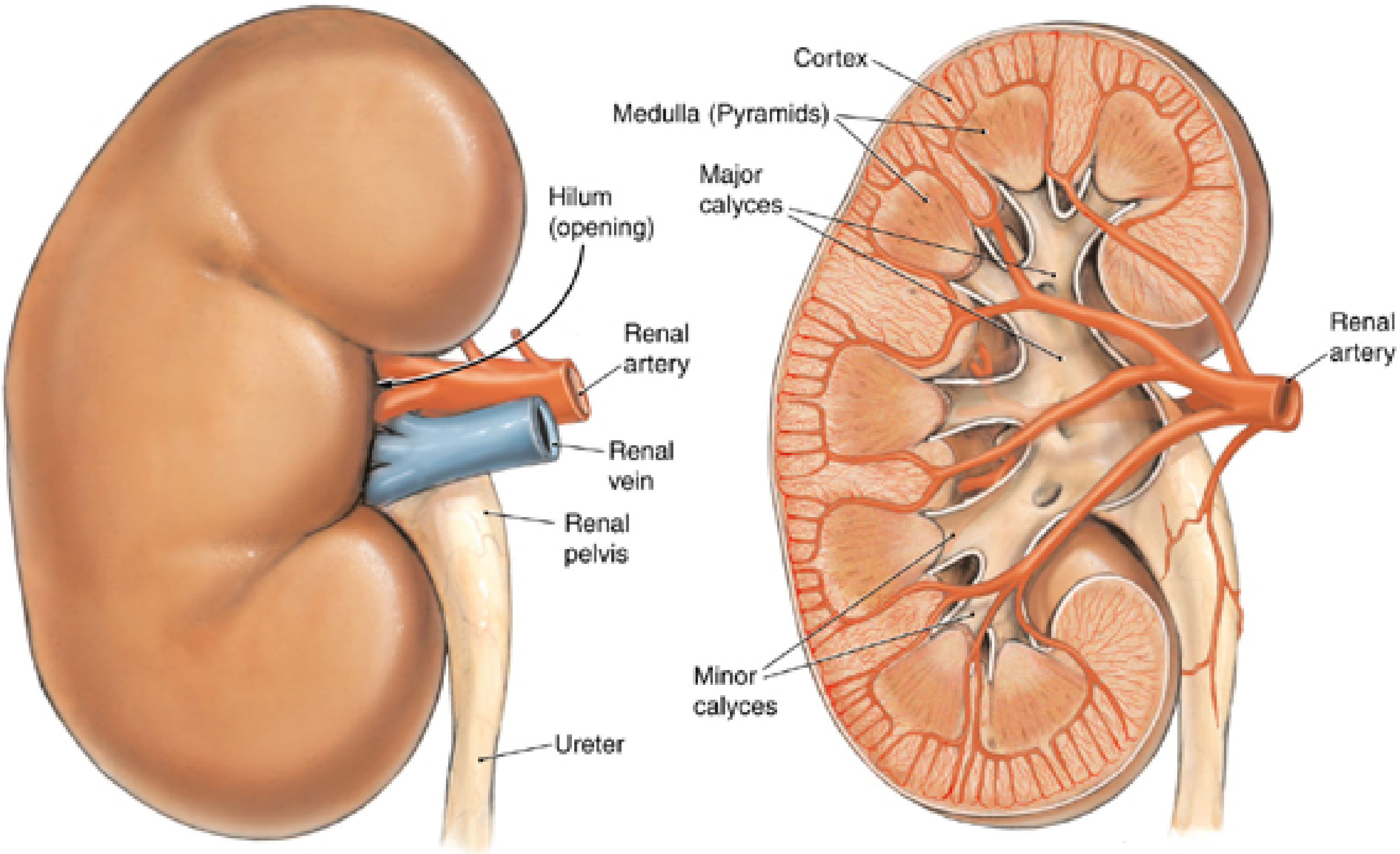
Urologic Surgeries and Procedures



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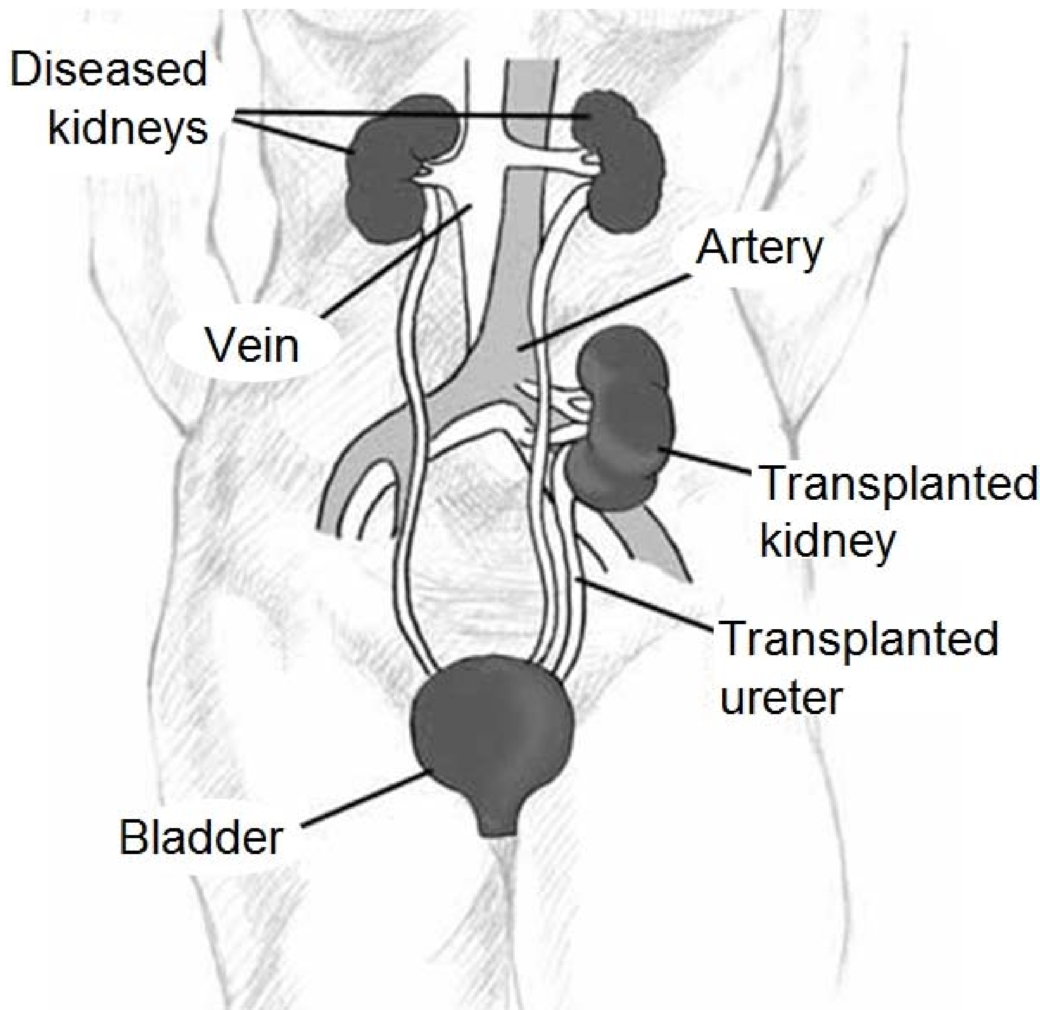
Kidney Transplantation



The donor kidney is typically placed inferior of the normal anatomical location.

Kidney transplantation or **renal transplantation** is the organ transplant of a kidney into a patient with end-stage renal disease. Kidney transplantation is typically classified as deceased-donor (formerly known as cadaveric) or living-donor transplantation depending on the source of the donor organ. Living-donor renal transplants are further characterized as genetically related (living-related) or non-related (living-unrelated) transplants, depending on whether a biological relationship exists between the donor and recipient.

History

The first cadaveric kidney transplantation in the United States was performed June 17, 1950, on Ruth Tucker, a 44-year-old woman with polycystic kidney disease, at Little Company of Mary Hospital in Evergreen Park, Illinois. Although the donated kidney was rejected ten months later because no immunosuppressive therapy was available at the time—the development of effective antirejection drugs was years away—the intervening time gave Tucker's remaining kidney time to recover and she lived another five years.

The first kidney transplants between living patients were undertaken in 1954 in Boston and Paris. The Boston transplantation, performed on December 23, 1954, at Brigham Hospital was performed by Joseph Murray, J. Hartwell Harrison, John Merrill and others. The procedure was done between identical twins to eliminate any problems of an immune reaction. For this and later work, Dr. Murray received the Nobel Prize for Medicine in 1990. The recipient died eight years after the transplantation.

The first kidney transplantation in the United Kingdom did not occur until 1960, when Michael Woodruff performed one between identical twins in Edinburgh. Until the routine use of medications to prevent and treat acute rejection, introduced in 1964, deceased donor transplantation was not performed. The kidney was the easiest organ to transplant: tissue typing was simple, the organ was relatively easy to remove and implant, live donors could be used without difficulty, and in the event of failure, kidney dialysis was available from the 1940s. Tissue typing was essential to the success: early attempts in the 1950s on sufferers from Bright's disease had been very unsuccessful.

The major barrier to organ transplantation between genetically non-identical patients lay in the recipient's immune system, which would treat a transplanted kidney as a "non-self" and immediately or chronically, reject it. Thus, having medications to suppress the immune system was essential. However, suppressing an individual's immune system places that individual at greater risk of infection and cancer (particularly skin cancer and lymphoma), in addition to the side effects of the medications.

The basis for most immunosuppressive regimens is prednisolone, a corticosteroid. Prednisolone suppresses the immune system, but its long-term use at high doses causes a multitude of side effects, including glucose intolerance and diabetes, weight gain, osteoporosis, muscle weakness, hypercholesterolemia, and cataract formation. Prednisolone alone is usually inadequate to prevent rejection of a transplanted kidney.

Thus other, non-steroid immunosuppressive agents are needed, which also allow lower doses of prednisolone.

Indications

The indication for kidney transplantation is end-stage renal disease (ESRD), regardless of the primary cause. This is defined as a drop in the glomerular filtration rate (GFR) to 20–25% of normal. Common diseases leading to ESRD include malignant hypertension, infections, diabetes mellitus, and focal segmental glomerulosclerosis; genetic causes include polycystic kidney disease, a number of inborn errors of metabolism, and autoimmune conditions such as lupus and Goodpasture's syndrome. Diabetes is the most common cause of kidney transplantation, accounting for approximately 25% of those in the US. The majority of renal transplant recipients are on some form of peritoneal dialysis, or the similar process of hemofiltration—at the time of transplantation. However, individuals with chronic renal failure who have a living donor available may undergo pre-emptive transplantation before dialysis is needed.

Contraindications and Requirements

Contraindications include both cardiac and pulmonary insufficiency, as well as hepatic disease. Concurrent tobacco use and morbid obesity are also among the indicators putting a patient at a higher risk for surgical complications.

Kidney transplant requirements vary from program to program and country to country. Many programs place limits on age (e.g. the person must be under a certain age to enter the waiting list) and require that one must be in good health (aside from the kidney disease). Significant cardiovascular disease, incurable terminal infectious diseases and cancer often are transplant exclusion criteria. In addition, candidates are typically screened to determine if they will be compliant with their medications, which is essential for survival of the transplant. People with mental illness and/or significant on-going substance abuse issues may be excluded.

HIV was at one point considered to be a complete contraindication to transplantation. There was fear that immunosuppressing someone with a depleted immune system would result in the progression of the disease. However, some research seem to suggest that immunosuppressive drugs and antiretrovirals may work synergistically to help both HIV viral loads/CD4 cell counts and prevent active rejection.

Sources of kidneys

Since medication to prevent rejection is so effective, donors do not need to be genetically similar to their recipient. Most donated kidneys come from deceased donors, however the utilization of living donors in the United States is on the rise. In 2006, 47% of donated kidneys were from living donors. This varies by country: for example, only 3% of kidneys transplanted during 2006 in Spain came from living donors.

Living donors

More than one in three donations in the UK is now from a live donor and almost one in three in Israel. The percentage of transplants from living donors is increasing. Potential donors are carefully evaluated on medical and psychological grounds. This ensures that the donor is fit for surgery and has no disease which brings undue risk or likelihood of a poor outcome for either the donor or recipient. The psychological assessment is to ensure the donor gives informed consent and is not coerced. In countries where paying for organs is illegal, the authorities may also seek to ensure that a donation has not resulted from a financial transaction. In the UK, the Human Tissue Act 2004 (HTA) dictated that donors must prove a familial or long term relationship or enduring friendship, for instance by providing photographs of themselves together spread over a period of time, or a birth or wedding certificate. Purely altruistic donation to strangers has recently been accepted by the Human Tissue Authority in the United Kingdom, and as of December 2007 only four people had been given permission to do this under the HTA. The decision must be approved by a panel, whereas the typical donation based on relationship is required only to go through an executive. There is good evidence that kidney donation is not associated with long term harm to the donor.

So called "daisy chain" transplants in the US involve one altruistic donor who donates a kidney to someone who has a family member willing to donate, who isn't a match. That family member then donates to a recipient who is a match. This "chain" can be continued with several more pairs of donors/recipients.

Traditionally, the donor procedure has been through a single incision of 4–7 inches (10–18 cm), but live donation is being increasingly performed by laparoscopic surgery. This reduces pain and accelerates recovery for the donor. Operative time and complications decreased significantly after a surgeon performed 150 cases. Live donor kidney grafts tend to perform better than those from deceased donors. Since the increase in the use of laparoscopic surgery, the number of live donors has increased. Any advance which leads to a decrease in pain and scarring and swifter recovery has the potential to boost donor numbers. In January 2009, the first all-robotic kidney transplant was performed at Saint Barnabas Medical Center through a two-inch incision. In the following six months, the same team performed eight more robotic-assisted transplants.

In 2004 the FDA approved the Cedars-Sinai High Dose IVIG therapy which reduces the need for the living donor to be the same blood type (ABO compatible) or even a tissue match. The therapy reduced the incidence of the recipient's immune system rejecting the donated kidney in highly sensitized patients.

In 2009 at the Johns Hopkins Medical Center, a healthy kidney was removed through the donor's vagina. Vaginal donations promise to speed recovery and reduce scarring. The first donor was chosen as she had previously had a hysterectomy. The extraction was performed using natural orifice transluminal endoscopic surgery, where an endoscope is inserted through an orifice, then through an internal incision, so that there is no external scar. The recent advance of single port access surgery requiring only one entry point at the navel is another advance with potential for more frequent use.

Organ trade

In the developing world some people sell their organs. Such people are often in grave poverty, or exploited by salespersons. People travelling to make use of such kidneys, sometimes known as "transplant tourists", are not looked upon favorably by organizations such as the US National Kidney Foundation. These patients may have increased complications due to poor infection control and lower medical and surgical standards. One surgeon has said organ trade could be legalized in the UK to prevent such tourism, but this is not seen by the National Kidney Research Fund as the answer to a deficit in donors.

Deceased donors

Deceased donors can be divided in two groups:

- Brain-dead (BD) donors
- Donation after Cardiac Death (DCD) donors

Although brain-dead (or "beating heart") donors are considered dead, the donor's heart continues to pump and maintain the circulation. This makes it possible for surgeons to start operating while the organs are still being perfused. During the operation, the aorta will be cannulated, after which the donor's blood will be replaced by an ice-cold storage solution, such as UW (Viaspan), HTK, or Perfadex. Depending on which organs are transplanted, more than one solution may be used simultaneously. Due to the temperature of the solution, and since large amounts of cold NaCl-solution are poured over the organs for a rapid cooling, the heart will stop pumping.

"Donation after Cardiac Death" donors are patients who do not meet the brain-dead criteria but, due to the small chance of recovery, have elected via a living will or through family to withdraw support. In this procedure, treatment is discontinued (mechanical ventilation is shut off). After a time of death has been pronounced, the patient is rushed to the operating room where the organs are recovered. Storage solution is flushed through the organs. Since the blood is no longer being circulated, coagulation must be prevented with large amounts of anti-coagulation agents such as heparin. Several ethical and procedural guidelines must be followed; most importantly, the organ recovery team should not participate in the patient's care in any manner until after death has been declared.

Compatibility

If plasmapheresis or IVIG is not performed, the donor and recipient have to be ABO blood group compatible. Also, they should ideally share as many HLA and "minor antigens" as possible. This decreases the risk of transplant rejection and the need for another transplant. The risk of rejection may be further reduced if the recipient is not already sensitized to potential donor HLA antigens, and if immunosuppressant levels are kept in an appropriate range. In the United States, up to 17% of all deceased donor kidney transplants have no HLA mismatch. However, HLA matching is a relatively minor predictor of transplant outcomes. In fact, living non-related donors are now almost as common as living (genetically)-related donors.

In the 1980s, experimental protocols were developed for ABO-incompatible transplants using increased immunosuppression and plasmapheresis. Through the 1990s these techniques were improved and an important study of long-term outcomes in Japan was published (). Now, a number of programs around the world are routinely performing ABO-incompatible transplants.

Procedure

In most cases the barely functioning existing kidneys are not removed, as this has been shown to increase the rates of surgical morbidities. Therefore the kidney is usually placed in a location different from the original kidney, often in the iliac fossa, so it is often necessary to use a different blood supply:

- The renal artery of the kidney, previously branching from the abdominal aorta in the donor, is often connected to the external iliac artery in the recipient.
- The renal vein of the new kidney, previously draining to the inferior vena cava in the donor, is often connected to the external iliac vein in the recipient.

