC CALCIFICATION
See: Extraskeletal Calcification.

 METHEMOGLOBINEMIA
Methemoglobinemia is loss of the oxygen-carrying ability of red blood cells.

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Microalbuminuria is the presence of tiny amounts of albumin (protein) in the urine. It can be an early sign of chronic kidney disease, because albumin is a large molecule that does not pass through healthy glomeruli. A class of blood pressure drugs called ACE inhibitors slows the rate of kidney failure in diabetic patients with microalbuminuria.

Microns are a unit of measure for filter pores. Filters with high micron sizes trap larger particles and allow smaller particles to flow through. A submicron filter may be needed to capture very small particles. (See also: Filters.)

Microorganisms are living things too small to be seen without a microscope, such as algae, fungi, bacteria, and viruses. Some can cause illness if they enter the body.

A modality is a type of treatment, such as hemodialysis, peritoneal dialysis, or transplant.

Molecular weight is a measure of the size of a molecule. The molecular weight of a substance is equal to the sum of the atomic weights of all elements in a molecule of the substance. Molecular weight is measured in Daltons (Da). Larger molecules (like beta-2-microglobulin) have higher molecular weights.

Molecular weight cutoff is the maximum solute size that can pass through a particular semipermeable membrane.

A molecule is the smallest complete unit of a substance that retains that substance's identity.

Morbidity is illness. Morbidity, sometimes measured as days of hospitalization, is used as one measure of patient outcomes.

Mortality is death. Mortality is used as a measure of patient outcomes.
MYALGIA
Myalgia is muscle pain.

MYOCARDIAL INFARCTION (MI)
Myocardial infarction is the blockage of a heart artery, which can lead to death of part of the heart muscle. The patient may feel severe or crushing chest pain—a heart attack. (See also: Arrhythmia.)

NANT
National Association of Nephrology Technicians/Technologists

NASOGASTRIC (NG) TUBE
A nasogastric tube is a tube that is inserted through the nose into the stomach. Patients who are malnourished may need to be fed through an NG tube.

NEEDLE SITE ROTATION
Needle site rotation is a technique used with fistulae and grafts to prevent damage that can occur when needles are placed many times in the same small area. At each treatment, needles are placed at least 1.5 inches away from the anastomosis and the sites used at the last treatment, moving up and down the entire length of the access. (See also: Buttonhole Technique.)

NEGATIVE PRESSURE
Negative pressure is pressure less than 0 mmHg. Negative pressure plus positive pressure equals transmembrane pressure (TMP).

NEOINTIMAL HYPERPLASIA
Neointimal hyperplasia occurs when smooth muscle cells at the venous anastomosis form extra layers of cells that fill up the graft lumen, reducing the blood flow. (See also: Intima.)

NEPHROLOGIST
A nephrologist is a licensed physician who specializes in kidney diseases.

NEPHROLOGY
Nephrology is the study of kidneys.

NEPHRON
A nephron is a tiny blood purification filter in the kidney, made up of a glomerulus and a tubule.
Nephrons filter wastes from the body and keep electrolyte and fluid balance. Each kidney has about a million nephrons.

NEUROPATHY
See: Peripheral Neuropathy.

NKF-KDOQI
See: Clinical Practice Guidelines.

NOCTURNAL HOME HEMODIALYSIS (NHHD)
Nocturnal home hemodialysis treatments are done for eight hours at night, while the patient sleeps at home. They may be done from three to six nights per week. Most home hemodialysis programs require the patient to have a partner; both must successfully complete several weeks of training. Dialysis needles and bloodline connections must be carefully taped to avoid line separation. Bedwetting alarms may be used to detect blood. Some programs monitor treatments over the Internet. The longer treatments allow for fewer fluid and diet limits, and most patients need few or no blood pressure drugs. Because the treatments are done at night, leaving days free, NHHD is a work-friendly treatment.

NORMAL SALINE
Normal saline is a sterile salt water solution containing 0.9% sodium chloride; this is equal to the concentration of sodium chloride found in the blood. In hemodialysis, normal saline is needed to prime and prepare the extracorporeal circuit. It may also be used for fluid replacement during the treatment.

NOSOCOMIAL
Nosocomial means hospital-acquired. The term is usually applied to infections or illnesses patients acquire during the course of their medical treatment.

OPPORTUNISTIC ILLNESSES
An opportunistic illness occurs when a patient’s immune system is impaired. Patients with AIDS, for example, are prone to these illnesses because their immune systems are weakened.

ORTHOSTATIC HYPOTENSION
Orthostatic hypotension is a drop in blood pressure of 15 mmHg or more that occurs when a person rises from sitting to standing.
OSMOSIS
Osmosis is the movement of fluid across a semipermeable membrane from an area of lower solute concentration (like blood) to an area of higher solute concentration (like dialysate) until the concentrations on both sides of the membrane are equal. Natural osmosis is too slow to produce enough fluid removal for hemodialysis, so fluid movement is aided by a hydraulic pressure gradient.

OSMOTIC GRADIENT
An osmotic gradient is a difference in the concentration of solutes on each side of a semipermeable membrane.

