

**DIALYSIS: THE TECHNIQUE OF REMOVAL OF TOXINS FROM LIQUID TISSUE
THROUGH BOWMAN'S CAPSULE****¹Sayani Maji, ¹Deeksha Singh*, ¹Dr. Dhruvo Jyoti Sen, ²Dr. Dhananjay Saha, ³Ravi M. Patel and ⁴Viral A. Prajapati**¹Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector-V, EM-4, Kolkata-700091, West Bengal, India.²Directorate of Technical Education, Bikash Bhavan, Salt Lake City, Kolkata-700091, West Bengal, India.³Shri Sarvajani Pharmacy College, Gujarat Technological University, Arvind Baug, Mehana-384001, Gujarat, India.⁴K.B. Institute of Pharmaceutical Education and Research (KBIPER), Sector-23, Near GH-6, Gandhinagar-382 023 Gujarat, India.***Corresponding Author: Deeksha Singh**Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector-V, EM-4, Kolkata-700091, West Bengal, India. **Email Id:** deekshasinghmuz@gmail.com.

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ABSTRACT

Kidneys are two bean-shaped organs that lie just below rib cage, on each side of spine. They remove waste and fluid from body, level out blood pressure, and keep bones strong. They also ensure that body have the right amount of minerals, like potassium and sodium (salt), in blood. Finally, they make the hormone that causes body to create red blood cells. It's a treatment that takes over kidney functions if those organs stop doing their job. There are two types of dialysis: Hemodialysis: Blood is put through a filter outside body, cleaned, and then returned back to the body. This is done either at a dialysis facility or at home. Peritoneal dialysis: Blood is cleaned inside body. A special fluid is put into abdomen to absorb waste from the blood that passes through small vessels in abdominal cavity. The fluid is then drained away. This type of dialysis is typically done at home. If kidney disease becomes very severe and crosses a point where there's not enough function to maintain the body, then the body needs either a transplant or dialysis. The patient typically start dialysis when the patient have symptoms or any lab tests show toxic levels of waste in the blood. Symptoms of kidney failure include nausea, fatigue, swelling, and throwing up. When anyone should start dialysis depends on age, energy level, overall health, lab test results and how willing the patient are to commit to a treatment plan. Although it can make the patient feels better and live longer, it involves a lot of time. Doctor will let you know when you should start treatment. They'll also explain which type might work best for you.

KEYWORD: Kidney, Nephron, Bowman's capsule, Toxin, Hemodialysis, Peritoneal dialysis, ECTR.**INTRODUCTION**

Dialysis is a procedure to remove waste products and excess fluid from the blood when the kidneys stop working properly. It often involves diverting blood to a machine to be cleaned. The kidneys are a pair of bean-shaped organs present in all vertebrates.^[1] They remove waste products from the body, maintain balanced electrolyte levels, and regulate blood pressure. The kidneys are some of the most important organs in the body. The ancient Egyptians left only the brain and kidneys in position before embalming a body, inferring that they held a higher value than other organs. The positioning trusted source of the kidneys is just below the rib cage, with one on each side of the spine. The right kidney is generally slightly lower than the left kidney to make space for the liver.^[2]

Each kidney is approximately 3 centimeters (cm) thick, 6 cm wide, and 12 cm long. In males, the average weighted trusted source of the kidneys is roughly 129 grams (g) for the right one and 137 g for the left. In females, the average weight of these organs is 108 g for the right kidney and 116 g for the left kidney. The main role of the kidneys is maintaining homeostasis.^[3] They manage fluid levels, electrolyte balance, and other factors that keep the internal environment of the body consistent and comfortable. The nephron is the structural and functional unit of the kidney. Each adult human kidney contains around 1 million nephrons, while a mouse kidney contains only about 12,500 nephrons.