There is disagreement in surgical textbooks regarding which side of the recipient’s pelvis to use in receiving the transplant. Campbell's Urology (2002) recommends placing the donor kidney in the recipient’s contralateral side (i.e. a left sided kidney would be transplanted in the recipient's right side) to ensure the renal pelvis and ureter are anterior in the event that future surgeries are required. In an instance where there is doubt over whether there is enough space in the recipient’s pelvis for the donor's kidney the textbook recommends using the right side because the right side has a wider choice of arteries and veins for reconstruction. Smith's Urology (2004) states that either side of the recipient's pelvis is acceptable, however the right vessels are “more horizontal” with respect to each other and therefore easier to use in the anastomoses. It is unclear what is meant by the words “more horizontal”. Glen's Urological Surgery (2004) recommends putting the kidney in the contralateral side in all circumstances. No reason is explicitly put forth however one can assume the rationale is similar to that of Campbell's- to ensure the renal pelvis and ureter are most anterior in the event that future surgical correction are necessary.

Kidney-pancreas transplant

Occasionally, the kidney is transplanted together with the pancreas. This is done in patients with diabetes mellitus type 1, in whom the diabetes is due to destruction of the beta cells of the pancreas and in whom the diabetes has caused renal failure (diabetic nephropathy). This is almost always a deceased donor transplant. Only a few living donor (partial) pancreas transplants have been done. For individuals with diabetes and renal failure, the advantages of earlier transplant from a living donor (if available) are far superior to the risks of continued dialysis until a combined kidney and pancreas are available from a deceased donor. A patient can either receive a living kidney followed by a donor pancreas at a later date (PAK, or pancreas-after-kidney) or a combined kidney-pancreas from a donor (SKP, simultaneous kidney-pancreas).

Transplanting just the islet cells from the pancreas is still in the experimental stage, but shows promise. This involves taking a deceased donor pancreas, breaking it down, and extracting the islet cells that make insulin. The cells are then injected through a catheter into the recipient and they generally lodge in the liver. The recipient still needs to take immunosuppressants to avoid rejection, but no surgery is required. Most people need two or three such injections, and many are not completely insulin-free.

Post operation

The transplant surgery takes about three hours. The donor kidney will be placed in the lower abdomen and its blood vessels connected to arteries and veins in the recipient's body. When this is complete, blood will be allowed to flow through the kidney again. The final step is connecting the ureter from the donor kidney to the bladder. In most cases, the kidney will soon start producing urine.

Depending on its quality, the new kidney usually begins functioning immediately. Living donor kidneys normally require 3–5 days to reach normal functioning levels, while cadaveric donations stretch that interval to 7–15 days. Hospital stay is typically for 4–7 days. If complications arise, additional medications (diuretics) may be administered to help the kidney produce urine.

Immunosuppressant drugs are used to suppress the immune system from rejecting the donor kidney. These medicines must be taken for the rest of the patient's life. The most common medication regimen today is a cocktail of tacrolimus, mycophenolate, and prednisone. Some patients may instead take cyclosporine, sirolimus, or azathioprine. Cyclosporine, considered a breakthrough immunosuppressive when first discovered in the 1980s, ironically causes nephrotoxicity and can result in iatrogenic damage to the newly transplanted kidney. Blood levels must be monitored closely and if the patient seems to have declining renal function, a biopsy may be necessary to determine whether this is due to rejection or cyclosporine intoxication.

Post operation diet

Grapefruit can decrease the proper metabolism of many drugs, and therefore decrease/or almost cancel out the effect of many critical drugs given after kidney transplants. Therefore, grapefruit products and certain other citrus products must be avoided.

Acute rejection occurs in 10–25% of people after transplant during the first sixty days. Rejection does not necessarily mean loss of the organ, but may require additional treatment and medication adjustments.

Complications

Problems after a transplant may include:

- Transplant rejection (hyperacute, acute or chronic)
- Infections and sepsis due to the immunosuppressant drugs that are required to decrease risk of rejection
- Post-transplant lymphoproliferative disorder (a form of lymphoma due to the immune suppressants)
- Imbalances in electrolytes including calcium and phosphate which can lead to bone problems amongst other things
- Other side effects of medications including gastrointestinal inflammation and ulceration of the stomach and esophagus, hirsutism (excessive hair growth in a male-pattern distribution), hair loss, obesity, acne, diabetes mellitus type 2, hypercholesterolemia, and others.

The average lifetime for a donated kidney is ten to fifteen years. When a transplant fails, a patient may opt for a second transplant, and may have to return to dialysis for some intermediary time.

Prognosis

Kidney transplantation is a life-extending procedure. The typical patient will live ten to fifteen years longer with a kidney transplant than if kept on dialysis. The years of life gained is greater for younger patients, but even 75 year-old recipients (the oldest group for which there is data) gain an average four more years' life. People generally have more energy, a less restricted diet, and fewer complications with a kidney transplant than if they stay on conventional dialysis.

Some studies seem to suggest that the longer a patient is on dialysis before the transplant, the less time the kidney will last. It is not clear why this occurs, but it underscores the need for rapid referral to a transplant program. Ideally, a kidney transplant should be pre-emptive, i.e. take place before the patient begins dialysis.

At least four professional athletes have made a comeback to their sport after receiving a transplant: New Zealand rugby union player Jonah Lomu, German-Croatian Soccer Player Ivan Klasnić, and NBA basketballers Sean Elliott and Alonzo Mourning.

Statistics

Statistics by country, year and donor type

Country	Year	Cadaveric donor	Living donor	Total transplants
Canada	2000	724	388	1,112
France	2003	1,991	136	2,127
Italy	2003	1,489	135	1,624
Spain	2003	1,991	60	2,051
United Kingdom	2003	1,297	439	1,736
United States	2008	10,551	5,966	16,517
Pakistan - SIUT	2008		1,854	1,932

- Bill Thompson is the longest surviving American kidney recipient. Having received his kidney in 1966 at age 15, it has survived over 40 years
- Denice Lombard of Washington, D.C., received her father's kidney on August 30, 1967, aged 13 and is still alive and healthy forty years later.
- In Kenya, John Dan of Nairobi is the longest known surviving kidney recipient in East Africa. He received a kidney from his brother in 1984 and is still alive twenty six years later.

In addition to nationality, transplantation rates differ based on race, sex, and income. A study done with patients beginning long term dialysis showed that the sociodemographic barriers to renal transplantation present themselves even before patients are on the transplant list. For example, different groups express definite interest and complete pretransplant workup at different rates. Previous efforts to create fair transplantation policies had focused on patients currently on the transplantation waiting list.

In the US health system

A major barrier to individuals being accepted by a kidney transplant program in the United States is lack of adequate insurance. Transplant recipients must take immunosuppressive anti-rejection drugs for as long as the transplanted kidney functions. For the routine immunosuppressives Prograf, Cellcept and prednisone, these drugs cost US$1,500 per month. In 1999 Congress passed a law that restricts Medicare from paying for more than three years for these drugs, unless the patient is otherwise Medicare eligible. Transplant programs may not transplant a patient unless the patient has a reasonable plan to pay for medication after the medicare expires, however, patients are almost never turned down for financial reasons alone. 50% of patients with end-stage renal disease only have Medicare coverage.

In March 2009 a bill was introduced in the Senate, 565 and in the House, H.R. 1458 that will extend Medicare coverage of the drugs for as long as the patient has a functioning transplant. This means that patients who have lost their jobs and insurance will not also lose their kidney and be forced back on dialysis. Dialysis is currently using up $17 billion yearly of Medicare funds and total care of these patients amounts to over 10% of the entire Medicare budget.

Chapter 2

Ureterostomy

	Intervention: Ureterostomy	
ICD-10 code:		
ICD-9 code:		56.61
MeSH		D014519
Other codes:		

A **ureterostomy** is the creation of a stoma (a new, artificial outlet) for a ureter or kidney.

The procedure is performed to divert the flow of urine away from the bladder when the bladder is not functioning or has been removed.

Indications may include: bladder cancer spinal cord injury malfunction of the bladder birth defects, such as spina bifida

Types

There are two basic types of urostomies. The first features the creation of a passage called an "ileal conduit." In this procedure, the ureters are detached from the bladder and joined to a short length of the small intestine (ileum). The other type of urostomy is cutaneous ureterostomy. With this technique, the surgeon detaches the ureters from the bladder and brings one or both to the surface of the abdomen. The hole created in the abdomen is called a stoma, a reddish, moist abdominal protrusion. The stoma is not painful; it has no sensation. Since it has no muscles to regulate urination, urine collects in a bag.

There are four common types of ureterostomies:

- Single ureterostomy. This procedure brings only one ureter to the surface of the abdomen.

- Bilateral ureterostomy. This procedure brings the two ureters to the surface of the abdomen, one on each side.
- Double-barrel ureterostomy. In this approach, both ureters are brought to the same side of the abdominal surface.
- Transuretero ureterostomy (TUU). This procedure brings both ureters to the same side of the abdomen, through the same stoma.

Diagnosis/Preparation

Ureterostomy patients may have the following tests and procedures as part of their diagnostic work-up:

- Renal function tests; blood, urea, nitrogen (BUN); and creatinine.
- Blood tests, complete blood count (CBC) and electrolytes.
- Imaging studies of the ureters and renal pelvis. These studies characterize the ureters, and define the surgery required to obtain adequate ureteral length.

The quality, character, and usable length of the ureters is usually assessed using any of the following tests:

Intravenous pyelogram (IVP). A special diagnostic test that follows the time course of excretion of a contrast dye through the kidneys, ureters, and bladder after it is injected into a vein. Retrograde pyelogram (RPG). x ray study of the kidney, focusing on the urine-collecting region of the kidney and ureters. Antegrade nephrostogram. CT scan. A special imaging technique that uses a computer to collect multiple x ray images into a two-dimensional cross-sectional image. MRI with intravenous gadolinium. A special technique used to image internal structures of the body, particularly the soft tissues. An MRI image is often superior to a routine x ray image. The pre-surgery evaluation also includes an assessment of overall patient stability. The surgery may take from two to six hours, depending on the health of the ureters, and the experience of the surgeon.

Aftercare

After surgery, the condition of the ureters is monitored by IVP testing, repeated postoperatively at six months, one year, and then yearly.

Following ureterostomy, urine needs to be collected in bags. Several designs are available. One popular type features an open bag fitted with an anti-reflux valve, which prevents the urine from flowing back toward the stoma. A urostomy bag connects to a night bag that may be attached to the bed at night. Urostomy bags are available as one- and two-piece bags:

One-piece bags: The adhesive and the bag are welded together. The advantage of using a one-piece appliance is that it is easy to apply, and the bag is flexible and soft. Two-piece bags: The bag and the adhesive are two separate components. The adhesive does not need to be removed frequently from the skin, and can remain in place for several days while the bag is changed as required. Risks

The complication rate associated with ureterostomy procedures is less than 5–10%. Risks during surgery include heart problems, pulmonary (lung) complications, development of blood clots (thrombosis), blocking of arteries (embolism), and injury to adjacent structures, such as bowel or vascular entities. Inadequate ureteral length may also be encountered, leading to ureteral kinking and subsequent obstruction. If plastic tubes need inserting, their malposition can lead to obstruction and eventual breakdown of the opening (anastomosis). Anastomotic leak is the most frequently encountered complication.

Normal results for a ureterostomy include the successful diversion of the urine pathway away from the bladder, and a tension-free, watertight opening to the abdomen that prevents urinary leakage.

Morbidity and mortality rates

The outcome and prognosis for ureterostomy patients depends on a number of factors. The highest rates of complications exist for those who have pelvic cancer or a history of radiation therapy.

In one study, a French medical team followed 69 patients for a minimum of one year (an average of six years) after TUU was performed. They reported one complication per four patients (6.3%), including a case requiring open drainage, prolonged urinary leakage, and common ureteral death (necrosis). Two complications occurred three and four years after surgery. The National Cancer Institute performed TUU for pelvic malignancy in 10 patients. Mean follow-up was 6.5 years. Complications include common ureteral narrowing (one patient); subsequent kidney removal, or nephrectomy (one patient); recurrence of disease with ureteral obstruction (one patient); and disease progression in a case of inflammation of blood vessels, or vasulitis (one patient). One patient died of sepsis (infection in the bloodstream) due to urine leakage at the anastomosis, one died after a heart attack, and three died from metastasis of their primary cancer.

Alternatives

There are several alternative surgical procedures available:

- Ileal conduit urostomy, also known as "Bricker's loop." The two ureters that transport urine from the kidneys are detached from the bladder, and then attached so that they will empty through a piece of the ileum. One end of the ileum piece is sealed off and the other end is brought to the surface of the abdomen to form the stoma. It is the most common technique used for urinary diversion.
- Cystostomy. The flow of urine is diverted from the bladder to the abdominal wall. It features placement of a tube through the abdominal wall into the bladder, and is

indicated in cases of blockage or stricture of the ureters. It can be temporary or permanent.

- Indiana pouch. A pouch is constructed using the end part of the ileum and the first part of the large intestine (cecum). The remaining ileum is first attached to the large intestine to maintain normal digestive flow. A pouch is then created from the removed cecum, and the attached ileum is brought to the surface of the abdominal wall to create a stoma.
- Percutaneous nephrostomy . A nephrostomy is created when the flow of urine is diverted directly from the kidneys to the abdominal wall. Tubes are placed within the kidney to collect the urine as it is generated, and transport it to the abdominal wall. This procedure is usually temporary; however, it may be permanent for cancer patients.

Chapter 3

Extracorporeal Shock Wave Lithotripsy, Ureterosigmoidostomy and Urinary Diversion

Extracorporeal shock wave lithotripsy

Extracorporeal shock wave lithotripsy (**ESWL**) is the non-invasive treatment of kidney stones (urinary calculosis) and biliary calculi (stones in the gallbladder or in the liver) using an acoustic pulse. **Lithotripsy** and the **lithotriptor** were developed in the early 1980s in Germany by *Dornier Medizintechnik GmbH* (now known as Dornier MedTech Systems GmbH), and came into widespread use with the introduction of the HM-3 lithotriptor in 1983. Within a few years, ESWL became a standard treatment of calculosis.

It is estimated that more than one million patients are treated annually with ESWL in the USA alone.

How it works

The lithotriptor attempts to break up the stone with minimal collateral damage by using an externally-applied, focused, high-intensity acoustic pulse. The sedated or anesthetized patient lies down in the apparatus' bed, with the back supported by a water-filled coupling device placed at the level of kidneys. A fluoroscopic x-ray imaging system or an ultrasound imaging system is used to locate the stone and aim the treatment. The first generation lithotriptor known as the HM3, has a half ellipsoid-shaped piece that opens toward the patient. The acoustic pulse is generated at the ellipsoidal focal point that is furthest from the patient and the stone positioned at the opposite focal point receives the focused shock wave. The treatment usually starts at the equipment's lowest power level, with a long gap between pulses, in order to accustom the patient to the sensation. The length of gap between pulses is also controlled to allow cavitation bubbles to disperse minimizing tissue damage. Second and later generation machines use an acoustic lens to focus the shock wave. This functions much like an optical lens, focusing the shock wave at the desired loci. The frequency of pulses are currently left at a slow rate for more effective comminution of the stone and to minimize morbidity while the power levels are then gradually increased, so as to break up the stone. The final power level usually depends on the patient's pain threshold and the obsevered success of stone breakage. If the stone is positioned near a bone (usually a rib in the case of kidney stones), this treatment may be more uncomfortable because the shock waves can cause a mild resonance in the bone which can be felt by the patient. The sensation of the treatment is likened to an elastic band twanging off the skin. Alternately the patient may be sedated during the procedure. This allows the power levels to be brought up more quickly and a much higher pulse frequency, often up to 120 shocks per minute.

The successive shock wave pressure pulses result in direct shearing forces, as well as cavitation bubbles surrounding the stone, which fragment the stones into smaller pieces that then can easily pass through the ureters or the cystic duct. The process takes about an hour. A ureteral stent (a kind of expandable hollow tube) may be used at the discretion of the urologist. The stent allows for easier passage of the stone by relieving obstruction and through passive dilatation of the ureter.

Some of the passed fragments of a 1-cm calcium oxalate stone that was smashed using lithotripsy.

Extracorporeal lithotripsy works best with stones between 4 mm and 2 cm in diameter that are still located in the kidney. It can be used to break up stones which are located in a ureter too, but with less success.

The patients undergoing this procedure can, in some cases, see for themselves the progress of their treatment. If allowed to view the ultrasound or x-ray monitor, they may be able to see their stones change from a distinct bright point (or dark spot depending on whether the fluoro unit is set up in native or bones white) to a fuzzy cloud as the stone is disintegrated into a fine powder.

ESWL is the least invasive of the commonplace modalities for definitive stone treatment, but provides a lower stone-free rate than other more invasive treatment methods, such as ureteroscopic manipulation with laser lithotripsy or percutaneous nephrolithotomy (PCNL). The passage of stone fragments may take a few days or a week and may cause mild pain. Patients may be instructed to drink as much water as practical during this time. Patients are also advised to void through a stone screen in order to capture stone fragments for analysis.

ESWL is not without risks. The shock waves themselves, as well as cavitation bubbles formed by the agitation of the urine medium, can lead to capillary damage, renal parenchymal or subcapsular hemorrhage. This can lead to long-term consequences such as renal failure and hypertension. Overall complication rates of ESWL range from 5–20%.

Ureterosigmoidostomy

Intervention: Ureterosigmoidostomy	
ICD-10 code:	
ICD-9 code:	56.71
Other codes:	

A **ureterosigmoidostomy** is a surgical procedure where the ureters which carry urine from the kidneys, are diverted into the sigmoid colon. It is done as a treatment for bladder cancer, where the urinary bladder had to be removed. Rarely, the cancer presents in children between the ages of 2 & 10 yrs old as an aggressive rhabdomyosarcoma, although there are diagnoses of children as young as 3 months old. The procedure was also used several decades ago as a correctional procedure for patients born with bladder exstrophy. In the case of some bladder exstrophy patients, occasional bowel incontinence (in this case, a mixture of urine and feces similar to diarrhea) at night is one uncontrollable consequence.