OSMOTIC PRESSURE
Osmotic pressure is a gradient created by using dialysate that contains substances, such as glucose, that cause fluid to move out of the blood and into the dialysate. (See also: Osmosis.)

PALPATE
To palpate is to examine by touching. Palpation of the thrill over the vascular access is one way to know if an access is working (patent).

PALPITATIONS
Palpitations are occasional, strong heartbeats that can be a symptom of cardiac arrhythmia.

PARATHYROID HORMONE (PTH)
PTH is a hormone produced by four parathyroid glands located in the neck. PTH is released into the bloodstream in large amounts when calcium levels are low—a common problem in patients with kidney failure—or when phosphorus levels are high. Too much PTH can cause bone disease. (See also: Calcium.)

PATENCY
Patency is a state of openness or lack of obstruction of a blood vessel or catheter. Before each dialysis treatment, patency of the patient’s access should be checked by listening for the bruit and feeling for the thrill.

PATHOGEN
A pathogen is an agent (such as bacteria) that causes disease in humans.

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PATIENT OUTCOMES
Patient outcomes are the results of care. Morbidity and mortality are common outcomes, but others such as functioning and well-being (the patient’s self-rated physical and mental health) are gaining in importance.

PERCUTANEOUS
Percutaneous means through the skin.

PERICARDIAL EFFUSION
Pericardial effusion is a build-up of fluid in the pericardium, or sac that surrounds the heart. In severe cases, pericardial effusion can lead to cardiac tamponade, a life-threatening problem in which fluid pressure makes it difficult or impossible for the heart to beat.

PERICARDITIS
Pericarditis is inflammation of the pericardium, the sac that surrounds the heart. Pericarditis causes low-grade fever, hypotension, and pain in the center of the chest that may be relieved by sitting up and taking deep breaths. Patients who are uremic or poorly dialyzed may be prone to pericarditis.

PERIPHERAL
Peripheral means away from the center of the body. For example, peripheral vascular disease affects the limbs, not the core, of the body.

PERIPHERAL NEUROPATHY
Peripheral neuropathy is nerve damage in the hands and feet. It causes symptoms of numbness, tingling, burning, pain, and weakness. In dialysis patients, neuropathy may be caused by one or more toxins retained in uremia and not well removed by hemodialysis. Diabetes can cause neuropathy. Neuropathy can also be caused by vascular access problems, which may lead to waste build-up due to inadequate dialysis. Many cases of peripheral neuropathy can be prevented or treated with adequate dialysis and adherence to diet.

PERIPHERAL VASCULAR RESISTANCE
Peripheral vascular resistance is a measure of how well the blood can flow through the blood vessels. A drop in peripheral vascular resistance (the blood vessels relax) will reduce the blood pressure if the heart cannot compensate. A rise in peripheral vascular resistance (the blood vessels narrow) will increase the blood pressure.
PERITONEAL DIALYSIS (PD)
Peritoneal dialysis uses the peritoneum (a blood-vessel-rich sac around the abdominal organs) as a semipermeable membrane to filter the blood. A catheter is surgically placed in the abdominal wall; it is used to allow sterile dialysate to fill the abdomen, dwell, and drain out. During the dwell time, wastes and excess fluid move from the blood across the peritoneum and into the dialysate by diffusion and osmosis. (See also: Continuous Ambulatory Peritoneal Dialysis, Continuous Cycling Peritoneal Dialysis, Dwell Time.)

PERITONEAL DIALYSIS ADEQUACY
Peritoneal dialysis (PD) adequacy is measurement of the dialysis dose to ensure that PD patients receive at least the minimum amount of treatment needed for survival. The KDOQI guidelines provide both recommended standards for adequacy and suggestions for attaining them.

PERITONEUM
The peritoneum is a smooth, thin layer of blood-vessel-rich tissue that covers the inside of the abdominal walls. The peritoneum forms a closed sac. Thus, it can be used as a semipermeable membrane and container for dialysate in peritoneal dialysis. (See also: Peritoneal Dialysis.)

PERITONITIS
Peritonitis is an infection of the peritoneum; it can occur when aseptic technique is not used during a peritoneal dialysis (PD) exchange. Peritonitis may cause scarring that can make further PD impossible.

PERMEABLE
Permeable means allowing substances to pass through. Cell membranes in the body are freely permeable to water, letting it pass in and out. Dialyzer membranes are semipermeable letting some substances through, but keeping others out.

pH
pH refers to the hydrogen ion concentration of a solution. A solution with a pH above 7 is alkaline, or a base. A solution with a pH below 7 is an acid. A solution with a pH of 7.0 is neutral. Normal body pH ranges between 7.35 and 7.45, slightly alkaline. The pH of dialysate must be kept within a certain range. Bicarbonate-buffered dialysate should have a pH of 7.2 to prevent bacterial growth and scale that could harm equipment. AAMI recommends that test water with a pH between 5.0 and 8.5 be used to mix dialysate. (See also: AAMI, Acid, Base, Bicarbonate.)

Reference Module
PHOSPHATE BINDERS
Phosphate binders are drugs that bind with phosphorous in food so the phosphorus is not absorbed in the intestines. Phosphorus is then eliminated in the stool. Patients should take more binders with larger meals and fewer binders with small meals or snacks.