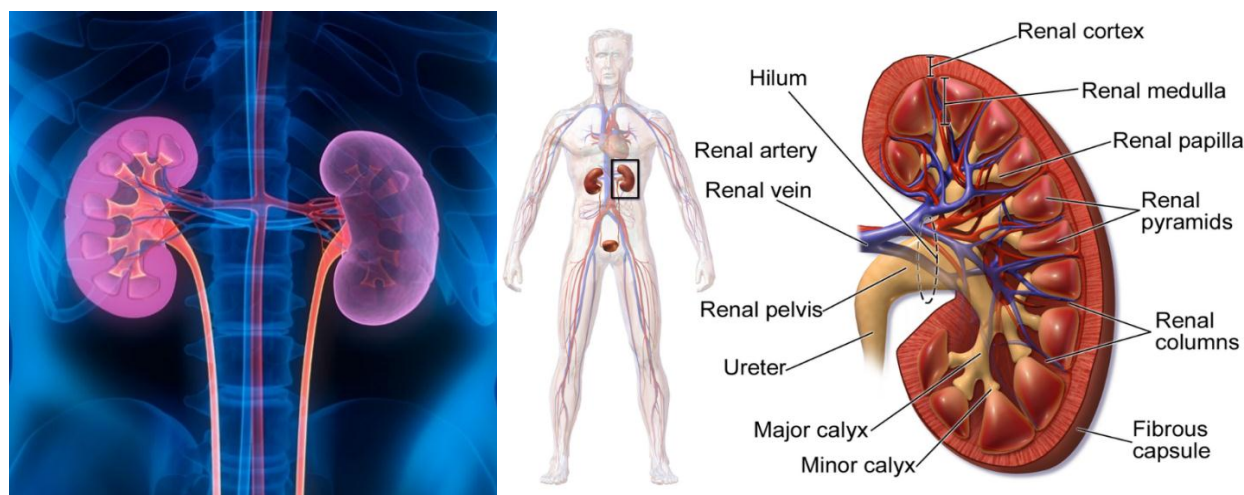


Figure-1: Kidney.

The kidneys also carry out functions independent of the nephrons. For example, they convert a precursor of vitamin D to its active form, calcitriol; and synthesize the hormones erythropoietin and renin. Chronic kidney disease (CKD) has been recognized as a leading public health problem worldwide. The global estimated prevalence of CKD is 13.4%, and patients with kidney failure needing renal replacement therapy are estimated between 5 and 7 million. Procedures used in the management of kidney disease include chemical and

microscopic examination of the urine (urinalysis), measurement of kidney function by calculating the estimated glomerular filtration rate (eGFR) using the serum creatinine; and kidney biopsy and CT scan to evaluate for abnormal anatomy. Dialysis and kidney transplantation are used to treat kidney failure; one (or both sequentially) of these are almost always used when renal function drops below 15%. Nephrectomy is frequently used to cure renal cell carcinoma.^[4]

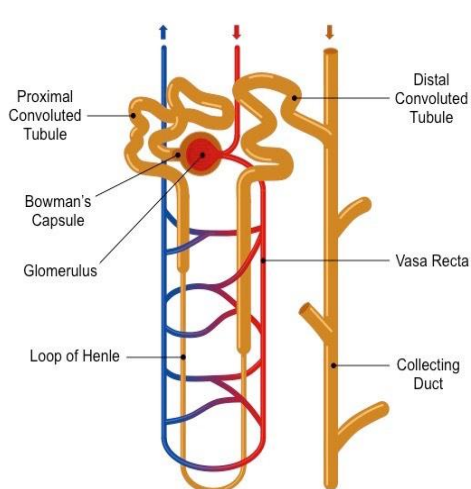


Figure-2: Nephron & Dialysis.

The first successful dialysis was performed in 1943. Willem Johan "Pim" Kolff (February 14, 1911 – February 11, 2009) was a pioneer of hemodialysis, artificial heart, as well as in the entire field of artificial organs. Willem was a member of the Kolff family, an old Dutch patrician family. He made his major discoveries in the field of dialysis for kidney failure during the Second World War. He immigrated in 1950 to the United States, where he obtained US citizenship in 1955, and received a number of awards and widespread recognition for his work.^[5]



Figure-3: Willem Johan "Pim" Kolff.

Dialysis is a procedure to remove waste products and excess fluid from the blood when the kidneys stop working properly. Willem Johan "Pim" Kolff was a pioneer of hemodialysis, artificial heart, as well as in the entire field of artificial organs. Willem was a member of the Kolff family, an old Dutch patrician family. He made his major discoveries in the field of dialysis for kidney failure during the Second World War. Willem Kolff is considered the father of dialysis. This young Dutch physician constructed the first dialyzer (artificial kidney) in 1943.^[6]

Who introduced dialysis in India? The first patient to receive dialysis in May 1961 was His Excellency Shri Gopeshwar Prasad Sahi, the erstwhile Maharaja of Hathwa, in the old state of Bihar, who had developed "chronic uremia." The first few sessions were supervised by Dr Satoru Nakamoto, who had been sent by Dr Willem Kolff. It often involves diverting blood to a machine to be cleaned. It is a treatment that substitutes for the function of normal kidneys. It may be instituted when approximately 85%–90% of kidney function is lost, as indicated by a glomerular filtration rate (GFR) of less than 15. It removes metabolic waste products as well as excess water and sodium (thereby contributing to regulating blood pressure); and maintains many chemical levels within the body. Life expectancy is 5–10 years for those on dialysis; some live up to 30 years. Dialysis can occur via the blood (through a catheter or arteriovenous fistula), or through the peritoneum (peritoneal dialysis)