Another consequence of this procedure is an increased risk of kidney infections (nephritis) due to bacteria from faeces travelling back up the ureters (reflux). Patients are commonly put on oral prophylactic antibiotics to combat infections in the uretery tract and the kidneys but this can lead to tolerance of the antibiotic, so over time the patient can build up tolerance to a large number of oral antibiotics, leading to a need for IV (intravenous) antibiotics administered while the patient is an inpatient.

As well as this, the urine entering the colon can cause diarrhea and salt imbalance due to the sodium and chloride in the urine. Urea levels in the blood are higher due to urea crossing the colon wall. In the large intestine, sodium is swapped for potassium, and chloride for bicarbonate, this causes an acidosis and hypokalaemia. Many patients take sodium bicarbonate to combat this.

Patients with ureterosigmoidostomy have an increased chance of developing carcinoma of the colon after living with the modification for a number of years, on average 20–30 years after the operation, which can also lead to severe surgical adhesions.

This operation is no longer popular in many countries, with an ileal conduit (where the ureters lead into a loop of small intestine) being preferred. However, it is still popular in developing countries as the maintenance of an ileal conduit or a catheter is seen to be easier.

Urinary diversion

Intervention: Urinary diversion	
ICD-10 code:	
ICD-9 code:	56.71
MeSH	D014547
Other codes:	

Urinary diversion is any one of several surgical procedures to reroute urine flow from its normal pathway. It may be necessary for diseased or defective ureters, bladder or urethra, either temporarily or permanently. Some diversions result in a stoma.

Types

- Ileal conduit urinary diversion (Bricker conduit)
- Indiana pouch
- Neobladder to urethra diversion
- Ureterocutaneostomia

Ureteroenteric anastomosis

A common feature of the three first, and most common, types of urinary diversion is the ureteroenteric anastomosis. This is the joining site of the ureters and the section of intestine used for the diversion.

The ureteroenteric anastomosis can be created in a number of different ways. There is the option of a refluxing or a non-refluxing type, and the two ureters can be joined into the intestinal segment either together or separately. The non-refluxing type has been associated with higher incidence of ureteroenteric anastomosis stricture, and there is doubt whether it has any advantages over the refluxing type. Therefore, many surgeons prefer the refluxing type which is simpler and apparently carries a lesser degree of complications.

Refluxing techniques include the Wallace and Wallace II and the Bricker end-to-side anastomosis. Non-refluxing techniques includes the Le Duc technique.

Complications

Complications include incisional hernia, neobladder-intestinal and neobladder-cutaneous fistulas, ureteroenteric anastomosis stricture, neobladder rupture and mucous formation.

Chapter 4

Cystoscopy and Suprapubic Cystostomy

Cystoscopy

A sterile flexible cystoscope in an operating theatre

cystoscopy is endoscopy of the urinary bladder via the urethra. It is carried out with a **cystoscope**.

Diagnostic cystoscopy is usually carried out with local anaesthesia. General anaesthesia is sometimes used for operative cystoscopic procedures.

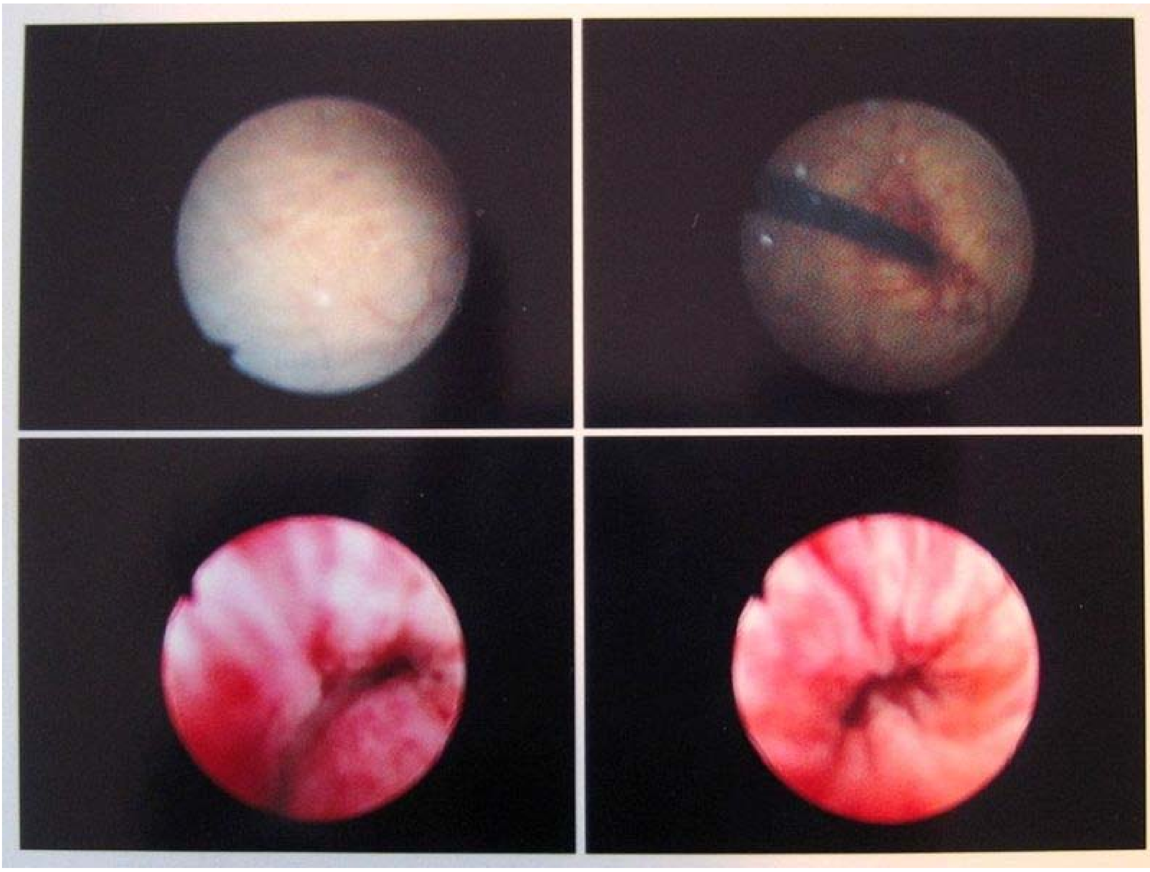
The urethra is the tube that carries urine from the bladder to the outside of the body. The cystoscope has lenses like a telescope or microscope. These lenses let the doctor focus on the inner surfaces of the urinary tract. Some cystoscopes use optical fibres (flexible glass fibres) that carry an image from the tip of the instrument to a viewing piece at the other end. Cystoscopes range from between the thickness of a pencil, up to approximately 9mm and have a light at the tip. Many cystoscopes have extra tubes to guide other instruments for surgical procedures to treat urinary problems.

There are two main types of cystoscopy - flexible and rigid - differing in the flexibility of the cystoscope. Flexible cystoscopy is carried out without the use of local anaesthesia on both sexes. Typically, xylocaine gel (such as the brand name Instillagel) is used as an anaesthetic, instilled in the urethra. Rigid cystoscopy can be performed under the same conditions, but is generally carried out under general anaesthesia, particularly in male subjects, due to the pain caused by the probe.

A doctor may recommend cystoscopy for any of the following conditions:

- Frequent urinary tract infections
- Blood in the urine (hematuria)
- Loss of bladder control (incontinence) or overactive bladder
- Unusual cells found in urine sample
- Need for a bladder catheter
- Painful urination, chronic pelvic pain, or interstitial cystitis
- Urinary blockage such as from prostate enlargement, stricture, or narrowing of the urinary tract
- Stone in the urinary tract
- Unusual growth, polyp, tumor, or cancer

Male and female urinary tracts



Images from a cystoscopy. The top two images show the interior of the bladder of a male patient. In the top-right image, the cystoscope has been bent within the bladder to look back on itself. The bottom two images show an inflamed urethra

If a patient has a stone lodged higher in the urinary tract, the doctor may use a much finer calibre scope called a ureteroscope through the bladder and up into the ureter. (The ureter is the tube that carries urine from the kidney to the bladder). The doctor can then see the stone and remove it with a small basket at the end of a wire which is inserted through an extra tube in the ureteroscope. For larger stones, the doctor may also use the extra tube in the ureteroscope to extend a flexible fiber that carries a laser beam to break the stone into smaller pieces that can then pass out of the body in the urine.

Test Procedures

Doctors may have special instructions, but in most cases, patients are able to eat normally and return to normal activities after the test. Patients are sometimes asked to give a urine sample before the test to check for infection. These patients should ensure that they do not urinate for a sufficient period time, such that they are able to urinate prior to this part of the test.

Patients will have to remove their clothing covering the lower part of the body, although some doctors may prefer if the patient wears a hospital gown for the examination and covers the lower part of the body with a sterile drape. In most cases, patients lie on their backs with their knees slightly parted. Occasionally, a patient may also need to have their knees raised. This is particularly when undergoing a Rigid Cystoscopy examination. For flexible cystoscopy procedures the patient is almost always alert and a local anesthetic is applied to reduce discomfort. In cases requiring a rigid cystoscopy it is not unusual for the patient to be given a general anesthetic, as these can be more uncomfortable, particularly for men. A doctor, nurse or technician will clean the area around the urethral opening and apply a local anesthetic. The local anesthetic is applied direct from a tube or needleless syringe into the urinary tract. Often, skin preparation is performed with Hibitane

Patients receiving a ureteroscopy may receive a spinal or general anaesthetic.

The doctor will gently insert the tip of the cystoscope into the urethra and slowly glide it up into the bladder. The procedure is more painful for men than for women due to the length and narrow diameter of the male urethra. Relaxing the pelvic muscles helps make this part of the test easier. A sterile liquid (water, saline, or glycine solution) will flow through the cystoscope to slowly fill the bladder and stretch it so that the doctor has a better view of the bladder wall.

As the bladder reaches capacity, patients typically feel some mild discomfort and the urge to urinate.

The time from insertion of the cystoscope to removal may be only a few minutes, or it may be longer if the doctor finds a stone and decides to remove it, or in cases where a biopsy is required. Taking a biopsy (a small tissue sample for examination under a microscope) will also make the procedure last longer. In most cases, the entire examination, including preparation, will take about 15 to 20 minutes.

After the test, patients often have some burning feeling when they urinate and often see small amounts of blood in their urine. Procedures using rigid instrumentation often result in urinary incontinence and leakage from idiopathic causes to urethral damage. Occasionally, patients may feel some lower abdominal pains, reflecting bladder muscle spasms, but these are not common.

Common prescriptions to relieve discomfort after the test include:

- Drinking 32 fluid ounces (1 L) of water over 2 hours.
- Taking a warm bath to relieve the burning feeling.
- Holding a warm, damp washcloth over the urethral opening.

Some doctors will prescribe an antibiotic to take for 1 or 2 days to prevent an infection. However, recent trends have been to discourage this kind of prophylactic treatment (prescribing antibiotics as a preventative when there is no other evidence of infection) because it tends to increase the rate at which bacteria develop resistance to the antibiotic drug.

Suprapubic cystostomy

Intervention: Suprapubic cystostomy	
ICD-10 code:	
ICD-9 code:	57.2
MeSH	D003559
Other codes:	

A **suprapubic cystostomy** (also known as a **vesicostomy** or **epicystostomy**) is a surgically-created connection between the urinary bladder and the skin which is used to drain urine from the bladder in individuals with obstruction of normal urinary flow. Urinary flow may be blocked by swelling of the prostate (benign prostatic hypertrophy), traumatic disruption of the urethra, congenital defects of the urinary tract, or by obstructions such as kidney stones passed into the urethra, and cancer. It is also a common treatment used among spinal cord injury patients who are unable or unwilling to use intermittent catheterization to empty the bladder, and cannot otherwise void due to detrusor sphincter dyssynergia.

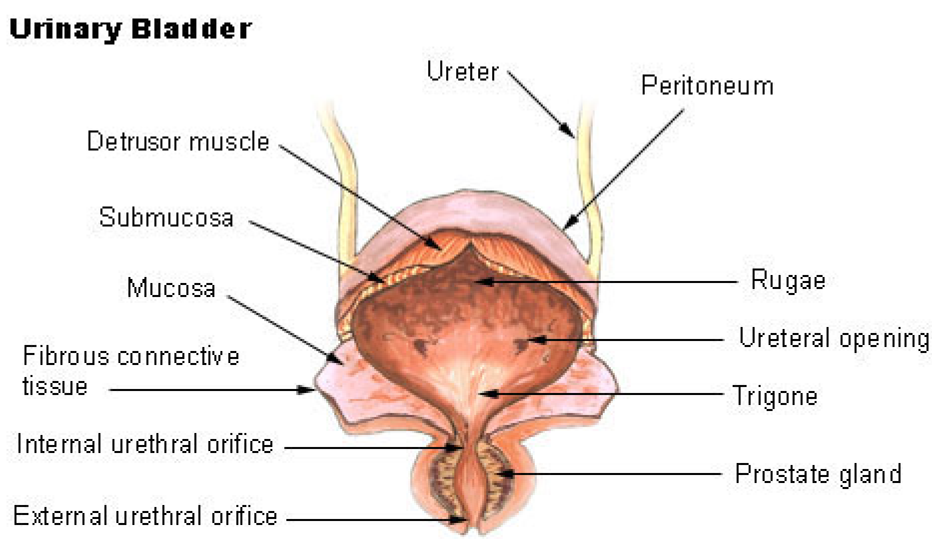
Initially, a thin tube (catheter) is placed through the skin just above the pubic bone into the bladder, often with the assistance of ultrasound imaging. This catheter initially remains in place for up to a month while the tissue around it scars and forms a tract (sinus) between the bladder and the body exterior. After the formation of scar tissue is complete, the catheter is replaced periodically in order to help prevent infections.

Indications for suprapubic catheters include: 1. failed urethral catheter, 2. long term usage (if left in urethral long terms catheters can lead to acquired hypospadius and recurrent/chronic UTIs) Contraindications: 1. need to rule out bladder cancer in cases of clot retention, 2. lower abdominal incisions with likelihood of adhesions, 3. pelvic fracture

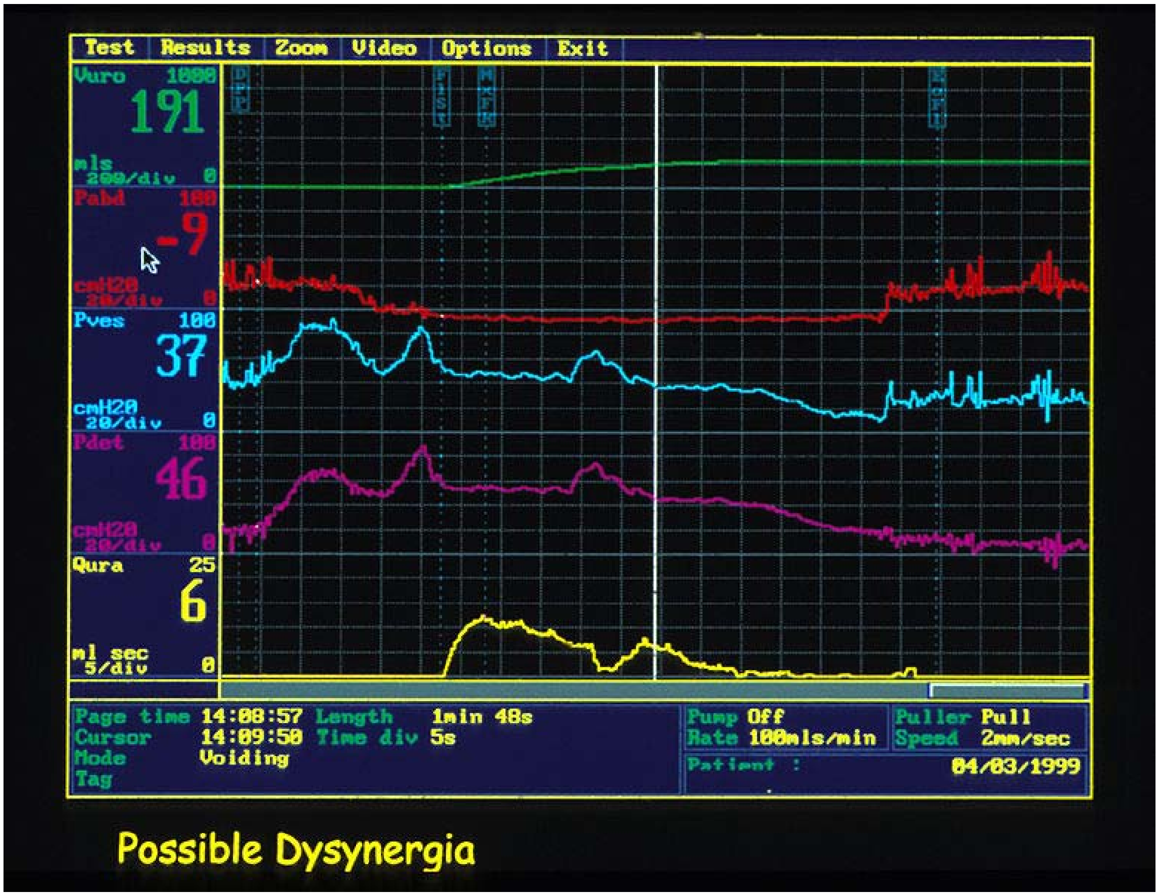
Chapter 5

Urodynamic Testing and Cystometry

Urodynamic testing



Urinary bladder



Urodynamic trace of detrusor sphincter dyssynergia.

Urodynamic testing refers to the process of performing urodynamics. Urodynamics is a study that assesses how the bladder and urethra are performing their job of storing and releasing urine. Urodynamic tests help your doctor see how well your bladder and sphincter muscles work and can help explain symptoms such as:

- incontinence
- frequent urination
- sudden, strong urges to urinate
- problems starting a urine stream
- painful urination
- problems emptying your bladder completely
- recurrent urinary tract infections

Urodynamic tests are usually performed in Urology, Gynecology, OB/GYN, Internal medicine, and Primary care offices. Urodynamics will provide the physician with the information necessary to diagnose the cause and nature of a patient's incontinence, thus giving the best treatment options available. Urodynamics is typically conducted by urologists, urogynecologists, or specialist urology nurses.