PHOSPHORUS
Phosphorus is a nonmetallic element present in dairy products, meat, poultry, fish, nuts, peanuts, chocolate, and colas. It is hard to avoid in the diet, and damaged kidneys cannot remove all the excess phosphorus from the blood. Too much phosphorus in the blood can cause itching, secondary hyperparathyroidism, and bone disease. Phosphorus levels are checked monthly before dialysis; most people with kidney failure take phosphate binders to control phosphorus. (See also: Secondary Hyperparathyroidism.)

PLASTICIZER
A plasticizer is a chemical that makes plastic flexible. Priming the dialyzer and blood tubing before use with saline helps remove residual plasticizers from manufacturing that could harm patients.

PLATELETS
Platelets are blood cells that promote clotting by clumping together when activated by signals sent by injured cells.

PNEUMOTHORAX
A pneumothorax is air in the chest cavity that keeps the lungs from expanding. Pneumothorax can occur during central venous catheter placement if the catheter punctures a blood vessel and passes into the space between the lungs and the chest wall.

POLYCYSTIC KIDNEY DISEASE (PKD)
PKD is a genetic disease that causes large, fluid-filled cysts to develop in the kidneys, liver, and sometimes the brain. The cysts can become so large and numerous that they crowd out normal kidney tissue, which can cause kidney failure.

PORES
Pores are holes. In a semipermeable dialyzer membrane, membrane filter, or reverse osmosis unit, the pores are designed to allow solutes of a certain size range to pass through, while trapping solutes that are larger.
POSITIONAL
Positional means affected by the patient’s body position. When hemodialysis catheters are positional, blood flow can be reduced when the patient moves. If the patient coughs or moves again, blood flow may improve because the catheter may move within the blood vessel.

POSITIVE PRESSURE
Positive pressure is pressure greater than 0 mmHg. In dialysis, positive pressure is created when the blood pump pushes blood through the dialyzer. Inside the dialyzer, positive pressure helps to push fluid through the membrane pores. Positive and negative pressure together equal transmembrane pressure.

POSTDIALYSIS PRESSURE
See: Venous Pressure.

POST-PUMP (ARTERIAL) PRESSURE
See: Predialyzer Pressure.

POTASSIUM
Potassium is a metallic element, and an important electrolyte in the human body. Levels of potassium that are too high or too low can cause illness or death in patients; levels must be kept within very tight limits. (See also: Electrolyte, Hyperkalemia, Hypokalemia.)

PRECIPITATE
See: Scale.

PREDIALYZER PRESSURE
Predialyzer pressure is the positive pressure after the blood pump and before the dialyzer. Predialyzer pressure is also called post-pump pressure, or post-pump arterial pressure.

PREPROCESSING
Preprocessing means putting a new dialyzer through all the reprocessing steps before it is used for the first time. This helps remove residual ETO or other substances used in manufacturing that might cause allergic reactions.

PRE-PUMP ARTERIAL PRESSURE
Pre-pump arterial pressure is measured between the patient’s arterial needle and the blood pump. It represents the negative pressure created by the blood pump. Arterial pressure monitoring guards against too much suction on the vascular access.

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PRESSURE
Pressure is force applied by something that comes in contact with an object. In the human body, blood pressure is the combination of force from the heart and resistance in the blood vessels. In hemodialysis, pressure is the combination of flow from the blood pump and resistance in the dialyzer and extracorporeal circuit.
PRESSURE GRADIENT
See: Transmembrane Pressure.
PRESSURE TESTING
Pressure testing, or leak testing, ensures that a dialyzer membrane is intact and no blood loss will occur during the next use. Pressure testing must be part of the reuse process. (See also: Reprocessing.)
PRIMING
In dialysis, priming is getting the bloodlines and dialyzer ready for use by flushing them with normal saline. Dialysate is used to prime the dialysate compartment. Priming is done before dialysis to remove air, disinfectants, and some plasticizers from the extracorporeal circuit and dialysate side of the dialyzer.
PRODUCT WATER
Product water is water that has been forced through a reverse osmosis membrane.
PROPORTIONING SYSTEM
A proportioning system is a type of dialysate delivery system. This system mixes liquid concentrate with measured amounts of treated water to form dialysate and deliver it to the dialyzer. There are two types: fixed-ratio pumps and servo-controlled mechanisms. Both systems use dual conductivity meters to check the mixed dialysate continuously and to support the system, should one monitor fail. (See also: Hemodialysis Delivery System.)
PROTEINURIA
Proteinuria means protein in the urine. When the kidneys are damaged, protein can leak through the glomeruli into the renal tubules, and then into the urine. (See also: Microalbuminuria.)
PROXIMAL
Proximal means near. In anatomy, proximal is near the center of the body (e.g., the shoulder is proximal to the hand).
PRURITUS
Pruritus is severe itching. Itching may develop in patients with kidney failure due to dry skin or a build-up of calcium phosphate crystals in the skin. Adequate dialysis, good management of calcium and phosphorus, limiting bathtub soaks (which dry out skin), and use of some lotions or creams can help reduce itching.