Dialysis is typically administered three times a week for several hours at free-standing dialysis centers, allowing recipients to lead an otherwise essentially normal life. Dialysis may need to be initiated when there is a sudden rapid loss of kidney function, known as acute kidney injury (previously called acute renal failure), or when a gradual decline in kidney function, chronic kidney disease, reaches stage 5. Stage 5 chronic renal failure is reached when the glomerular filtration rate is 10–15% of normal, creatinine clearance is less than 10 mL per minute and uremia is present.^[7] In research laboratories, dialysis technique can also be used to separate molecules based on their size. Additionally, it can be used to balance buffer between a sample and the solution "dialysis bath" or "dialysate" that the sample is in. For dialysis in a laboratory, a tubular semipermeable membrane made of cellulose acetate or nitrocellulose is used. Pore size is varied according to the size separation required with larger pore sizes allowing larger molecules to pass through the membrane. Solvents, ions and buffer can diffuse easily across the semipermeable membrane, but larger molecules are unable to pass through the pores. This can be used to purify proteins of interest from a complex mixture by removing smaller proteins and molecules.^[8]

There are 3 main types of dialysis: in-center hemodialysis, home hemodialysis, and peritoneal dialysis. Each type has pros and cons.



Figure–4: Peritoneal Dialysis.

There are two types of dialysis we may use: peritoneal and hemodialysis.

Peritoneal Dialysis

To perform peritoneal dialysis, we will:

1. Surgically place a soft, hollow tube into the lower abdomen near the navel.
2. Instill a special solution called dialysate into the peritoneal cavity. The peritoneal cavity is the space

in the abdomen that houses the organs and is lined by two special membrane layers called the peritoneum.

3. Leave the dialysate in the abdomen for a certain period of time, which we will determine on an individual basis. The dialysate fluid absorbs the waste products and toxins through the peritoneum.
4. Drain the fluid from the abdomen, measure it and then discard it.^[9]

Types of Peritoneal Dialysis

There are three different types of peritoneal dialysis

- Continuous ambulatory peritoneal dialysis (CAPD): Does not require a machine. Exchanges, often referred to as "passes," can be done three to five times a day, during waking hours.
- Continuous cyclic peritoneal dialysis (CCPD): Requires the use of a special dialysis machine that can be used in the home. This type of dialysis is done automatically, even while you are asleep.
- Intermittent peritoneal dialysis (IPD): Uses the same type of machine as CCPD, but treatments take longer. IPD can be done at home, but it is usually in the hospital.^[10]

Peritoneal Dialysis: Possible Complications

Possible complications of peritoneal dialysis include an infection of the peritoneum, or peritonitis, where the catheter enters the body. Peritonitis causes fever and stomach pain. A dietitian will help plan your diet

during peritoneal dialysis, so we can ensure you are choosing appropriate meals. During dialysis:

- You may have different protein, salt and fluid needs.
- You may have different potassium restrictions.
- You may need to reduce your calorie intake, since the sugar in the dialysate may cause weight gain.

Hemodialysis

Hemodialysis is can be performed at home or in a dialysis center or hospital by trained healthcare professionals. During the procedure, we will:

1. Surgically place a special type of access, called an arteriovenous (AV) fistula, usually in your arm. We will need to join an artery and a vein together. (We may also insert an external, central intravenous (IV) catheter, but is less common for long-term dialysis.)
2. Connect you to a large hemodialysis machine.
3. The machine drains the blood, bathes it in a special dialysate solution to remove waste substances and fluid and then returns it to your bloodstream.^[11]