Purpose of testing

The tests are most often arranged for men with enlarged prostate glands, and for women with incontinence that has either failed conservative treatment or requires surgery.

Symptoms reported by the patient are often an unreliable guide to the underlying dysfunction of the lower urinary tract. The purpose of urodynamics is to provide objective confirmation of the pathology that a patient's symptoms would suggest.

For example, a patient complaining of urinary urgency (or rushing to the toilet), with increased frequency of urination can be said on the basis of their symptoms to have overactive bladder syndrome. The cause of this might be detrusor overactivity, in which the bladder muscle (the detrusor) contracts unexpectedly during bladder filling. Urodynamics can be used to confirm the presence of detrusor overactivity, which may help guide treatment. An overactive detrusor can be associated with urge incontinence.

Specific tests

These tests may be as simple as urinating behind a curtain while a doctor or nurse listens or more complicated, involving imaging equipment that films urination and pressure monitors that record the pressures of the bladder and urethra.

A typical urodynamic test takes about 30 minutes to perform. It involves the use of a small catheter used to fill the bladder and record measurements. What is done depends on what the presenting problem is, but some of the common tests conducted are;

- Post-void residual volume: Most tests begin with the insertion of a urinary catheter/transducer following complete bladder emptying by the patient. The urine volume is measured (this shows how efficiently the bladder empties). High volumes (180 ml) may be associated with urinary tract infections. A volume of greater than 50 ml in children has been described as constituting post-void residual urine. High levels can be associated with overflow incontinence.

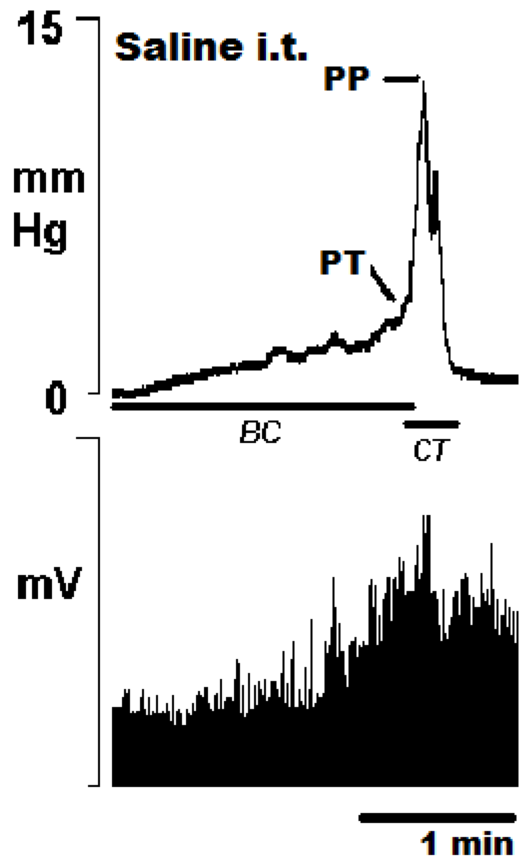
- The urine is often sent for microscopy and culture to check for infection.

- Uroflowmetry: free uroflowmetry measures how fast the patient can empty his/her bladder. Pressure uroflowmetry again measures the rate of voiding, but with simultaneous assessment of bladder and rectal pressures. It helps demonstrate the reasons for difficulty in voiding, for example bladder muscle weakness or obstruction of the bladder outflow.

- Multichannel cystometry: measures the pressure in the rectum and in the bladder, using two pressure catheters, to deduce the presence of contractions of the bladder wall, during bladder filling, or during other provocative manoeuvres. The strength of the urethra can also be tested during this phase, using a cough or Valsalva manouvre, to confirm genuine stress incontinence.

- Urethral pressure profilometry: measures strength of sphincter contraction.
- Electromyography (EMG) measurement of electrical activity in the bladder neck.
- Assessing the "tightness" along the length of the urethra.
- Fluoroscopy (moving video x-rays) of the bladder and bladder neck during voiding.

Cystometry



Example cystometrogram.

Cystometry, also known as **flow cystometry**, is a clinical diagnostic procedure used to evaluate bladder function. Specifically, it measures contractile force of the bladder when voiding. The resulting chart generated from cystometric analysis is known as a **cystometrogram** (CMG), which plots volume of liquid emptied from bladder against intravesical pressure.

Use

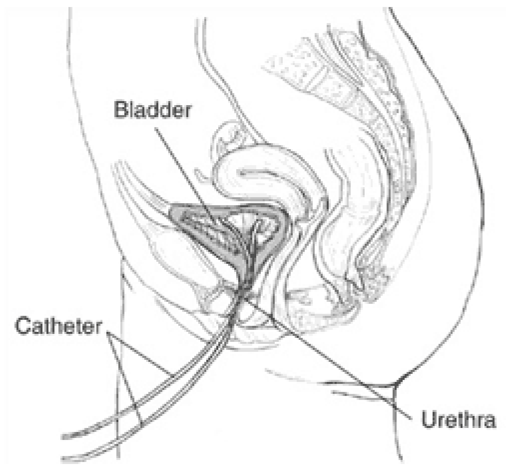


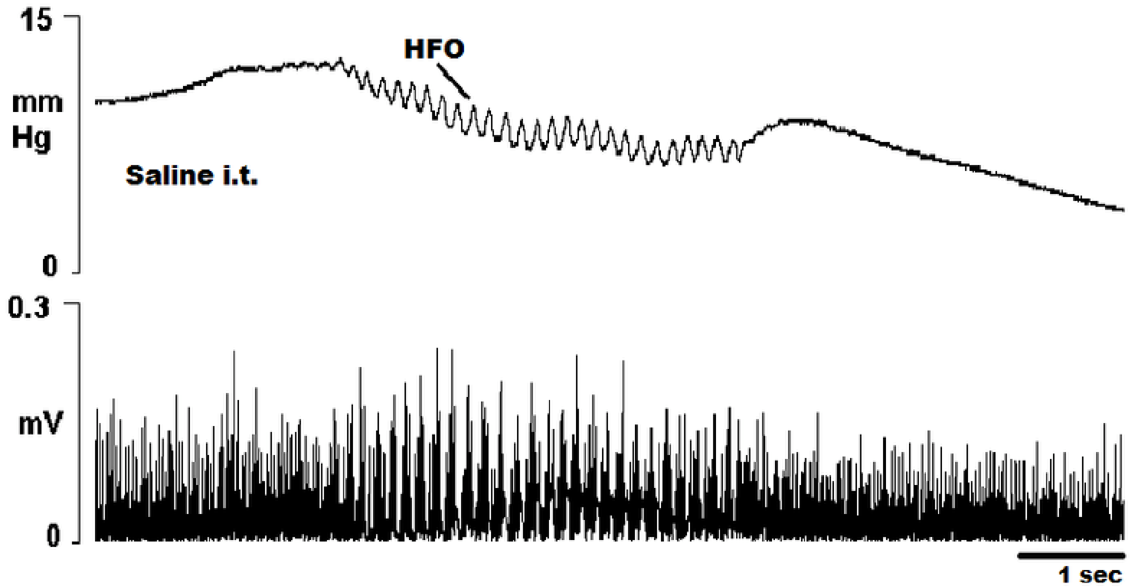
Diagram of cystometry in a female patient.

Cystometric analysis is used to evaluate the bladder's capacity to contract and expel urine. It helps determine the source of urinary problems. A normal CMG effectively rules out primary vesical dysfunction. It is used as a component for diagnosis of various disorders including urinary tract infections, multiple sclerosis, stroke, spinal cord injury, urethral obstruction, and overactive bladder, among others.

Procedure

The procedure is relatively short, ranging from fifteen minutes to an hour in duration. It involves the insertion of one or two catheters into an emptied bladder through the urethra. In the two catheter method, one catheter transfers liquid while the other is a manometer (pressure sensor). In the single catheter method, a specialized catheter performs both functions. An additional rectal catheter may also be placed for additional data. The bladder will then be filled with saline and the patient's awareness of the event will be queried. The patient will often be asked to note when presence of liquid is felt, when the bladder feels full, and when the urgency to void is felt. The patient is then asked to void, and both flow and pressure are recorded. These are plotted against each other to create the cystometrogram.

Results



Cystometrogram showing high frequency oscillations characteristic of expulsion of liquid in the rat.

The primary results of cystometric analysis is the cystometrogram. The x-axis is the volume of liquid and the y-axis is the intraluminal pressure of the bladder. In normal patients, the plot is a series of spikes whose local minimums form a non-linear curve resembling an exponential growth curve. The spikes correspond to the bladder contractions associated with the micturation reflex. The curve formed by the bottom of the plot reflects the level of pressure necessary to void. In normal patients, the first couple hundred milliliters of urine flow with minimal applied pressure. Increasing pressure is necessary to void 200-300 millileters of urine. Beyond that, the pressure necessary to void additional urine rises sharply.

Risks & Contraindications

As with any catheterization, the primary risk is of urinary tract infection. As a result, the procedure is contraindicated in any patient with an active UTI because the results may be skewed and the infection may spread.

There is also the potential for trauma to the bladder and urethtra, which may result in hematuria (blood in the urine).

Chapter 6

Cystectomy, Intravenous Pyelogram and Retrograde Urethrogram

Cystectomy

	Intervention: Cystectomy
ICD-10 code:	
ICD-9 code:	57.6 57.7
MeSH	D015653
Other codes:	

Cystectomy is a medical term for surgical removal of all or part of the urinary bladder. It may also be rarely used to refer to the removal of a cyst, or the gallbladder. The most common condition warranting removal of the urinary bladder is bladder cancer. After the bladder has been removed, an Ileal conduit urinary diversion is necessary. An alternative to this method is to construct a pouch from a section of ileum or colon, which can act as a form of replacement bladder, storing urine until the patient desires to release it, which can be achieved by either abdominal straining or self catheterisation. Future treatment for this condition may involve a full replacement with an artificial bladder.

One of the follow-up solutions to a **cystectomy** is the creation of a neobladder (one form of which is named Studer's Ileal Neobladder or the Studer Pouch). A neobladder is a loop of intestine that is surgically fashioned into a pouch and placed in the location of the original bladder. It is then attached to the ureters and the urethra, thus simulating the function of the original organ. The kidneys filter the urine into the neobladder which can often be emptied by muscle control. There are side effects of this complex surgery, including partial shut down of the digestive system (in response to removal of the piece of intestine), incontinence, and the loss of the nerves that signal a full bladder.

Intravenous pyelogram

Intervention:
Intravenous pyelogram

ICD-10 code:
ICD-9 code: 87.73
Other codes:

An **intravenous pyelogram** (also known as **IVP**, **pyelography**, **intravenous urogram** or **IVU**) is a radiological procedure used to visualize abnormalities of the urinary system, including the kidneys, ureters, and bladder.

Procedure

An Example of an IVU radiograph

An injection of x-ray contrast media is given to a patient via a needle or cannula into the vein, typically in the arm. The contrast is *excreted* or removed from the bloodstream via the kidneys, and the contrast media becomes visible on x-rays almost immediately after injection. X-rays are taken at specific time intervals to capture the contrast as it travels through the different parts of the urinary system. This gives a comprehensive view of the patient's anatomy and some information on the functioning of the renal system.

Normal Appearances

Immediately after the contrast is administered, it appears on an x-ray as a 'renal blush'. This is the contrast being filtered through the cortex. At an interval of 3 minutes, the renal blush is still evident (to a lesser extent) but the calyces and renal pelvis are now visible. At 9 – 13 minutes the contrast begins to empty into the ureters and travel to the bladder which has now begun to fill. To visualize the bladder correctly, a post micturition x-ray is taken, so that the bulk of the contrast (which can mask a pathology) is emptied.

An IVP can be performed in either emergency or routine circumstances.

Emergency IVP

This procedure is carried out on patients who present to an Emergency department, usually with severe renal colic and a positive hematuria test. In this circumstance the attending physician requires to know whether a patient has a kidney stone and if it is causing any obstruction in the urinary system.

Patients with a positive find for kidney stones but with no obstruction are usually discharged with a follow-up appointment with a urologist.

Patients with a kidney stone *and* obstruction are usually required to stay in hospital for monitoring or further treatment.

An Emergency IVP is carried out roughly as follows:

- plain KUB or Abdominal x-ray;
- an injection of contrast media, typically 50 ml;
- delayed Abdominal x-ray, taken at roughly 15 minutes post injection.

If no obstruction is evident on this film a post-micturition film is taken and the patient is sent back to the Emergency department. If an obstruction *is* visible, a post-micturition film is still taken, but is followed up with a series of radiographs taken at a "double time" interval. For example, at 30 minutes post-injection, 1 hour, 2 hours, 4 hours, and so forth, until the obstruction is seen to resolve. This time delay can give important information to the urologist on where and how severe the obstruction is.

Routine IVP

This procedure is most common for patients who have unexplained microscopic or macroscopic hematuria. It is used to ascertain the presence of a tumour or similar anatomy-altering disorders. The sequence of images are roughly as follows:

- plain or Control KUB image;
- immediate x-ray of just the renal area;
- 5 minute x-ray of just the renal area.

At this point, compression may or may not be applied (this is contraindicated in cases of obstruction).

- If compression is applied: a 10 minutes post-injection x-ray of the renal area is taken, followed by a KUB on release of the compression.
- If compression is not given: a standard KUB is taken to show the ureters emptying. This may sometimes be done with the patient lying in a prone position.

- A post-micturition x-ray is taken afterwards. This is usually a coned bladder view.

Image Assessment

The kidneys are assessed and compared for:

- Regular appearance, smooth outlines, size, position, equal filtration and flow.

The ureters are assessed and compared for:

- Size, a smooth regular and symmetrical appearance. A 'standing column' is suggestive of a partial obstruction.

The bladder is assessed for:

- Regular smooth appearance and complete voiding.

Contraindications

Historically, the drug metformin has been required to stop 48 hours pre and post procedure, as it known to cause a reaction with the contrast agent. However the newest guidelines published by the Royal College of Radiologists suggests this is not as important for patients having <100mls of contrast, who have a normal renal function. If renal impairment is found before administration of the contrast, metformin should be stopped 48 hours before and after the procedure.

Diagnoses

- Chronic Pyelonephritis
- Kidney stones
- Renal cell carcinoma or RCC
- Transitional cell carcinoma, or TCC
- Polycystic kidneys
- Anatomical variations, i.e. horseshoe kidney or a duplex collecting system
- Obstruction (commonly at the pelvic-ureteric junction or *PUJ* and the vesicoureteric junction or *VUJ*)

Other tests

An IVP can and should be used in conjunction with the following tests:

- Ultrasound
- Cystoscopy
- CT
- MRI
- Video cystometrography or VCMG
- Blood test
- Urine analysis

Treatment

Depending on the outcome and diagnosis following an IVP, treatment may be required for the patient. These include surgery, lithotripsy, ureteric stent insertion and radiofrequency ablation. Sometimes no treatment is necessary as stones <5mm can be passed without any intervention.

The Future of the intravenous pyelogram

The IVP is now becoming more and more obsolete. It has largely been taken over by Computed tomography (CT), which gives greater detail on anatomy and function.

Retrograde urethrogram

A **retrograde urethrogram** is a routine radiologic procedure (most typically in males) used to image the integrity of the urethra. Hence a retrograde urethrogram is essential for diagnosis of urethral injury, or urethral stricture.

Process

The procedure involves the insertion of a Foley catheter into the distal urethra and minimally inflating it. This is followed by instillation of 30mL of water soluble contrast and a plain radiograph is obtained. No attempt at insertion of a bladder catheter should be made in case of suspected urethral injury, until a negative retrograde urethrogram is obtained eg., no spillage of the contrast dye seen on radiograph, to avoid further damaging a urethral injury.

It is used when there is suspicion of urethral trauma, such as a history of trauma to the area followed by pain, inability to void urine, or the presence of blood at the urethral meatus, a scrotal hematoma, free-floating prostate on rectal examination.

If a urethral injury is suspected, a retrograde urethrogram should be performed before attempting to place a Foley catheter. If there is a urethral disruption, a suprapubic catheter should be placed.

Leakage of the dye at any point between the bladder and tip of the penis suggests urethral injury (usually secondary to pelvic trauma) and is an indication for surgical intervention.

Chapter 7

Urinary Catheterization and Urethral Sounding

Urinary catheterization

In **urinary catheterization**, or "**cathing**" for short, a plastic tube known as a urinary catheter that is gently slid into a patient's bladder via his or her urethra. Catheterization allows the patient's urine to drain freely from the bladder for collection, or to inject liquids used for treatment or diagnosis of bladder conditions. The procedure of catheterization will usually be done by a clinician, often a nurse, although self-catheterization is possible as well.

Catheter types

Catheters come in several basic designs:

- A **Foley catheter** (indwelling urinary catheter)is retained by means of a balloon at the tip which is inflated with sterile water. The balloons typically come in two different sizes: 5 cc and 30 cc. They are commonly made in silicone rubber or natural rubber.
- A **Robinson catheter** is a flexible catheter used for short term drainage of urine. Unlike the Foley catheter, it has no balloon on its tip and therefore cannot stay in place unaided.
- A Coudé catheter is designed with a curved tip that makes it easier to pass through the curvature of the prostatic urethra.
- A hematuria (or haematuria) catheter is a type of Foley catheter used for Post-TURP hemostasis. This is useful following endoscopic surgical procedures or in the case of gross hematuria. There are both 2-way and 3-way hematuria catheters (double and triple lumen).
- An external Texas or condom catheter is used for incontinent males and carries a lower risk of infection than an indwelling catheter.