PSEUDOANEURYSM
A pseudoaneurysm is a false aneurysm: a bulging pocket of blood around a fistula or, more commonly, a graft. Pseudoaneurysms can occur if a graft has been damaged by repeated punctures in the same area. They can rupture, which is a medical emergency. A graft with a pseudoaneurysm may need to be repaired or replaced. (See also: Aneurysm.)

PULMONARY EDEMA
Pulmonary edema is fluid build-up in the lungs. Fluid overload or failure to remove enough fluid during dialysis can cause or worsen pulmonary edema. (See also: Congestive Heart Failure.)

PUMP OCCLUSION
Pump occlusion is the amount of space between the rollers of the blood pump and the pump housing. The rollers should compress the blood tubing segment against the pump housing enough to close the lumen completely. Overocclusion creates excess pressure that may crack the tubing and cause the pumping segment to rupture. If occlusion is not complete, there will be backflow of blood with each pump stroke.

PURE ULTRAFILTRATION
See: Isolated Ultrafiltration.

PURPURA
Purpura is bleeding under the skin, which may be a symptom of too much heparin or a platelet dysfunction.

PYROGEN
A pyrogen is a fever-producing substance, such as endotoxin.

PYROGENIC REACTION
Pyrogenic (fever) reactions are caused by pyrogens (such as endotoxin). Symptoms may include chills, shaking, fever, hypotension, vomiting, and muscle pain. Patients may have pyrogenic reactions if there is a break in water treatment or if a reprocessed dialyzer contains endotoxin.

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QUALITY ASSURANCE (QA)
QA is way to monitor, evaluate, and improve care. It is based on measuring center quality of care against benchmark standards. (See also: Continuous Quality Improvement.)

RADIAL PULSE
The radial pulse is the pulse felt on the thumb side of the wrist.

RADIOCEPHALIC FISTULA
A radiocephalic fistula connects the radial artery and cephalic vein in the distal forearm. This is the most common type of AV fistula.

REAGENT
A reagent is a material that will react in the presence of a certain chemical. Reagent strips are used to be sure that all chemical residues are removed from a reprocessed dialyzer or the dialysis delivery system, or to test for the presence of blood in dialysate. (See also: Hemastix.)

RECIRCULATION
Recirculation occurs when dialyzed blood coming back to the patient through the venous needle mixes with undialyzed blood going out through the arterial needle. Blood entering the dialyzer can thus be diluted with blood that has just left the dialyzer. This occurs if there is retrograde flow through the access between the arterial and venous needles. Recirculation of more than 15% is significant, and reduces treatment adequacy.

REJECTION
Rejection occurs when the immune system of a transplant patient attacks the transplanted organ because it is foreign to the body. The patient’s blood and tissue types are matched to the organ to reduce this risk. Matching means the body is less likely to attack the organ as foreign. Immunosuppressant drugs are also used to reduce the body’s immune response to the new organ.

REJECT WATER
Reject water is the waste or reject stream that is sent to the drain along with the solutes removed by reverse osmosis.

RENAL OSTEO DySTROPHY
Renal osteodystrophy is bone disease that is caused by too high or too low levels of PTH. (See also: Secondary Hyperparathyroidism.)

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REPROCESSING
Reprocessing is cleaning and disinfecting dialyzers and, in some cases, bloodlines, to be used again by the same patient. Done carefully, reprocessing reduces the cost of dialyzers and offers some benefits to patients. The hazardous chemicals used in reprocessing must be handled with care by staff. A number of regulations and guidelines are in place to protect patients and staff when reprocessed dialyzers are used.

RESISTANCE
Resistance is created by any factor that partly obstructs flow. In dialysis, there is resistance against the flow of blood in the blood vessels or in the extracorporeal circuit. Flow and resistance influence pressure.

RESISTIVITY
Resistivity is the measure of the forces that oppose the flow of electricity through a fluid. (See also: Conductivity.)

RETROGRADE
Retrograde means against the direction of blood flow. In a fistula or graft, retrograde flow is backward, toward the anastomosis. The arterial needle may be placed either retrograde or antegrade in the access.

REUSE
See: Reprocessing.

REVERSE OSMOSIS (RO)
RO is a membrane separation process for removing solutes from a solution. A reverse osmosis unit is a cartridge that holds a water pressure pump and a semipermeable membrane. The RO membrane can remove 90% to 99% of many substances, including bacteria, endotoxin, viruses, salts, particles, and dissolved organics. RO membranes are used to treat water used for hemodialysis or reprocessing.

RO membranes are costly and delicate. To avoid damage, other water treatment components are used to remove particles in feed water before it reaches the RO membrane.

RINSEBACK
Rinseback is the process of using saline to flush the patient’s blood back into the body after dialysis.

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ROLLER PUMP
A roller pump is the most common type of blood pump. A motor turns the roller head, moving blood through the extracorporeal circuit. (See also: Pump Occlusion.)

ROPE LADDER TECHNIQUE
See: Needle Site Rotation.

SALINE INFUSION LINE
The saline infusion line allows saline to be given to the patient during dialysis. It is connected to the arterial blood tubing segment just before the blood pump, so saline can be pulled into the circuit.