Catheter diameters are sized by the French catheter scale (F). The most common sizes are 10 F (3.3mm) to 28 F (9.3mm). The clinician selects a size large enough to allow free flow of urine, and large enough to control leakage of urine around the catheter. A larger size can become necessary when the urine is thick, bloody or contains large amounts of sediment. Larger catheters, however, are more likely to cause damage to the urethra. Some people develop allergies or sensitivities to latex after long-term latex catheter use making it necessary to use silicone or Teflon types. Silver alloy coated urinary catheters may reduce infections.

Sex differences

In males, the catheter tube is inserted into the urinary tract through the penis. A condom or Texas catheter can also be used. In females, the catheter is inserted into the urethral meatus, after a cleansing using povidone-iodine. The procedure can be complicated in females due to varying layouts of the genitalia (due to age, obesity, Female genital cutting, childbirth, or other factors), but a good clinician should rely on anatomical landmarks and patience when dealing with such a patient. In the UK it is generally accepted that cleaning the area surrounding the urethral meatus with 0.9% sodium chloride solution is sufficient for both male and female patients as there is no reliable evidence to suggest that the use of antiseptic agents reduces the risk of urinary tract infection. Males may have a slightly higher incidence of Bladder Spasms. If bladder spasms occur or there is no urine in the drainage bag, the catheter may be blocked by: blood; thick sediment; a kink in the catheter or drainage tubing. Sometimes spasms are caused by the catheter irritating the bladder, prostate or penis. Such spasms can be controlled with medication such as Butylscopolamine, although most patients eventually adjust to the irritation and the spasms go away.

Common indications to catheterize a patient include acute or chronic urinary retention - (which can damage the kidneys), orthopedic procedures that may limit a patient's movement, the need for accurate monitoring of input and output (such as in an ICU), benign prostatic hyperplasia, incontinence, and the effects of various surgical interventions involving the bladder and prostate.

For some patients the insertion and removal of a catheter causes excruciating pain, so a topical anesthetic is used. Catheterization should be performed as a sterile medical procedure and should only be done by trained, qualified personnel, using equipment designed for this purpose, except in the case of intermittent self catheterization where the patient has been trained to perform the procedure himself or herself. If correct technique is not used there may be trauma to the urethra or prostate (male), urinary tract infection, or a paraphimosis in the uncircumcised male.

Catheter maintenance

A catheter that is left in place for more than a short period of time is generally attached to a drainage bag to collect the urine. This also allows for measurement of urine volume.

There are two types of drainage bags: The first is a leg bag, a smaller drainage device that attaches by elastic bands to the leg. A leg bag is usually worn during the day, as it fits discreetly under pants or skirts, and is easily emptied into a toilet. The second type of drainage bag is a larger device called a down drain that may be used overnight. This device is hung on a hook under the patient's bed - they are never to be placed on the floor due to the risk of bacterial infection.

During long-term use, the catheter may be left in place during the entire time, or a patient may be instructed on a procedure for placing a catheter just long enough to empty the bladder and then removing it (known as *intermittent self-catheterization*). Patients undergoing major surgery are often catheterized and may remain so for some time. The patient may require irrigation of the bladder with sterile saline injected through the catheter to flush out clots or other matter that does not drain.

Effects of long term use

The duration of cathetarization can have significance for the patient. Incontinent patients commonly are catheterized to reduce their cost of care. However, long-term catheterization carries a significant risk of urinary tract infection. Because of this risk catheterization is a last resort for the management of incontinence where other measures have proved unsuccessful. Other long term complications may include blood infections (sepsis), urethral injury, skin breakdown, bladder stones, and blood in the urine (hematuria). After many years of catheter use, bladder cancer may also develop.

Combating infection

Everyday care of catheter and drainage bag is important to reduce the risk of infection. Such precautions include:

- Cleansing the urethral area (area where catheter exits body) and the catheter itself.
- Disconnecting drainage bag from catheter only with clean hands
- Disconnecting drainage bag as seldom as possible.
- Keeping drainage bag connector as clean as possible and cleansing the drainage bag periodically.
- Use of a thin catheter where possible to reduce risk of harming the urethra during insertion.
- Drinking sufficient liquid to produce at least two liters of urine daily
- Sexual activity is very high risk for urinary infections, especially for catheterized women.

Recent developments in the field of the temporary prostatic stent have been viewed as a possible alternative to indwelling catheterization and the infections associated with their use.

History

Early development is attributed to Benjamin Franklin.

Urethral sounding

Sounding or **urethral sounding** is the medical use of probes called sounds to increase the inner diameter of the urethra and to locate obstructions in it. Sounds are also used to stretch the urethra in order to receive piercing.

Urethral sounding and **urethral play** are also used to refer to this practice in a sexual context.

Urethral play can involve the introduction of either soft or rigid items into the meatus of the penis (as well as farther in). Objects such as sounds are usually only inserted about halfway into the glans and can usually be easily retrieved. Other toys and items, such as catheters, may be introduced deeper (in some cases even into the bladder). Some items may even be allowed to curl several times or expand within the bladder. This action in the male may be directly or indirectly associated with stimulation of the prostate gland and some types of bladder control.

Risks

If not conducted carefully, sounding carries a risk of irritation, tearing of the urethra, or of urinary tract infection. Infections may become serious if they progress to the bladder or kidneys, and should be referred to a doctor.

Chapter 8

Kidneys, Ureters, Bladder X-ray and MAG3 Scan

Kidneys, ureters, and bladder x-ray

KUB X-ray showing constipation

Constipation in a young child as seen by KUB X-ray. Circles represent areas of fecal matter (stool is opaque white (not to be confused with white opaque skeletal mass and muscle mass) surrounded by black bowel gas).

In medicine, **KUB** refers to a diagnostic medical imaging technique of the abdomen and stands for **K**idneys, **U**reters, and **B**ladder.

A KUB is a plain frontal supine radiograph of the abdomen. It is often supplemented by an upright PA view of the chest (to rule out air under the diaphragm or thoracic etiologies presenting as abdominal complaints) and a standing view of the abdomen (to differentiate obstruction from ileus by examining gastrointestinal air/water levels).

Uses

Despite its name, a KUB is not typically used to investigate pathology of the kidneys, ureters, or bladder, since these structures are difficult to assess (for example, the kidneys may not be visible due to overlying bowel gas.) In order to assess these structures with X-ray, a technique called an intravenous pyelogram is utilized.

KUB is typically used to investigate gastrointestinal conditions such as a bowel obstruction and gallstones, and can detect the presence of kidney stones. The KUB is often used to diagnose constipation as stool can be seen readily. The KUB is also used to assess positioning of indwelling devices such as ureteric stents and nasogastric tubes. KUB is also done as a scout film for other procedures such as barium enemas.

Projection

It should include on the upright projections both right and left visualizations of the diaphragm. In at least one projection, the pubic symphysis must be present as the lower end of the area of interest. If the patient is large, more than one film loaded in the Bucky in a "landscape" direction may be used for each projection. This is done to ensure that the majority of bowel can be reviewed.

MAG3 scan

A **MAG3 scan** is a diagnostic imaging procedure that allows a nuclear medicine physician or radiologist to visualize the kidneys and learn more about how they are functioning. MAG3 is an acronym for mercapto acetyl tri glycine, a compound that is chelated with a radioactive element - technetium-99m.

Scan procedure

After injection into the venous system, the compound is excreted by the kidneys and its progress through the renal system can be tracked with a gamma camera. If the kidney is not getting blood for example, it will not be viewed at all, even if it looks structurally normal in medical ultrasonography or magnetic resonance imaging. If the kidney is getting blood, but there is an obstruction lower down, the contrast will not pass beyond the level of the obstruction, whereas if there is a partial obstruction then there is a delayed transit time for the MAG3 to pass. More information can be gathered by calculating time activity curves; with normal kidney perfusion, peak activity should be observed after 3–5 minutes. The relative quantitative information gives the differential function between each kidney's filtration activity.

Clinical use

The technique is very useful in evaluating the functioning of kidneys. It is widely used before renal transplantation to assess the vascularity of the kidney to be transplanted and with a test dose of captopril to highlight possible renal artery stenosis in the donor's other kidney, and later the performance of the transplant.

The use of the test to identify reduced renal function after test doses of captopril (an angiotensin converting enzyme inhibitor drug) has also been used to identify the cause of hypertension in patients with renal failure. Initially there was uncertainty as to the usefulness, or best test parameter to identify renal artery stenosis, the eventual consensus was that the distinctive finding is of alteration in the differential function.

History

In 1986, it was developed at the University of Utah by Dr. Alan R. Fritzberg, Dr. Sudhakar Kasina, and Dr. Dennis Eshima. The drug underwent clinical trials in 1987 and passed Phase III testing in 1988.

99mTc-MAG3 has replaced the older iodine-131 orthoiodohippurate or I131-Hippuran because of better quality imaging regardless of the level of renal function, and with the benefit of being able to administer lower radiation dosages.

Chapter 9

Dialysis

A hemodialysis machine

In medicine, **dialysis** (from Greek "dialusis", meaning dissolution, "dia", meaning through, and "lysis", meaning loosening) is primarily used to provide an artificial replacement for lost kidney function in people with renal failure. Dialysis may be used for those with an acute disturbance in kidney function (acute kidney injury, previously acute renal failure) or for those with progressive but chronically worsening kidney function–a state known as chronic kidney disease stage 5 (previously chronic renal failure or end-stage kidney disease). The latter form may develop over months or years, but in contrast to acute kidney injury is not usually reversible, and dialysis is regarded as a "holding measure" until a renal transplant can be performed, or sometimes as the only supportive measure in those for whom a transplant would be inappropriate.

The kidneys have important roles in maintaining health. When healthy, the kidneys maintain the body's internal equilibrium of water and minerals (sodium, potassium, chloride, calcium, phosphorus, magnesium, sulfate). Those acidic metabolism end products that the body cannot get rid of via respiration are also excreted through the kidneys. The kidneys also function as a part of the endocrine system producing erythropoietin and calcitriol. Erythropoietin is involved in the production of red blood cells and calcitriol plays a role in bone formation. Dialysis is an imperfect treatment to replace kidney function because it does not correct the endocrine functions of the kidney. Dialysis treatments replace some of these functions through diffusion (waste removal) and ultrafiltration (fluid removal).

History

Dr. Willem Kolff, a Dutch physician, constructed the first working dialyzer in 1943 during the Nazi occupation of the Netherlands. Due to the scarcity of available resources, Kolff had to improvise and build the initial machine using sausage casings, beverage cans, a washing machine and various other items which were available at the time. Over the following two years, Kolff used his machine to treat 16 patients who suffered from acute kidney failure, but the results were unsuccessful. Then, in 1945, a 67-year-old woman in uremic coma regained consciousness following 11 hours of hemodialysis with the dialyzer, and lived for another seven years before dying of an unrelated condition. She was the first-ever patient successfully treated with dialysis.

Principle

Dialysis works on the principles of the diffusion of solutes and ultrafiltration of fluid across a semi-permeable membrane. Diffusion describes a property of substances in water. Substances in water tend to move from an area of high concentration to an area of low concentration. Blood flows by one side of a semi-permeable membrane, and a dialysate, or special dialysis fluid, flows by the opposite side. A semipermeable membrane is a thin layer of material that contains various sized holes, or pores. Smaller solutes and fluid pass through the membrane, but the membrane blocks the passage of larger substances (for example, red blood cells, large proteins).

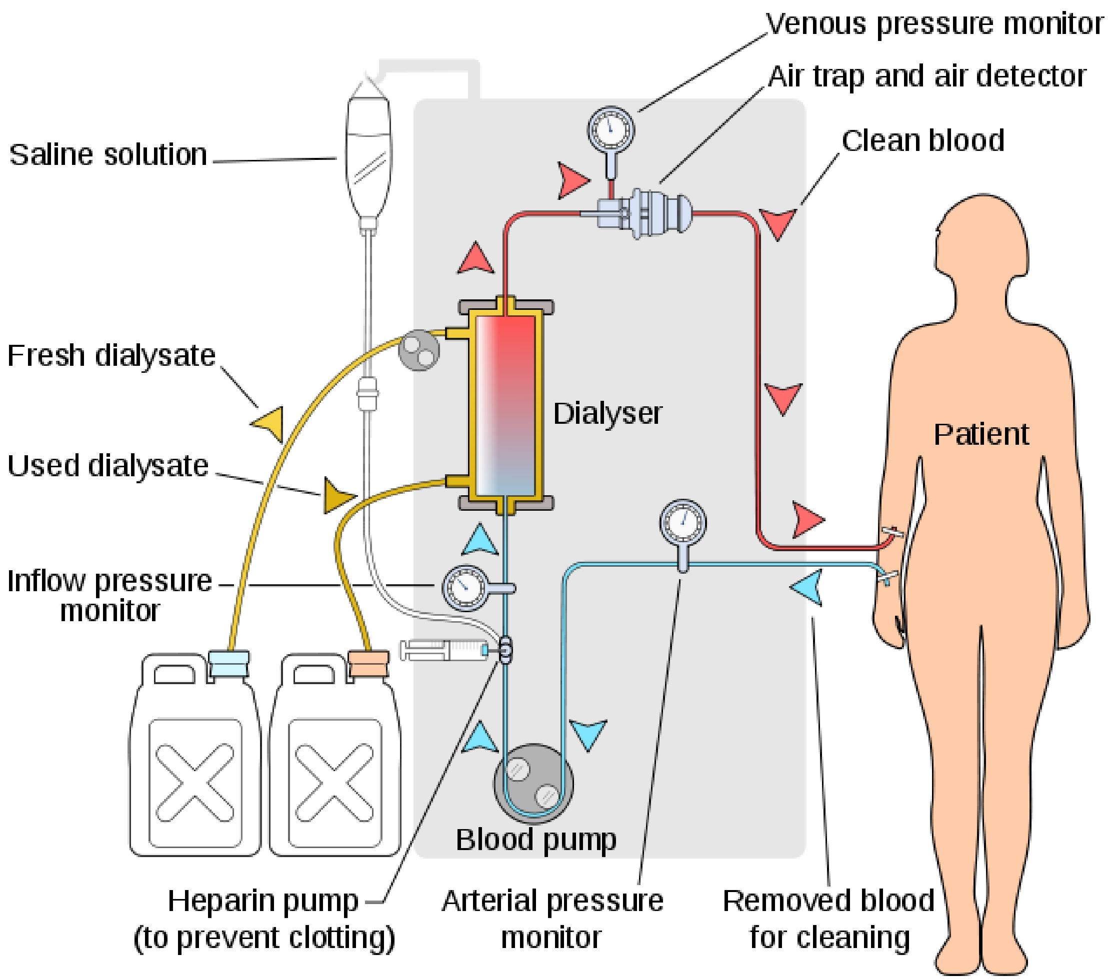
The two main types of dialysis, hemodialysis and Peritoneal dialysis, remove wastes and excess water from the blood in different ways. Hemodialysis removes wastes and water by circulating blood outside the body through an external filter, called a dialyzer, that contains a semipermeable membrane. The blood flows in one direction and the dialysate flows in the opposite. The counter-current flow of the blood and dialysate maximizes the concentration gradient of solutes between the blood and dialysate, which helps to remove more urea and creatinine from the blood. The concentrations of solutes (for example potassium, phosphorus, and urea) are undesirably high in the blood, but low or absent in the dialysis solution and constant replacement of the dialysate ensures that the concentration of undesired solutes is kept low on this side of the membrane. The dialysis solution has levels of minerals like potassium and calcium that are similar to their natural concentration in healthy blood. For another solute, bicarbonate, dialysis solution level is set at a slightly higher level than in normal blood, to encourage diffusion of bicarbonate into the blood, to act as a pH buffer to neutralize the metabolic acidosis that is often present in these patients. The levels of the components of dialysate are typically prescribed by a nephrologist according to the needs of the individual patient.

In peritoneal dialysis, wastes and water are removed from the blood inside the body using the *peritoneal membrane* of the peritoneum as a natural semipermeable membrane. Wastes and excess water move from the blood, across the peritoneal membrane, and into a special dialysis solution, called dialysate, in the abdominal cavity which has a composition similar to the fluid portion of blood.

Types

There are three primary and two secondary types of dialysis: hemodialysis (primary), peritoneal dialysis (primary), hemofiltration (primary), hemodiafiltration (secondary), and intestinal dialysis (secondary).

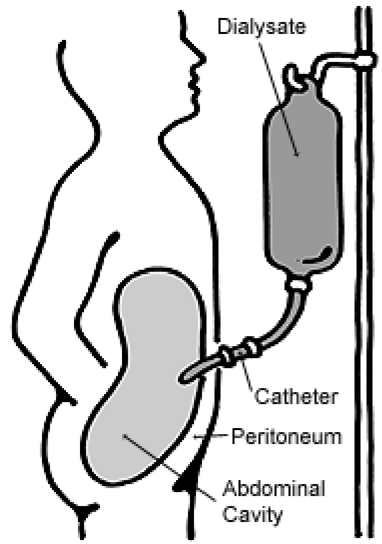
Hemodialysis



Hemodialysis schematic

In hemodialysis, the patient's blood is pumped through the blood compartment of a dialyzer, exposing it to a partially permeable membrane. The dialyzer is composed of thousands of tiny synthetic hollow fibers. The fiber wall acts as the semipermeable membrane. Blood flows through the fibers, dialysis solution flows around the outside the fibers, and water and wastes move between these two solutions. The cleansed blood is then returned via the circuit back to the body. Ultrafiltration occurs by increasing the hydrostatic pressure across the dialyzer membrane. This usually is done by applying a negative pressure to the dialysate compartment of the dialyzer. This pressure gradient causes water and dissolved solutes to move from blood to dialysate, and allows the removal of several litres of excess fluid during a typical 3 to 5 hour treatment. In the US, hemodialysis treatments are typically given in a dialysis center three times per week (due in the US to Medicare reimbursement rules); however, as of 2007 over 2,500 people in the US are dialyzing at home more frequently for various treatment lengths. Studies have demonstrated the clinical benefits of dialyzing 5 to 7 times a week, for 6 to 8 hours. This type of hemodialysis is usually called "nocturnal daily hemodialysis", which a study has shown a significant improvement in both small and large molecular weight clearance and decrease the requirement of taking phosphate binders. These frequent long treatments are often done at home while sleeping, but home dialysis is a flexible modality and schedules can be changed day to day, week to week. In general, studies have shown that both increased treatment length and frequency are clinically beneficial.

Peritoneal dialysis



Schematic diagram of peritoneal dialysis

In peritoneal dialysis, a sterile solution containing glucose is run through a tube into the peritoneal cavity, the abdominal body cavity around the intestine, where the peritoneal membrane acts as a semipermeable membrane.The peritoneal membrane or peritoneum is a layer of tissue containing blood vessels that lines and surrounds the peritoneal, or abdominal, cavity and the internal abdominal organs (stomach, spleen, liver, and intestines). The dialysate is left there for a period of time to absorb waste products, and then it is drained out through the tube and discarded. This cycle or "exchange" is normally repeated 4-5 times during the day, (sometimes more often overnight with an automated system). Each time the dialysate fills and empties from the abdomen is called one exchange. A dwell time means that the time of dialysate stay in patient's abdominal cavity - wastes, chemicals and extra fluid move from patient's blood to the dialysate across the peritoneum. A drain process is the process after the dwell time, the dialysate full with waste products and extra fluid is drained out of patient's blood. Ultrafiltration occurs via osmosis; the dialysis solution used contains a high concentration of glucose, and the resulting osmotic pressure causes fluid to move from the blood into the dialysate. As a result, more fluid is drained than was instilled. Peritoneal dialysis is less efficient than hemodialysis, but because it is carried out for a longer period of time the net effect in terms of removal of waste products and of salt and water are similar to hemodialysis. Peritoneal dialysis is carried out at home by the patient. Although support is helpful, it is not essential. It does free patients from the routine of having to go to a dialysis clinic on a fixed schedule multiple times per week, and it can be done while travelling with a minimum of specialized equipment.

Hemofiltration

Hemofiltration is a similar treatment to hemodialysis, but it makes use of a different principle. The blood is pumped through a dialyzer or "hemofilter" as in dialysis, but no dialysate is used. A pressure gradient is applied; as a result, water moves across the very permeable membrane rapidly, "dragging" along with it many dissolved substances, importantly ones with large molecular weights, which are cleared less well by hemodialysis. Salts and water lost from the blood during this process are replaced with a "substitution fluid" that is infused into the extracorporeal circuit during the treatment. Hemodiafiltration is a term used to describe several methods of combining hemodialysis and hemofiltration in one process.

Hemodiafiltration

Hemodialfiltration is a combination of hemodialysis and hemofiltration. In theory, this technique offers the advantages of both hemodialysis and hemofiltration.

Intestinal dialysis

In intestinal dialysis, the diet is supplemented with soluble fibres such as acacia fibre, which is digested by bacteria in the colon. This bacterial growth increases the amount of nitrogen that is eliminated in fecal waste. An alternative approach utilizes the ingestion of 1 to 1.5 liters of non-absorbable solutions of polyethylene glycol or mannitol every fourth hour.

Starting indications

The decision to initiate dialysis or hemofiltration in patients with renal failure depends on several factors. These can be divided into acute or chronic indications.

- Indications for dialysis in the patient with acute kidney injury are:
    1. Metabolic acidosis in situations where correction with sodium bicarbonate is impractical or may result in fluid overload.
    2. Electrolyte abnormality, such as severe hyperkalemia, especially when combined with AKI.
    3. Fluid overload not expected to respond to treatment with diuretics.
    4. Complications of uremia, such as pericarditis, encephalopathy, or gastrointestinal bleeding.
    5. Intoxication, that is, acute poisoning with a dialyzable substance. These substances can be represented by the mnemonic SLIME: salicylic acid, lithium, isopropanol, Magnesium-containing laxatives, and ethylene glycol.

- Chronic indications for dialysis:
    1. Symptomatic renal failure
    2. Low glomerular filtration rate (GFR) (RRT often recommended to commence at a GFR of less than 10-15 mls/min/1.73m^2). In diabetics dialysis is started earlier.
    3. Difficulty in medically controlling fluid overload, serum potassium, and/or serum phosphorus when the GFR is very low

Chapter 10

Hemodialysis

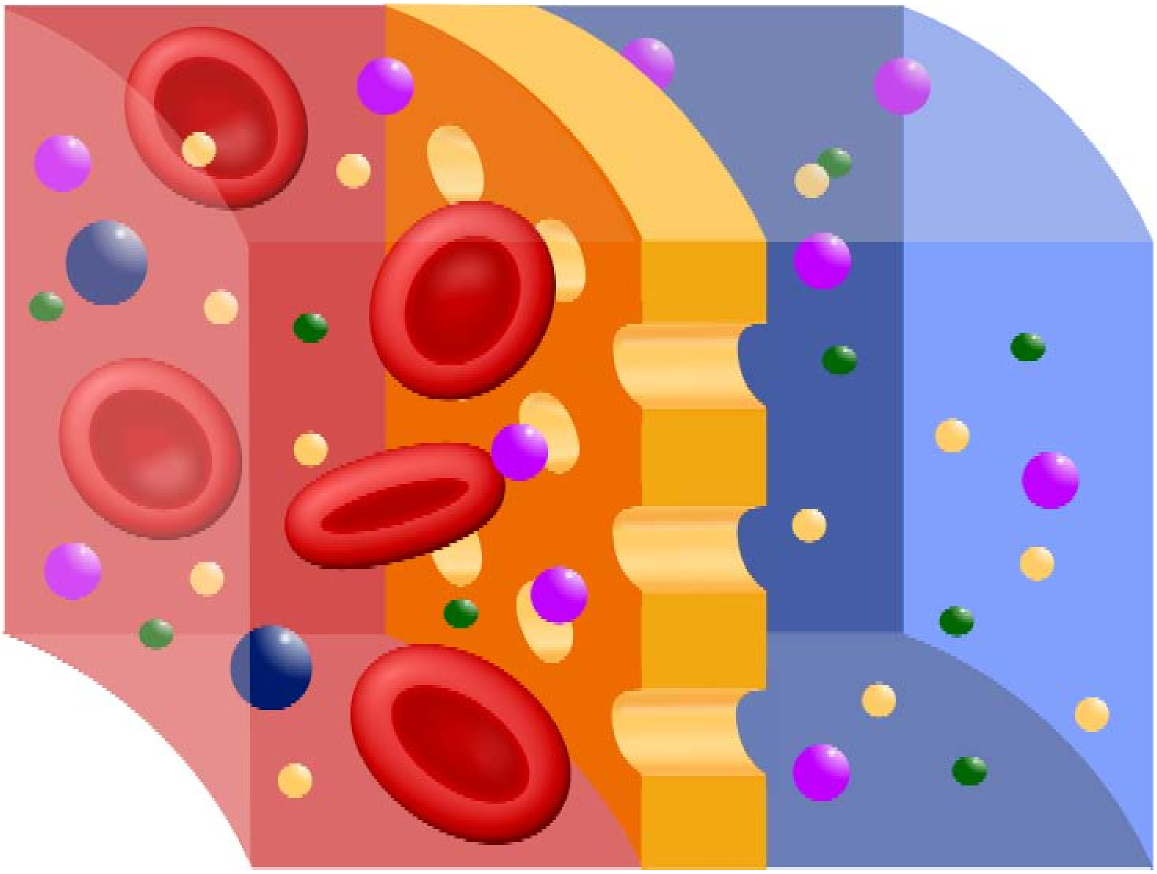
Hemodialysis in progress

Hemodialysis machine

In medicine, **hemodialysis** (also **haemodialysis**) is a method for removing waste products such as creatinine and urea, as well as free water from the blood when the kidneys are in renal failure. Hemodialysis is one of three renal replacement therapies (the other two being renal transplant; peritoneal dialysis).

Hemodialysis can be an outpatient or inpatient therapy. Routine hemodialysis is conducted in a dialysis outpatient facility, either a purpose built room in a hospital or a dedicated, stand alone clinic. Less frequently hemodialysis is done at home. Dialysis treatments in a clinic are initiated and managed by specialized staff made up of nurses and technicians; dialysis treatments at home can be self initiated and managed or done jointly with the assistance of a trained helper who is usually a family member.

Principle



Semipermeable membrane

The principle of hemodialysis is the same as other methods of dialysis; it involves diffusion of solutes across a semipermeable membrane. Hemodialysis utilizes counter current flow, where the dialysate is flowing in the opposite direction to blood flow in the extracorporeal circuit. Counter-current flow maintains the concentration gradient across the membrane at a maximum and increases the efficiency of the dialysis.

Fluid removal (ultrafiltration) is achieved by altering the hydrostatic pressure of the dialysate compartment, causing free water and some dissolved solutes to move across the membrane along a created pressure gradient.

The dialysis solution that is used may be a sterilized solution of mineral ions or comply with Britich Pharmacopea. Urea and other waste products, potassium, and phosphate diffuse into the dialysis solution. However, concentrations of sodium and chloride are similar to those of normal plasma to prevent loss. Sodium bicarbonate is added in a higher concentration than plasma to correct blood acidity. A small amount of glucose is also commonly used.

Note that this is a different process to the related technique of hemofiltration.

History

Many have played a role in developing dialysis as a practical treatment for renal failure, starting with Thomas Graham of Glasgow, who first presented the principles of solute transport across a semipermeable membrane in 1854. The artificial kidney was first developed by Abel, Rountree and Turner in 1913,, the first hemodialysis in a human being was by Hass (February 28, 1924) and the artificial kidney was developed into a clinically useful apparatus by Kolff in 1943 - 1945. This research showed that life could be prolonged in patients dying of renal failure.

Dr. Willem Kolff was the first to construct a working dialyzer in 1943. The first successfully treated patient was a 67-year-old woman in uremic coma who regained consciousness after 11 hours of hemodialysis with Kolff's dialyzer in 1945. At the time of its creation, Kolff's goal was to provide life support during recovery from acute renal failure. After World War II ended, Kolff donated the five dialyzers he had made to hospitals around the world, including Mount Sinai Hospital, New York. Kolff gave a set of blueprints for his hemodialysis machine to George Thorn at the Peter Bent Brigham Hospital in Boston. This led to the manufacture of the next generation of Kolff's dialyzer, a stainless steel Kolff-Brigham dialysis machine.

By the 1950s, Willem Kolff's invention of the dialyzer was used for acute renal failure, but it was not seen as a viable treatment for patients with stage 5 chronic kidney disease (CKD). At the time, doctors believed it was impossible for patients to have dialysis indefinitely for two reasons. First, they thought no man-made device could replace the function of kidneys over the long term. In addition, a patient undergoing dialysis suffered from damaged veins and arteries, so that after several treatments, it became difficult to find a vessel to access the patient's blood.

Dr. Nils Alwall: The original Kolff kidney was not very useful clinically, because it did not allow for removal of excess fluid. Dr. Nils Alwall encased a modified version of this kidney inside a stainless steel canister, to which a negative pressure could be applied, in this way effecting the first truly practical application of hemodialysis, which was done in 1946 at the University of Lund. Alwall also was arguably the inventor of the arteriovenous shunt for dialysis. He reported this first in 1948 where he used such an arteriovenous shunt in rabbits. Subsequently he used such shunts, made of glass, as well as his canister-enclosed dialyzer, to treat 1500 patients in renal failure between 1946 and 1960, as reported to the First International Congress of Nephrology held in Evian in September 1960. Alwall was appointed to a newly-created Chair of Nephrology at the University of Lund in 1957. Subsequently, he collaborated with Swedish businessman Holger Crafoord to found one of the key companies that would manufacture dialysis equipment in the past 50 years, Gambro. The early history of dialysis has been reviewed by Stanley Shaldon .

Dr. Belding H. Scribner working with a surgeon, Dr. Wayne Quinton, modified the glass shunts used by Alwall by making them from Teflon. Another key improvement was to connect them to a short piece of silicone elastomer tubing. This formed the basis of the so-called Scribner shunt, perhaps more properly called the Quinton-Scribner shunt. After treatment, the circulatory access would be kept open by connecting the two tubes outside the body using a small U-shaped Teflon tube, which would shunt the blood from the tube in the artery back to the tube in the vein .

In 1962, Scribner started the world's first outpatient dialysis facility, the Seattle Artificial Kidney Center, later renamed the Northwest Kidney Centers. Immediately the problem arose of who should be given dialysis, since demand far exceeded the capacity of the six dialysis machines at the center. Scribner decided that the decision about who would receive dialysis and who wouldn't, would not be made by him. Instead, the choices would be made by an anonymous committee, which could be viewed as one of the first bioethics committees.

Prescription

A prescription for dialysis by a nephrologist (a medical kidney specialist) will specify various parameters for a dialysis treatment. These include frequency (how many treatments per week), length of each treatment, and the blood and dialysis solution flow rates, as well as the size of the dialyzer. The composition of the dialysis solution is also sometimes adjusted in terms of its sodium and potassium and bicarbonate levels. In general, the larger the body size of an individual, the more dialysis he/she will need. In the North America and UK, 3-4 hour treatments (sometimes up to 5 hours for larger patients) given 3 times a week are typical. Twice-a-week sessions are limited to patients who have a substantial residual kidney function. Four sessions per week are often prescribed for larger patients, as well as patients who have trouble with fluid overload. Finally, there is growing interest in short daily home hemodialysis, which is 1.5 - 4 hr sessions given 5-7 times per week, usually at home. There also is interest in nocturnal dialysis, which involves dialyzing a patient, usually at home, for 8–10 hours per night, 3-6 nights per week. Nocturnal in-center dialysis, 3-4 times per week is also offered at a handful of dialysis units in the United States.

Side effects and complications

Hemodialysis often involves fluid removal (through ultrafiltration), because most patients with renal failure pass little or no urine. Side effects caused by removing too much fluid and/or removing fluid too rapidly include low blood pressure, fatigue, chest pains, leg-cramps, nausea and headaches. These symptoms can occur during the treatment and can persist post treatment; they are sometimes collectively referred to as the dialysis hangover or dialysis washout. The severity of these symptoms is usually proportionate to the amount and speed of fluid removal. However, the impact of a given amount or rate of fluid removal can vary greatly from person to person and day to day. These side effects can be avoided and/or their severity lessened by limiting fluid intake between treatments or increasing the dose of dialysis e.g. dialyzing more often or longer per treatment than the standard three times a week, 3–4 hours per treatment schedule.

Since hemodialysis requires access to the circulatory system, patients undergoing hemodialysis may expose their circulatory system to microbes, which can lead to sepsis, an infection affecting the heart valves (endocarditis) or an infection affecting the bones (osteomyelitis). The risk of infection varies depending on the type of access used (see below). Bleeding may also occur, again the risk varies depending on the type of access used. Infections can be minimized by strictly adhering to infection control best practices.

Heparin is the most commonly used anticoagulant in hemodialysis, as it is generally well tolerated and can be quickly reversed with protamine sulfate. Heparin allergy can infrequently be a problem and can cause a low platelet count. In such patients, alternative anticoagulants can be used. In patients at high risk of bleeding, dialysis can be done without anticoagulation.

First Use Syndrome is a rare but severe anaphylactic reaction to the artificial kidney. Its symptoms include sneezing, wheezing, shortness of breath, back pain, chest pain, or sudden death. It can be caused by residual sterilant in the artificial kidney or the material of the membrane itself. In recent years, the incidence of First Use Syndrome has decreased, due to an increased use of gamma irradiation, steam sterilization, or electron-beam radiation instead of chemical sterilants, and the development of new semipermeable membranes of higher biocompatibility. New methods of processing previously acceptable components of dialysis must always been considered. For example, in 2008, a series of first-use type or reactions, including deaths occurred due to heparin contaminated during the manufacturing process with oversulfated chondroitin sulfate.

Longterm complications of hemodialysis include amyloidosis, neuropathy and various forms of heart disease. Increasing the frequency and length of treatments have been shown to improve fluid overload and enlargement of the heart that is commonly seen in such patients.

Listed below are specific complications associated with different types of hemodialysis access.

Access

In hemodialysis, three primary methods are used to gain access to the blood: an intravenous catheter, an arteriovenous (AV) fistula and a synthetic graft. The type of access is influenced by factors such as the expected time course of a patient's renal failure and the condition of his or her vasculature. Patients may have multiple accesses, usually because an AV fistula or graft is maturing and a catheter is still being used. The creation of all these three major types of vascular accesses requires surgery.

Catheter

Catheter access, sometimes called a CVC (Central Venous Catheter), consists of a plastic catheter with two lumens (or occasionally two separate catheters) which is inserted into a large vein (usually the vena cava, via the internal jugular vein or the femoral vein) to allow large flows of blood to be withdrawn from one lumen, to enter the dialysis circuit, and to be returned via the other lumen. However, blood flow is almost always less than that of a well functioning fistula or graft.

Catheters are usually found in two general varieties, tunnelled and non-tunnelled.

Non-tunnelled catheter access is for short-term access (up to about 10 days, but often for one dialysis session only), and the catheter emerges from the skin at the site of entry into the vein.

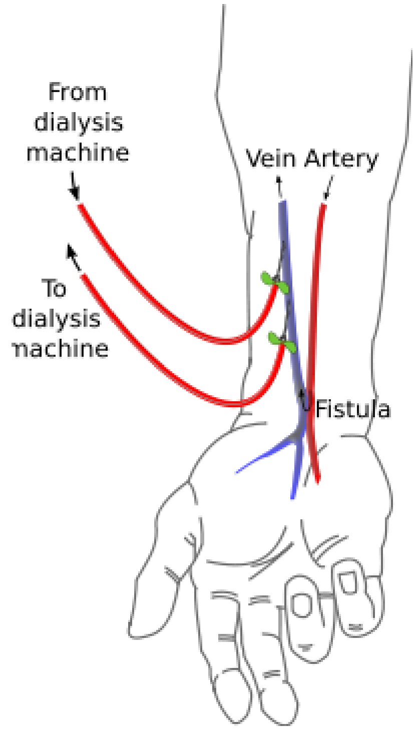
Tunnelled catheter access involves a longer catheter, which is tunnelled under the skin from the point of insertion in the vein to an exit site some distance away. It is usually placed in the internal jugular vein in the neck and the exit site is usually on the chest wall. The tunnel acts as a barrier to invading microbes, and as such, tunnelled catheters are designed for short- to medium-term access (weeks to months only), because infection is still a frequent problem.