SCALE
Scale, or precipitate, is solid particles that settle out of a solution (e.g., water, dialysate) and can clog pipes or damage components of the water treatment system. Hard water, which contains more minerals and salts, can form scale.

SECONDARY HYPERPARATHYROIDISM
Secondary hyperparathyroidism is the release of excess parathyroid hormone (PTH) due to kidney failure, which can cause bone disease. With too much PTH in the blood, calcium is withdrawn from the bones, making them weak. The condition is treated with phosphate binders and calcitriol supplements, which reduce PTH, calcium, and phosphorus levels.

SEDIMENT FILTER
See: Filters.

SEIZURES
Seizures are involuntary muscle spasms and loss of consciousness. Some patients may have seizures as a dialysis side effect (severe hypotension). Or, seizures may occur during dialysis as an adverse reaction to a problem such as the use of improperly prepared dialysate.

SELF-CARE HEMODIALYSIS
Self-care hemodialysis is done in-center; patients do most or all of their own care with little staff assistance. Self-care patients may set up their own machines, insert needles, take their own vital signs, monitor the treatment, and clean up their station after treatment. Taking part in self-care at some level helps patients regain control of their lives, and helps their rehabilitation.
SEMIPERMEABLE MEMBRANE
A semipermeable membrane is a material with microscopic openings or pores. In hemodialysis, the pores allow some substances (such as water) to pass through freely, while keeping other substances (such as red blood cells) from passing through. The membrane pore size is one factor that affects dialysis efficiency. Solute particles that are larger than the pores are retained. Very small particles pass through the membrane more quickly than larger particles.

SEPSIS/SEPTICEMIA
Sepsis is a life-threatening blood infection caused by bacteria that enter the bloodstream. It is also called septicemia or bacteremia.

SEQUENTIAL ULTRAFILTRATION
See: Isolated Ultrafiltration.

SERUM
Serum is the clear liquid that can be separated from blood. Many blood tests are run on serum; for example, tests for serum calcium and serum phosphorus.

SHORT DAILY HOME HEMODIALYSIS (SDHHD)
Short daily home hemodialysis is 2–3 hour treatments done at home 5–7 days per week. Most home hemodialysis programs require the patient to have a partner; both must successfully complete several weeks of training. The more frequent treatments allow for fewer fluid and diet limits. Because the treatments are done on the patient’s own schedule, SDHHD is a work-friendly treatment.

SHUNT
A shunt is a tube that is inserted into the body. A shunt, or cannula, was the first permanent vascular access for dialysis developed in 1960 by Dr. Belding Scribner and Dr. Wayne Quinton. A Teflon® tube was used to connect a flexible length of Silastic® tubing to a patient’s artery and vein creating a vascular access that could be used for multiple dialysis treatments, so patients with chronic kidney failure could receive dialysis. Since the shunt was outside the skin, it easily became infected or clotted, and is no longer used.

Reference Module
SIEVING COEFFICIENT (SC)
The sieving coefficient is the amount of solute removed from a solution by convection (solvent drag).

SODIUM
Sodium is an element and an electrolyte in the body. Sodium causes fluid to move across the cell membranes between the intracellular and extracellular spaces. Sodium is present in dialysate. Too little sodium in dialysate can cause hemolysis. Too much sodium in dialysate can cause crenation.

SODIUM MODELING
Sodium modeling is tailoring the concentration of sodium in the dialysate throughout the treatment to fit the needs of a patient, according to the nephrologist’s prescription. This sodium variation can create more efficient fluid shifts in the body, and thus more effective fluid removal, as well as better control of blood pressure. However, sodium modeling may cause thirst, so patients drink more fluid after dialysis and their blood pressure rises between treatments.

SOLUTE
A solute is a particle dissolved in fluid. Many of the wastes that need to be removed from the blood of kidney patients (such as urea) are solutes dissolved in the blood. Solute size is measured by molecular weight. Different semipermeable membrane materials are more or less efficient at removing solutes of a certain size.

SOLUTION
A solution is a combination of a solvent (fluid) and a solute.

SOLVENT
A solvent is a fluid in which substances are dissolved, e.g., water.

SOLVENT DRAG
Solvent drag occurs when molecules of a dissolved substance are dragged along in a solvent that passes through a semipermeable membrane. Solvent drag is also called convection, or convective solute transfer.

SORBENT DIALYSIS SYSTEMS
A sorbent dialysis system uses a sorbent cartridge, with several chemical layers, to create and then regenerate dialysate. Six liters of tap water and premixed chemicals are needed to make dialysate, and the cartridge takes on the functions of a water treatment system. No additional water is needed. The system needs no drain and can be used anywhere with an electrical outlet (or suitable generator).
SPORE
Spores are the reproductive form of bacteria or fungi, and are very resistant to heat. Bleach is effective against many spores. (See also: Bacteria, Disinfectant, Heat Disinfection.)

STAFF-ASSISTED DIALYSIS
See: In-center Hemodialysis.

STANDARD PRECAUTIONS
See: Hemodialysis Infection Control Precautions.