Aside from infection, venous stenosis is another serious problem with catheter access. The catheter is a foreign body in the vein and often provokes an inflammatory reaction in the vein wall. This results in scarring and narrowing of the vein, often to the point of occlusion. This can cause problems with severe venous congestion in the area drained by the vein and may also render the vein, and the veins drained by it, useless for creating a fistula or graft at a later date. Patients on long-term hemodialysis can literally 'run out' of access, so this can be a fatal problem.

Catheter access is usually used for rapid access for immediate dialysis, for tunnelled access in patients who are deemed likely to recover from acute renal failure, and for patients with end-stage renal failure who are either waiting for alternative access to mature or who are unable to have alternative access.

Catheter access is often popular with patients, because attachment to the dialysis machine doesn't require needles. However, the serious risks of catheter access noted above mean that such access should be contemplated only as a long-term solution in the most desperate access situation.

AV fistula



A radiocephalic fistula.

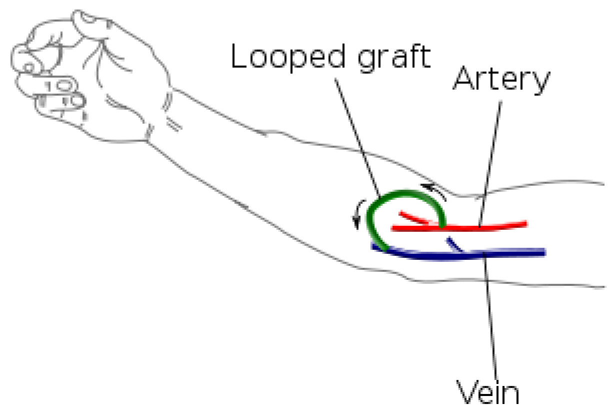
AV (arteriovenous) fistulas are recognized as the preferred access method. To create a fistula, a vascular surgeon joins an artery and a vein together through anastomosis. Since this bypasses the capillaries, blood flows rapidly through the fistula. One can feel this by placing one's finger over a mature fistula. This is called feeling for "thrill" and produces a distinct 'buzzing' feeling over the fistula. One can also listen through a stethoscope for the sound of the blood "whooshing" through the fistula, a sound called *bruit*.

Fistulas are usually created in the nondominant arm and may be situated on the hand (the 'snuffbox' fistula'), the forearm (usually a **radiocephalic** fistula, or so-called Brescia-Cimino fistula, in which the radial artery is anastomosed to the cephalic vein), or the elbow (usually a brachiocephalic fistula, where the brachial artery is anastomosed to the cephalic vein). A fistula will take a number of weeks to mature, on average perhaps 4–6 weeks. During treatment, two needles are inserted into the fistula, one to draw blood and one to return it.

The advantages of the AV fistula use are lower infection rates, because no foreign material is involved in their formation, higher blood flow rates (which translates to more effective dialysis), and a lower incidence of thrombosis. The complications are few, but if a fistula has a very high blood flow and the vasculature that supplies the rest of the limb is poor, a steal syndrome can occur, where blood entering the limb is drawn into the fistula and returned to the general circulation without entering the limb's capillaries. This results in cold extremities of that limb, cramping pains, and, if severe, tissue damage.

One long-term complication of an AV fistula can be the development of an aneurysm, a bulging in the wall of the vein where it is weakened by the repeated insertion of needles over time. To a large extent the risk of developing an aneurysm can be reduced by carefully rotating needle sites over the entire fistula, or using the "buttonhole"(constant site) technique. Aneurysms may necessitate corrective surgery and may shorten the useful life of a fistula. To prevent damage to the fistula and aneurysm or pseudoaneurysm formation, it is recommended that the needle be inserted at different points in a rotating fashion. Another approach is to cannulate the fistula with a blunted needle, in exactly the same place. This is called a 'buttonhole' approach. Often two or three buttonhole places are available on a given fistula. This also can prolong fistula life and help prevent damage to the fistula.

AV graft



An arteriovenous graft.

AV (arteriovenous) grafts are much like fistulas in most respects, except that an artificial vessel is used to join the artery and vein. The graft usually is made of a synthetic material, often PTFE, but sometimes chemically treated, sterilized veins from animals are used. Grafts are inserted when the patient's native vasculature does not permit a fistula. They mature faster than fistulas, and may be ready for use several weeks after formation (some newer grafts may be used even sooner). However, AV grafts are at high risk to develop narrowing, especially in the vein just downstream from where the graft has been sewn to the vein. Narrowing often leads to clotting or thrombosis. As foreign material, they are at greater risk for becoming infected. More options for sites to place a graft are available, because the graft can be made quite long. Thus a graft can be placed in the thigh or even the neck (the 'necklace graft').

Fistula First project

AV fistulas have a much better access patency and survival than do venous catheters or grafts. They also produce better patient survival and have far fewer complications compared to grafts or venous catheters. For this reason, the Centers for Medicare &

Medicaid (CMS) has set up a Fistula First Initiative , whose goal is to increase the use of AV fistulas in dialysis patients.

There is ongoing research to make bio-engineered blood vessels, which may be of immense importance in creating AV fistulas for patients on hemodialysis, who do not have good blood vessels for creation of one. It involves growing cells which produce collagen and other proteins on a biodegradable micromesh tube followed by removal of those cells to make the 'blood vessels' storable in refrigerators.

Types

There are three types of hemodialysis: conventional hemodialysis, daily hemodialysis, and nocturnal hemodialysis. Below is the adaption and summary from a brochure of The Ottawa Hospital.

Conventional hemodialysis

Chronic hemodialysis is usually done three times per week, for about 3-4 hours for each treatment, during which the patient's blood is drawn out through a tube at a rate of 3-400 cc/min. The tube is connected to a 15, 16, or 17 gauge needle inserted in the dialysis fistula or graft, or connected to one port of a dialysis catheter. The blood is then pumped through the dialyser, and then the processed blood is pumped back into the patient's bloodstream through another tube (connected to a second needle or port). During the procedure, the patient's blood pressure is closely monitored, and if it becomes low, or the patient develops any other signs of low blood volume such as nausea, the dialysis attendant can administer extra fluid through the machine. During the treatment, the patient's entire blood volume (about 5000 cc) circulates through the machine every 15 minutes.

Daily hemodialysis

Daily hemodialysis is typically used by those patients who do their own dialysis at home. It is less stressful (more gentle) but does require more frequent access. This is simple with catheters, but more problematic with fistulas or grafts. The "buttonhole technique" can be used for fistulas requiring frequent access. Daily hemodialysis is usually done for 2 hours six days a week.

Nocturnal hemodialysis

the procedure of nocturnal hemodialysis is similar to conventional hemodialysis except it is performed six nights a week and six-ten hours per session while the patient sleeps.

Advantages and disadvantages

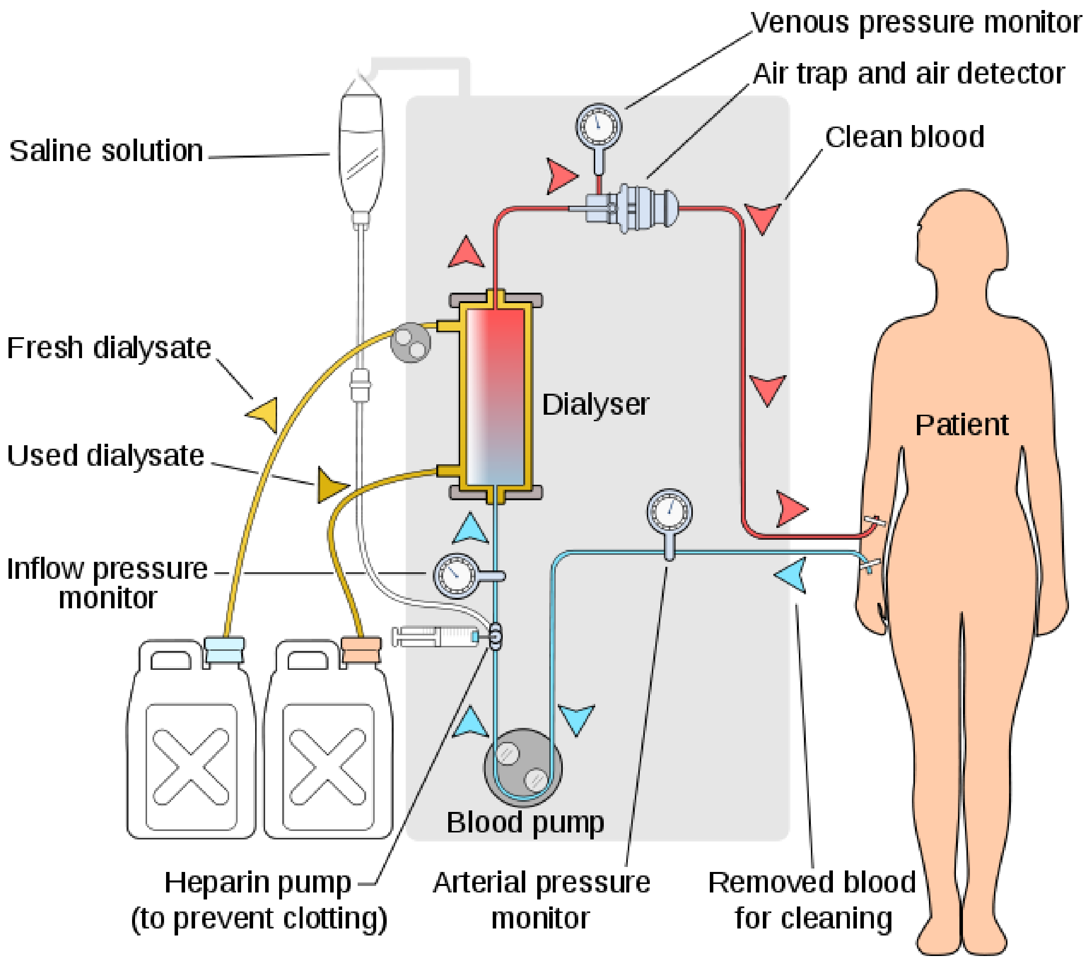
Advantages

- Low mortality rate
- Better control of blood pressure and abdominal cramps
- Less diet restriction
- Better solute clearance effect for the daily hemodialysis: better tolerance and fewer complications with more frequent dialysis

Disadvantages

- Restricts independence, as people undergoing this procedure cannot travel around because of supplies' availability
- Requires reliable technology such as high water quality and electricity
- Requires more supplies like dialysis machines
- The procedure is complicated and requires that care givers have more knowledge
- Requires time to set up and clean dialysis machines, and expense with machines and associated staff

Equipment



Schematic of a hemodialysis circuit

The hemodialysis machine pumps the patient's blood and the dialysate through the dialyzer. The newest dialysis machines on the market are highly computerized and continuously monitor an array of safety-critical parameters, including blood and dialysate flow rates; dialysis solution conductivity, temperature, and pH; and analysis of the dialysate for evidence of blood leakage or presence of air. Any reading that is out of normal range triggers an audible alarm to alert the patient-care technician who is monitoring the patient. Manufacturers of dialysis machines include companies such as Fresenius, Gambro, Baxter, B. Braun, NxStage and Bellco.

Water system

A hemodialysis unit's dialysate solution tanks

An extensive water purification system is absolutely critical for hemodialysis. Since dialysis patients are exposed to vast quantities of water, which is mixed with dialysate concentrate to form the dialysate, even trace mineral contaminants or bacterial endotoxins can filter into the patient's blood. Because the damaged kidneys cannot perform their intended function of removing impurities, ions introduced into the bloodstream via water can build up to hazardous levels, causing numerous symptoms or death. Aluminum, chloramine, fluoride, copper, and zinc, as well as bacterial fragments and endotoxins, have all caused problems in this regard.

For this reason, water used in hemodialysis is carefully purified before use. Initially it is filtered and temperature-adjusted and its pH is corrected by adding an acid or base. Then it is softened. Next the water is run through a tank containing activated charcoal to adsorb organic contaminants. Primary purification is then done by forcing water through a membrane with very tiny pores, a so-called reverse osmosis membrane. This lets the water pass, but holds back even very small solutes such as electrolytes. Final removal of leftover electrolytes is done by passing the water through a tank with ion-exchange resins, which remove any leftover anions or cations and replace them with hydroxyl and hydrogen molecules, respectively, leaving ultrapure water.

Even this degree of water purification may be insufficient. The trend lately is to pass this final purified water (after mixing with dialysate concentrate) through a dialyzer membrane. This provides another layer of protection by removing impurities, especially those of bacterial origin, that may have accumulated in the water after its passage through the original water purification system.

Once purified water is mixed with dialysate concentrate, its conductivity increases, since water that contains charged ions conducts electricity. During dialysis, the conductivity of dialysis solution is continuously monitored to ensure that the water and dialysate concentrate are being mixed in the proper proportions. Both excessively concentrated dialysis solution and excessively dilute solution can cause severe clinical problems.

Dialyzer

The dialyzer is the piece of equipment that actually filters the blood. Almost all dialyzers in use today are of the hollow-fiber variety. A cylindrical bundle of hollow fibers, whose walls are composed of semi-permeable membrane, is anchored at each end into potting compound (a sort of glue). This assembly is then put into a clear plastic cylindrical shell with four openings. One opening or blood port at each end of the cylinder communicates with each end of the bundle of hollow fibers. This forms the "blood compartment" of the dialyzer. Two other ports are cut into the side of the cylinder. These communicate with the space around the hollow fibers, the "dialysate compartment." Blood is pumped via the blood ports through this bundle of very thin capillary-like tubes, and the dialysate is pumped through the space surrounding the fibers. Pressure gradients are applied when necessary to move fluid from the blood to the dialysate compartment.

Membrane and flux

Dialyzer membranes come with different pore sizes. Those with smaller pore size are called "low-flux" and those with larger pore sizes are called "high-flux." Some larger molecules, such as beta-2-microglobulin, are not removed at all with low-flux dialyzers; lately, the trend has been to use high-flux dialyzers. However, such dialyzers require newer dialysis machines and high-quality dialysis solution to control the rate of fluid removal properly and to prevent backflow of dialysis solution impurities into the patient through the membrane.

Dialyzer membranes used to be made primarily of cellulose (derived from cotton linter). The surface of such membranes was not very biocompatible, because exposed hydroxyl groups would activate complement in the blood passing by the membrane. Therefore, the basic, "unsubstituted" cellulose membrane was modified. One change was to cover these hydroxyl groups with acetate groups (cellulose acetate); another was to mix in some compounds that would inhibit complement activation at the membrane surface (modified cellulose). The original "unsubstituted cellulose" membranes are no longer in wide use, whereas cellulose acetate and modified cellulose dialyzers are still used. Cellulosic membranes can be made in either low-flux or high-flux configuration, depending on their pore size.

Another group of membranes is made from synthetic materials, using polymers such as polyarylethersulfone, polyamide, polyvinylpyrrolidone, polycarbonate, and polyacrylonitrile. These synthetic membranes activate complement to a lesser degree than unsubstituted cellulose membranes. Synthetic membranes can be made in either low- or high-flux configuration, but most are high-flux.

Nanotechnology is being used in some of the most recent high-flux membranes to create a uniform pore size. The goal of high-flux membranes is to pass relatively large molecules such as beta-2-microglobulin (MW 11,600 daltons), but not to pass albumin (MW ~66,400 daltons). Every membrane has pores in a range of sizes. As pore size increases, some high-flux dialyzers begin to let albumin pass out of the blood into the dialysate. This is thought to be undesirable, although one school of thought holds that removing some albumin may be beneficial in terms of removing protein-bound uremic toxins.

Membrane flux and outcome

Whether using a high-flux dialyzer improves patient outcomes is somewhat controversial, but several important studies have suggested that it has clinical benefits. The NIH-funded HEMO trial compared survival and hospitalizations in patients randomized to dialysis with either low-flux or high-flux membranes. Although the primary outcome (all-cause mortality) did not reach statistical significance in the group randomized to use high-flux membranes, several secondary outcomes were better in the high-flux group . A recent Cochrane analysis concluded that benefit of membrane choice on outcomes has not yet been demonstrated . A collaborative randomized trial from Europe, the MPO (Membrane Permeabilities Outcomes) study, comparing mortality in patients just starting dialysis using either high-flux or low-flux membranes, found a nonsignificant trend to improved survival in those using high-flux membranes, and a survival benefit in patients with lower serum albumin levels or in diabetics.

Membrane flux and beta-2-microglobulin amyloidosis

High-flux dialysis membranes and/or intermittent on-line hemodiafiltration (IHDF) may also be beneficial in reducing complications of beta-2-microglobulin accumulation. Because beta-2-microglobulin is a large molecule, with a molecular weight of about 11,600 daltons, it does not pass at all through low-flux dialysis membranes. Beta-2-M is removed with high-flux dialysis, but is removed even more efficiently with IHDF. After several years (usually at least 5-7), patients on hemodialysis begin to develop complications from beta-2-M accumulation, including carpal tunnel syndrome, bone cysts, and deposits of this amyloid in joints and other tissues. Beta-2-M amyloidosis can cause very serious complications, including spondyloarthropathy, and often is associated with shoulder joint problems. Observational studies from Europe and Japan have suggested that using high-flux membranes in dialysis mode, or IHDF, reduces beta-2-M complications in comparison to regular dialysis using a low-flux membrane.