STANDING ORDERS
Standing orders are orders that stay the same; they are written by the physician to meet patients’ usual treatment needs. The orders should include all aspects of the care of renal patients (i.e., blood flow rate, dialysate flow rate, dialyzer, and dialysate composition).

STEAL SYNDROME
Steal syndrome occurs when a fistula or graft steals too much blood away from the distal part of the limb (hand or foot). When the access is in use during dialysis, some of the patient’s blood bypasses the hand or foot and goes through the extracorporeal circuit instead. The resulting loss of blood flow (ischemia) can damage tissue. Signs of this problem include coldness, poor function, and even gangrene if it is not addressed promptly.

STENOSIS
Stenosis is narrowing of a blood vessel. Stenosis slows the flow of blood and causes turbulence inside the vessel, setting the stage for more serious complications such as thrombosis.

STENTS
Stents are small, expanding metal rings that can be placed inside a fistula or graft or blood vessels that the fistula or graft feeds into to help keep the lumen from narrowing.

STERILANT
A sterilant is a germ-killing solution. Sterilants are used in reprocessing dialyzers.

STERILE
Sterile means completely free of all living organisms (bacteria, viruses, microorganisms).

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STERILE TECHNIQUE
See: Aseptic Technique.

STERILIZATION
Sterilization is destruction of bacteria with chemicals or heat.

SUBCLAVIAN CATHETER
A subclavian catheter is a catheter placed in the subclavian vein. According to KDOQI Clinical Practice Guidelines for Vascular Access, the subclavian vein should not be used for a dialysis catheter. The internal jugular vein is preferred, because it is less likely to cause central venous stenosis.

SUBCUTANEOUS
Subcutaneous means under the skin. Some medications, such as Lidocaine®, a local anesthetic, are injected subcutaneously.

SURFACE AREA
Surface area in hemodialysis is the amount of membrane in direct contact with blood and dialysate. A larger surface area (in hemodialysis or peritoneal dialysis) allows more diffusion. Large surface area dialyzers normally have more urea clearance. (See also: Diffusion.)

SYNTHETIC
See: Artificial.

SYSTEMIC
Systemic means affecting the entire body. For example, sepsis is a systemic infection.

SYSTOLIC
Systolic pressure is the pressure inside the arteries during a heartbeat. It is the top number of a blood pressure reading. (See also: Diastolic.)

TEMPERATURE ALARM
A temperature alarm indicates that the dialysate temperature is too high or too low. Dialysate that is too hot can cause hemolysis. Too-cool dialysate can cause patient discomfort and reduce the efficiency of the treatment.

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TEMPORARY CATHETERS
A temporary catheter is a central venous catheter that is used for short-term vascular access, for example, when a fistula has not matured. According to KDOQI Clinical Practice Guidelines for Vascular Access, the preferred site for a temporary catheter is the internal jugular (IJ) or femoral vein. Temporary catheters may be stitched, or sutured, in place.

THRILL
The thrill is the vibration of blood flowing through the patient’s fistula or graft. It can be felt by touching a patient’s access.

THROMBECTOMY
A thrombectomy is surgery or drug treatment (i.e., with a clot-dissolving medication) to remove a thrombus, or blood clot.

THROMBOLYSIS
Thrombolysis is the process of injecting a drug to dissolve a thrombus. Thrombolysis may be followed by surgery.

THROMBOSIS
Thrombosis is the formation of a thrombus, or blood clot. Thrombosis is the most common cause of access failure. Early thrombosis in a graft or fistula is most often caused by surgical problems with the anastomosis, or by twisting of the vessel or graft.

THROMBUS
A thrombus is a clot formed in a blood vessel or a blood passage. A clot may occur when platelets are activated by contact with damaged blood vessel walls, dialyzer materials, or turbulence inside a blood vessel.

TOTAL CELL VOLUME (TCV)
See: Fiber Bundle Volume.

TOTAL PARENTERAL NUTRITION (TPN)
TPN is a form of intravenous feeding to provide nutrients to patients who cannot eat or absorb food through their gastrointestinal tracts. Interdialytic parenteral nutrition (IDPN) is TPN given during dialysis.

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TRANSDUCER PROTECTORS
Transducer protectors are small plastic caps containing filters that keep blood or fluid from entering the pressure monitors on the dialysis machine. The transducer protectors are connected to the arterial and/or venous pressure monitors. The monitoring lines are connected to the transducer protectors.

TRANSMEMBRANE PRESSURE (TMP)
TMP is the pressure across the dialyzer membrane (blood compartment pressure plus dialysate compartment pressure). To keep dialysate from moving into the bloodstream, blood compartment pressure must be equal to or greater than dialysate compartment pressure.

TRENDELENBURG POSITION
The Trendelenburg position puts the head at a 45° incline, with the legs up. This helps relieve hypotension by bringing more blood to the brain. Patients who may have an air embolism should be placed in Trendelenburg position on their left sides.

UKM
See: Urea Kinetic Modeling.

ULTRAFILTER
An ultrafilter is a fine membrane filter that removes very small particles; it is the most effective water treatment component for removing bacteria endotoxin.

ULTRAFILTRATION (UF)
In hemodialysis, UF is filtration caused by a pressure gradient between two sides of a porous (filtering) material. The rate of UF depends on the transmembrane pressure and the characteristics of the dialyzer.

ULTRAFILTRATION RATE (UFR)
The UFR is the rate at which fluid moves from the blood into the dialysate through the semipermeable membrane. This rate depends on transmembrane pressure and the membrane characteristics. The UFR is calculated by dividing the amount of fluid to be removed by the minutes of treatment time. In ultrafiltration control or volumetric machines, dialysate inflow and outflow are exactly balanced through special pumps. (See also: Transmembrane Pressure.)

ULTRAVIOLET (UV) LIGHT
UV is a form of invisible radiation that can destroy microorganisms by changing their DNA (genes) so they cannot multiply. Some microorganisms are more sensitive to the effects of UV light than others.
UV light is generated by a mercury vapor lamp that emits light at a specific wavelength, housed inside a quartz sleeve. Feed water flows over the quartz material and is exposed to the UV light.

UREA KINETIC MODELING (UKM)
Urea kinetic modeling refers to changes in a patient’s blood urea level during a dialysis treatment. UKM is used to assess whether a patient’s dialysis is adequate. UKM also can help a doctor predict the required treatment time, and check a patient’s protein catabolic rate to better meet the patient’s dialysis and nutritional needs. The results of UKM are described as Kt/V, in which K is the dialyzer urea clearance in mL/min, t is treatment time in minutes, and V is the volume of blood in which the urea is distributed. Postdialysis BUN levels must be drawn using the slow flow, or stop pump technique to ensure accuracy of the Kt/V result. (See also: Hemodialysis Adequacy.)

UREA REDUCTION RATIO (URR)
URR is the simplest way to estimate the delivered dose of dialysis, but it does not provide all the information needed to prescribe a treatment. BUN levels are measured before and after treatment; the difference is how much urea was removed during the treatment. (See also: Hemodialysis Adequacy.)

UREMIA
Uremia is a build-up of wastes in the blood that occurs in the last stage of kidney failure or in patients who are not receiving adequate dialysis. Patients with uremia may have yellow-gray skin, edema, hypertension, flu-like symptoms, dyspnea, fatigue and weakness, and mental changes. If uremic symptoms appear when a patient is on dialysis, it means that more dialysis is needed. (See also: Hemodialysis Adequacy.)

USRDS
United States Renal Data System

VASCULAR ACCESS
The vascular access is a way to gain repeated entry to the patient’s bloodstream for hemodialysis. A vascular access must permit high enough blood flow rates to ensure effective dialysis. There are three types of access. A fistula is a surgical connection between a patient’s artery and a vein. A graft connects an artery and vein with a piece of artificial vein. A catheter is a plastic tube inserted into a central vein. The vascular access is the patient’s lifeline; great care must be taken to protect it through good cannulation and needle site rotation or use of the buttonhole technique.

VASOCONSTRICT
To vasoconstrict means to tighten the blood vessels.

Reference Module
VASOCONSTRICTOR
A vasoconstrictor is a drug that causes the blood vessels to constrict.

VEIN
A vein is a blood vessel that carries blood back to the heart.

VENIPUNCTURE
Venipuncture is inserting a needle into a blood vessel. Skilled and gentle venipuncture prolongs the life of a patient’s access and enhances patient comfort. Proper venipuncture also helps ensure that the patient will receive a good dialysis treatment. It is also important to rotate venipuncture sites or use the buttonhole technique to avoid causing aneurysms or pseudoaneurysms to form in the patient’s access. (See also: Buttonhole Technique, Needle Site Rotation.)

VENOUS PRESSURE
Venous pressure is the measurement of the extracorporeal blood circuit pressure after the dialyzer and before the blood reenters the patient’s body. It may also be called postdialyzer pressure.

VENOUS PRESSURE HIGH/LOW ALARM
The venous pressure alarm monitors pressure from the monitoring site to the patient’s venous puncture site.

VIRUS
A virus is a microorganism that must obtain energy and food from other living cells. Many diseases, such as the common cold, measles, polio, and HIV, are caused by viruses. Although tiny, viruses are too large to cross an intact dialyzer membrane. If the membrane is damaged, any viruses in the dialysis water could enter the patient’s blood. Viruses can be killed by various chemicals.

VOLUMETRIC
Volumetric means volume-measuring. Most dialysate delivery systems use volumetric fluid-balancing systems that compare the volume of dialysate entering and leaving the dialyzer. With volumetric control, the delivery system can be programmed to remove precisely the prescribed amount of fluid, delivering an exact prescription for ultrafiltration.