Dialyzer size and efficiency

Dialyzers come in many different sizes. A larger dialyzer with a larger membrane area (A) will usually remove more solutes than a smaller dialyzer, especially at high blood flow rates. This also depends on the membrane permeability coefficient K_0 for the solute in question. So dialyzer efficiency is usually expressed as the K_0A - the product of permeability coefficient and area. Most dialyzers have membrane surface areas of 0.8 to 2.2 square meters, and values of K_0A ranging from about 500 to 1500 mL/min. K_0A, expressed in mL/min, can be thought of as the maximum clearance of a dialyzer at very high blood and dialysate flow rates.

Reuse of dialyzers

The dialyzer may either be discarded after each treatment or be reused. Reuse requires an extensive procedure of high-level disinfection. Reused dialyzers are not shared between patients. There was an initial controversy about whether reusing dialyzers worsened patient outcomes. The consensus today is that reuse of dialyzers, done carefully and properly, produces similar outcomes to single use of dialyzers .

Nursing care for hemodialysis patient

Adapt from nephrology nursing practice recommendations developed by Canadian Association of Nephrology and Technology (CANNT) based on best available evidence and clinical practice guidelines, a nephrology nurse should perform :

Hemodialysis Vascular Access: Assess the fistula/graft and arm before, after each dialysis or every shift: the access flow, complications Assess the complication of central venous catheter: the tip placement, exit site, complications document and notify appropriate health care provider regarding any concerns. educates the patient with appropriate cleaning of fistula/graft and exit site; with recognizing and reporting signs and symptoms of infection and complication.

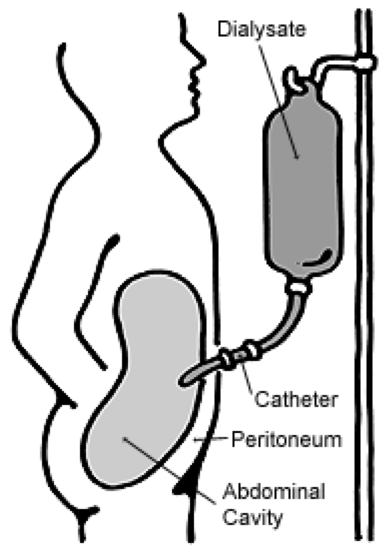
Hemodialysis adequacy: Assesses patient constantly for signs and symptoms of inadequate dialysis. Assesses possible causes of inadequate dialysis. Educations patients the importance of receiving adequate dialysis.

Hemodialysis treatment and complications: Performs head to toe physical assessment before, during and after hemodialysis regarding complications and access's security. Confirm and deliver dialysis prescription after review most update lab results. Address any concerns of the patient and educate patient when recognizing the learning gap.

Medication management and infection control practice: Collaborate with the patient to develop a medication regimen. Follow infection control guidelines as per unit protocol.

Chapter 11

Peritoneal Dialysis



Schematic diagram of peritoneal dialysis

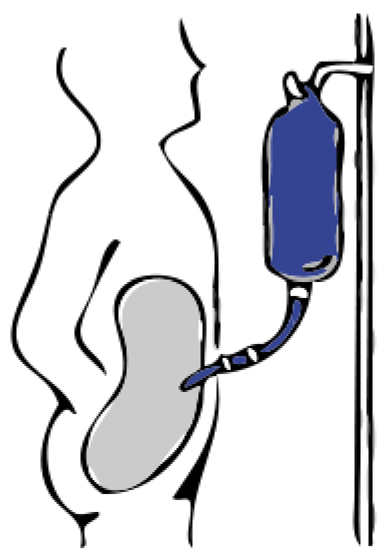
Peritoneal dialysis (PD) is a treatment for patients with severe chronic kidney disease. The process uses the patient's peritoneum in the abdomen as a membrane across which fluids and dissolved substances (electrolytes, urea, glucose, albumin and other small molecules) are exchanged from the blood. Fluid is introduced through a permanent tube in the abdomen and flushed out either every night while the patient sleeps (automatic peritoneal dialysis) or via regular exchanges throughout the day (continuous ambulatory peritoneal dialysis). PD is used as an alternative to hemodialysis though it is far less common. It has comparable risks and expenses, with the primary advantage being the ability to undertake treatment without visiting a medical facility. The primary complication with PD is a risk of infection due to the presence of a permanent tube in the abdomen.

Best practices

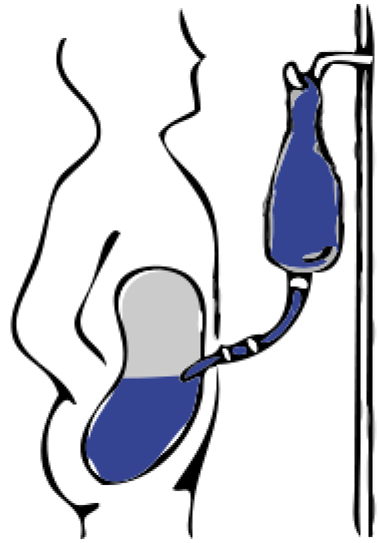
Best practices for peritoneal dialysis state that before peritoneal dialysis should be implemented, the patient's understanding of the process and support systems should be assessed, with education on how to care for the catheter and to address any gaps in understanding that may exist. The patient should receive ongoing monitoring to ensure adequate dialysis, and be regularly assessed for complications. Finally, the patient should be educated on the importance of infection control and an appropriate medical regimen established with their cooperation.

Method

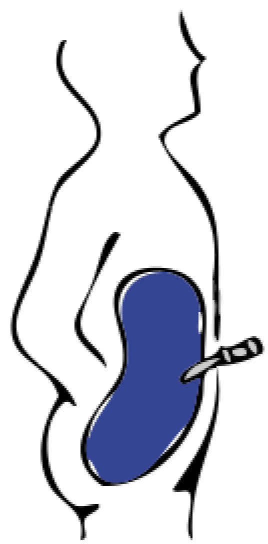
- Dialysis process



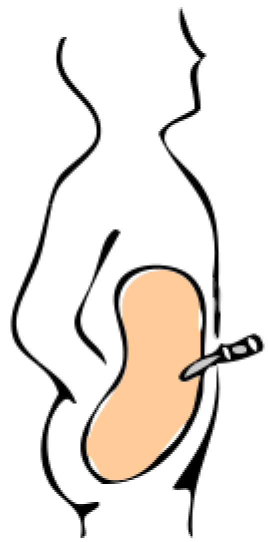
Hookup



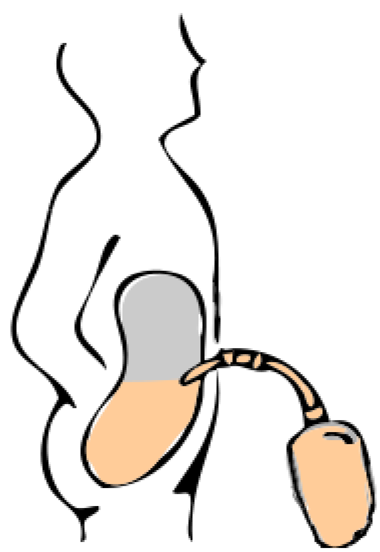
Infusion



Diffusion (fresh)



Diffusion (waste)



Drainage

The abdomen is cleaned in preparation for surgery, and a catheter is surgically inserted with one end in the abdomen and the other protruding from the skin. Before each infusion the area must be cleaned, and flow into and out of the abdomen tested. A large volume of fluid is introduced to the abdomen over the next ten to fifteen minutes. The total volume is referred to as a *dwell* while the fluid itself is referred to as dialysate. The dwell can be as much as 2.5 litres, and medication can also be added to the fluid immediately before infusion. The dwell remains in the abdomen and waste products diffuse across the peritoneum from the underlying blood vessels. After a variable period of time depending on the treatment (usually 4-6 hours), the fluid is removed and replaced with fresh fluid.

This can occur automatically while the patient is sleeping (automated peritoneal dialysis, APD), or during the day by keeping two litres of fluid in the abdomen at all times, exchanging the fluids four to six times per day (continuous ambulatory peritoneal dialysis, CAPD).

The fluid used typically contains sodium, chloride, lactate or bicarbonate and a high percentage of glucose to ensure hyperosmolarity. The amount of dialysis that occurs depends on the volume of the dwell, the regularity of the exchange and the concentration of the fluid. APD cycles between 3 and 10 dwells per night, while CAPD involves four dwells per day of 2-2.5 litres per dwell, with each remaining in the abdomen for 4-8 hours. The viscera accounts for roughly four-fifths of the total surface area of the membrane, but the parietal peritoneum is the more important of the two portions for PD. Two complementary models explain dialysis across the membrane - the three pore model (in which molecules are exchanged across membranes which filter molecules, either proteins, electrolytes or water, based on the size of the pore) and the distributed model (which emphasizes the role of capillaries and the solution's ability to increase the number of active capillaries involved in PD). The high concentration of glucose drives the exchange of fluid from the blood with glucose from the peritoneum. The solute flows from the peritoneal cavity to the organs, and thence into the lymphatic system. Individuals differ in the amount of fluid absorbed through the lymphatic vessels, though it is not understood why. The ability to exchange fluids between the peritoneum and blood supply can be classified as high, low or intermediate. High transporters tend to diffuse substances well (easily exchanging small molecules between blood and the dialysis fluid, with somewhat improved results frequent, short-duration dwells such as with APD) while low transporters filter fluids better (transporting fluids across the membrane into the blood more quickly with somewhat better results with long-term, high-volume dwells such) though in practice either type of transporter can generally be managed through the appropriate use of either APD or CAPD.

Though there are several different shapes and sizes of catheters that can be used, different insertion sites, number of cuffs in the catheter and immobilization, there is no evidence to show any advantages in terms of morbidity, mortality or number of infections, though the quality of information is not yet sufficient to allow for firm conclusions.

Complications

The volume of dialysate removed and weight of the patient are normally monitored; if more than 500ml of fluid are retained or a litre of fluid is lost across three consecutive treatments, the patient's physician is generally notified. Excessive loss of fluid can result in hypovolemic shock or hypotension while excessive fluid retention can result in hypertension and edema. Also monitored is the color of the fluid removed: normally it is pink-tinged for the initial four cycles and clear or pale yellow afterwards. The presence of pink or bloody effluent suggests bleeding inside the abdomen while feces indicates a perforated bowel and cloudy fluid suggests infection. The patient may also experience pain or discomfort if the dialysate is too acidic, too cold or introduced too quickly, while diffuse pain with cloudy discharge may indicate an infection. Severe pain in the rectum or perinium can be the result of an improperly placed catheter. The dwell can also increase pressure on the diaphragm causing impaired breathing, and constipation can interfere with the ability of fluid to flow through the catheter.

A potentially fatal complication estimated to occur in roughly 2.5% of patients is encapsulating peritoneal sclerosis, in which the bowels become obstructed due to the growth of a thick layer of fibrin within the peritoneum.

Risks and benefits

PD is less efficient at removing wastes from the body than hemodialysis, and the presence of the tube presents a risk of peritonitis due to the potential to introduce bacteria to the abdomen; peritonitis is best treated through the direct infusion of antibiotics into the peritoneum with no advantage for other frequently used treatments such as routine peritoneal lavage or use of urokinase. The tube site can also become infected; the use of prophylactic nasal mupirocin can reduce the number of tube site infections, but does not help with peritonitis. Infections can be as frequent as once every 15 months (0.8 episodes per patient year). Compared to hemodialysis, PD allows greater patient mobility, produces fewer swings in symptoms due to its continuous nature, and phosphate compounds are better removed, but large amounts of albumin are removed which requires constant monitoring of nutritional status. The costs and benefits of hemodialysis and PD are roughly the same - PD equipment is cheaper but the costs associated with peritonitis are higher. There is insufficient research to adequately compare the risks and benefits between CAPD and APD; a Cochrane Review of three small clinical trials found no difference in clinically important outcomes (i.e. morbidity or mortality) for patients with end stage renal disease, nor was there any advantage in preserving the functionality of the kidneys. The results suggested APD may have psychosocial advantages for younger patients and those who are employed or pursuing an education.

Other complications include hypotension (due to excess fluid exchange and sodium removal), low back pain and hernia or leaking fluid due to high pressure within the abdomen. PD may also be used for patients with cardiac instability as it does not result in rapid and significant alterations to body fluids, and for patients with insulin-dependent diabetes mellitus due to the inability to control blood sugar levels through the catheter. Hypertriglyceridemia and obesity are also concerns due to the large volume of glucose in the fluid, which can add as many as 1200 calories to the diet per day. Of the three types of connection and fluid exchange systems (standard, twin-bag and y-set; the latter two involving two bags and only one connection to the catheter, the y-set uses a single y-shaped connection between the bags involving emptying, flushing out then filling the peritoneum through the same connection) the twin-bag and y-set systems were found superior to conventional systems at preventing peritonitis.

Frequency

In a 2004 worldwide survey of patients in end stage renal disease, approximately 11% were receiving PD, compared to the much more common hemodialysis. In the United Kingdom, South Korea and Mexico PD was more common than the world average, with the latter conducting most of its dialysis (75%) through PD.

Improvised peritoneal dialysis

Peritoneal dialysis has been improvised in austere medical conditions such as combat surgery or disaster relief. Surgical catheters have been modified and dialysate made from routinely available medical solutions to provide temporary renal replacement for patients with no other options.

Chapter 12

Hemofiltration

In medicine, **hemofiltration**, also **haemofiltration**, is a renal replacement therapy similar to hemodialysis which is used almost exclusively in the intensive care setting. Thus, it is almost always used for acute renal failure. It is a *slow continuous* therapy in which sessions usually last between 12 to 24 hours and are usually performed daily. During hemofiltration, a patient's blood is passed through a set of tubing (a *filtration circuit*) via a machine to a semipermeable membrane (the *filter*) where waste products and water are removed. Replacement fluid is added and the blood is returned to the patient.

The Principle of Hemofiltration

As in dialysis, in hemofiltration one achieves movement of solutes across a semi-permeable membrane. However, solute movement with hemofiltration is governed by convection rather than by diffusion. With hemofiltration, dialysate is not used. Instead, a positive hydrostatic pressure drives water and solutes across the filter membrane from the blood compartment to the filtrate compartment, from which it is drained. Solutes, both small and large, get dragged through the membrane at a similar rate by the flow of water that has been engineered by the hydrostatic pressure. So convection overcomes the reduced removal rate of larger solutes (due to their slow speed of diffusion) seen in hemodialysis.

Replacement fluid composition

An isotonic replacement fluid is added to the blood to replace fluid volume and electrolytes. The replacement fluid must be of high purity, because it is infused directly into the blood line of the extracorporeal circuit. The replacement hemofiltration fluid usually contains lactate or acetate as a bicarbonate-generating base, or bicarbonate itself. Use of lactate can occasionally be problematic in patients with lactic acidosis or with severe liver disease, because in such cases the conversion of lactate to bicarbonate can be impaired. In such patients use of bicarbonate as a base is preferred.

Hemodiafiltration

Hemofiltration is sometimes used in combination with hemodialysis, when it is termed hemodiafiltration. Blood is pumped through the blood compartment of a high flux dialyzer, and a high rate of ultrafiltration is used, so there is a high rate of movement of water and solutes from blood to dialysate that must be replaced by substitution fluid that is infused directly into the blood line. However, dialysis solution is also run through the dialysate compartment of the dialyzer. The combination is theoretically useful because it results in good removal of both large and small molecular weight solutes.

Intermittent vs. continuous modes of therapy

These treatments can be given intermittently, or continuously. The latter is usually done in an intensive care unit setting.

On-line intermittent hemofiltration (IHF) or hemodiafiltration (IHDF)

Either of these treatments can be given in outpatient dialysis units, three or more times a week, usually 3-5 hours per treatment. IHDF is used almost exclusively, with only a few centers using IHF. With both IHF or IHDF, the substitution fluid is prepared on-line from dialysis solution by running dialysis solution through a set of two membranes to purify it before infusing it directly into the blood line. In the United States, regulatory agencies have not yet approved on-line creation of substitution fluid because of concerns about its purity. For this reason, hemodiafiltration is almost never used in an outpatient setting in the United States as of 2007. Use of sterile, pre-packaged substitution fluid would be cost-prohibitive in the current economic environment.

Continuous hemofiltration (CHF) or hemodiafiltration (CHDF)

Hemofiltration is most commonly used in an intensive care unit setting, where it is either given as 8-12 hours treatments, so called SLEF (slow extended hemofiltration), or as CHF (continuous hemofiltration also sometimes called continuous veno-venous hemofiltration (CVVH)) or Continuous Renal Replacement Therapy (CRRT). Hemodiafiltration (SLED-F or CHDF or CVVHDF) also is widely used in this fashion. In the United States, the substitution fluid used in CHF or CHDF is commercially prepared, prepackaged, and sterile (or sometimes is prepared in the local hospital pharmacy), avoiding regulatory issues of on-line creation of replacement fluid from dialysis solution.

With slow continuous therapies, the blood flow rates are usually in the range of 100-200 ml/min, and access is usually achieved through a central venous catheter placed in one of the large central veins. In such cases a blood pump is used to drive blood flow through the filter. Native access for hemodialysis (eg AV fistulas or grafts) are unsuitable for CHF because the prolonged residence of the access needles required might damage such accesses.

Is on-line intermittent hemodiafiltration (IHDF) better than regular hemodialysis?

There is controversy about whether intermittent on-line hemodiafiltration (IHDF) gives better results than hemodialysis in an outpatient setting. In Europe, several observational studies have compared outcomes in patients getting dialysis with those getting IHDF. These have suggested a lower mortality rate and other favorable outcomes in patients getting IHDF vs. those getting ordinary hemodialysis. However, the issue is not settled at this time, because the required randomized controlled clinical trials have not been done. Another problem has been that in several of the trials done, IHDF was compared to dialysis using low-flux (small pore) membranes, and the benefit found may have been due more to the use of a high-flux membrane than to the addition of convective transport (filtration) to dialysis. A recent Cochrane database review of available trials could not find a definite benefit of either IHF or IHDF vs. hemodialysis in terms of outcomes.