WATER SOFTENER
A water softener is used in water treatment to reduce the concentration of calcium and magnesium that form scale. Water softeners work by ion exchange. Ions of calcium and magnesium are removed from the water by a bed of electrically charged resin beads and traded for sodium ions, which form sodium chloride.
Abbreviations
ARBD: aluminum-related bone disease
AV: arteriovenous
APD: automated peritoneal dialysis
BUN: blood urea nitrogen
CAPD: continuous ambulatory peritoneal dialysis
CCPD: continuous cycling peritoneal dialysis
CFU: colony-forming unit
CHF: congestive heart failure
CKD: chronic kidney disease
CQI: continuous quality improvement
CRRT: continuous renal replacement therapy
EDW: estimated dry weight
EPO: erythropoietin
ESRD: end-stage renal disease
ETO: ethylene oxide
FBV: fiber bundle volume
GFR: glomerular filtration rate
Hct: hematocrit
Hgb: hemoglobin
HIPAA: Health Insurance Portability and Accountability Act
HIV: human immunodeficiency virus
IJ: internal jugular
IU: isolated ultrafiltration
K: clearance
Kt/V: measure of adequacy
KUF: coefficient of ultrafiltration
LDO: large dialysis organization
MI: myocardial infarction
NG: nasogastric
PD: peritoneal dialysis
pH: measure of acidity
PTH: parathyroid hormone
QA: quality assurance
RO: reverse osmosis
SDHHD: short daily home hemodialysis
SC: sieving coefficient
TCV: total cell volume
TMP: transmembrane pressure
TPN: total parenteral nutrition
UF: ultrafiltration
UFR: ultrafiltration rate
UKM: urea kinetic modeling
UV: ultraviolet
URR: urea reduction ratio
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Organizations
AAKP American Association of Kidney Patients
AAMI Association for the Advancement of Medical Instrumentation
ADA American Diabetes Association
AKF American Kidney Fund
ANNA American Nephrology Nurses Association
ASN American Society of Nephrology
BONENT Board of Nephrology Examiners Nursing and Technology
CBNT Certified in Biomedical Nephrology Technology
CCHT Certified Clinical Hemodialysis Technician
CCNT Certified in Clinical Nephrology Technology
CMS Centers for Medicare and Medicaid Services
DFC Dialysis Facility Compare
FDA Food and Drug Administration
KDIGO Kidney Disease: Improving Global Outcomes
KDOQI Kidney Disease Outcomes Quality Initiative (also, NKF-KDOQITM)
NANT National Association of Nephrology Technicians/Technologists
NKF National Kidney Foundation
NRAA National Renal Administrators Association
PKD Foundation Polycystic Kidney Disease Foundation
RPA Renal Physicians Association
RSN Renal Support Network
UNOS United Network for Organ Sharing
USRDS United States Renal Data System
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Weights and Measures

Liquid Measurement
1 fluid ounce = 29.572 milliliters (approximately 30 mL)
1 cup = 8 fluid ounces = 236.565 milliliters (approximately 240 mL)
1 quart = 32 fluid ounces = 0.9463 liters (approximately 945 mL)
1 liter = 1.0567 quarts = 0.26417 gallons
1 gallon = 4 quarts = 3.7853 liters (approximately 3785 mL)

Metric Liquid Measures
10 milliliters (mL) = 1 centiliter
10 centiliters = 1 deciliter (dL)
10 deciliters = 1,000 milliliters = 1 liter (L)
10 liters = 1 decaliter
10 decaliters = 1 hectoliter
10 hectoliters = 1 kiloliter

Length
1 inch = 2.54 centimeters
1 millimeter (mm) = 0.03937 inches
1 centimeter (cm) = 0.01 meters
1 meter (m) = 39.37 inches

Weight
1 gram = 0.035273 avoirdupois ounces (approximately 1/28 oz)
1 ounce = 28.35 grams
1 nanogram = 1 billionth of a gram
1 avoirdupois oz = 28.349527 grams (approximately 28 g)
1,000 grams = 1 kilogram (kg) = 2.20462 avoirdupois pounds (approximately 2.2 lb)
1 avoirdupois lb = 0.453592 kilograms (approximately 0.45 kg)

Reference Module 356
Metric Weight
10 milligrams = 1 centigram
10 centigrams = 1 decigram
10 decigrams = 1,000 milligrams = 1 gram
10 grams = 1 decagram
10 decagrams = 1 hectogram
10 hectograms = 1,000 grams = 1 kilogram
100 kilograms = 1 quintal
10 quintals = 1 ton

Linear Measures
10 millimeters = 1 centimeter
10 centimeters = 1 decimeter
10 decimeters = 1,000 millimeters = 1 meter
10 meters = 1 decameter
10 decameters = 1 hectometer
10 hectometers = 1,000 meters = 1 kilometer

Metric Square Measures
100 sq. millimeters = 1 sq. centimeter
100 sq. centimeters = 1 sq. decimeter
100 sq. decimeters = 10,000 sq. centimeters = 1 sq. meter
100 sq. meters = 1 sq. decameter
100 sq. decameters = 1 sq. hectometer
100 sq. hectameters = 1,000,000 sq. meters = 1 sq. kilometer

Metric Cubic Measures
1 milliliter (mL) = 1 cubic centimeter (cc)
1,000 cubic millimeters = 1 cubic centimeter
1,000 cubic centimeters = 1 cubic decimeter
1,000 cubic decimeters = 1,000,000 cubic centimeters = 1 cubic meter

Temperature Conversion
Fahrenheit temperature (°F) = (°C x 1.8) + 32
Celsius temperature (°C) = (°F − 32) ÷ 1.8
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