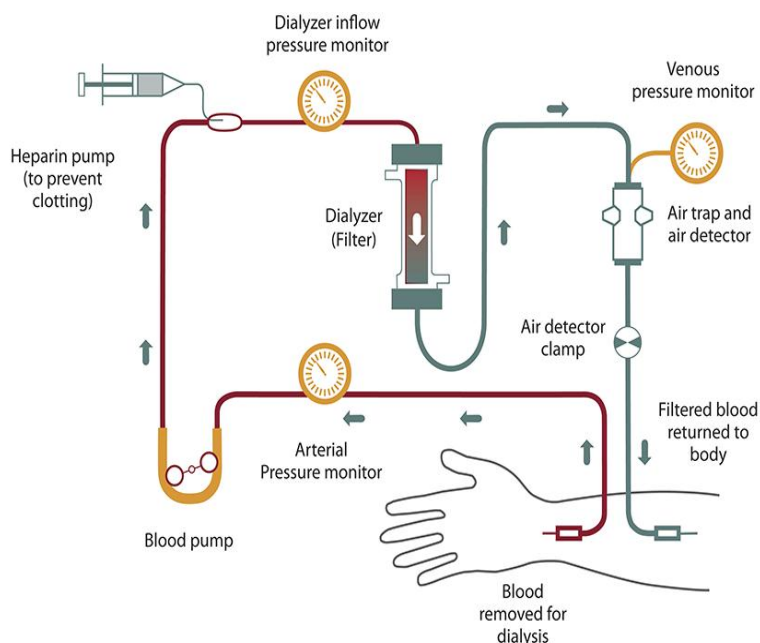


Figure-5: Hemodialysis.

Tips for Undergoing Hemodialysis

- Hemodialysis is usually performed several times a week and lasts for four to five hours. Because of the length of time hemodialysis takes, it may be helpful to bring reading material, in order to pass the time during this procedure.
- During treatment you can read, write, sleep, talk or watch TV.
- At home, hemodialysis is done with the help of a partner, often a family member or friend. If you choose to do home hemodialysis, you and your partner will receive special training.^[12]

- *Hemodialysis: Dialysis Access Management*
- Interventional radiologists work closely with you, your nephrologist and your vascular surgeon to help maintain functional hemodialysis access.
- Treating stenosis and clots: If you have arteriovenous fistulas or grafts, hemodialysis may fail if narrowing, called stenosis, develop in your blood vessels. Those narrowing cause poor flow, which affects the ability to efficiently dialyze the blood. The narrowing may cause additional symptoms, such as swelling of the head and arms. Without treatment, poor flow can result in clot formation, which prevents the ability to dialyze. It can even lead to permanent fistula or graft failure.
- Interventional radiologists are skilled at treating clots with special devices and by administering

clot-dissolving drugs directly into the clot. They are also skilled at treating sites of narrowing with angioplasty and, if appropriate, stent placement.

- Tunneled hemodialysis catheters: Interventional radiologists can also place tunneled hemodialysis catheters. Patients with long-standing use of tunneled hemodialysis catheters may develop blockages in the commonly used veins of the neck and chest. Those blockages may make it challenging to place a new catheter.

Interventional radiologists can often open a channel through the blockage to allow placement of a new catheter. If that is not possible, we can use alternative sites (through the veins draining the legs, through the liver, or through the back) for placing the catheter.^[13]

Hemodialysis: Possible Complications

Possible complications of hemodialysis include muscle cramps and hypotension (sudden drop in blood pressure). Hypotension may cause you to feel dizzy, weak or sick to your stomach. You can usually avoid side effects by following the proper diet and taking your medications.

A dietitian will work with you to plan your meals according to your physician's orders. Generally:

- You may eat foods high in protein such as meat and chicken (animal proteins).
- You may have different potassium restrictions.
- You may need to limit the amount you drink.
- You may need to avoid salt.
- You may need to limit foods containing mineral phosphorus (such as milk, cheese, nuts, dried beans, and soft drinks).

Hemodialysis is the choice of renal replacement therapy for patients who need dialysis acutely, and for many patients as maintenance therapy. It provides excellent, rapid clearance of solutes.^[14]

A nephrologist (a medical kidney specialist) decides when hemodialysis is needed and the 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, potassium, and bicarbonate levels. In general, the larger the body size of an individual, the more dialysis he/she will need. In North America and the 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 is also 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.^[15]

Advantages: Home therapies allows for longer and slower dialysis, so can **improve kidney function and life expectancy**; one study showed a 13% lower risk of death in patients, and a 77% improvement in health. Dialyzing more frequently is also proven to reduce recovery times, from eight hours in-centre to one hour after HHD. One of the main advantages of PD over hemodialysis is that the procedure can be carried out in the comfort of the patients' home. For most, all that is required is a washroom with fresh running water, a sterile area of the house for the procedure to take place, and space to store the fluid for dialysis. This also allows patients to travel. For elderly patients who may be unable to administer the procedure themselves, assistance may be given by a trained carer or community nurse. Additionally, the procedure can even be run while the patient sleeps.

Disadvantages

- Restricts independence, as people undergoing this procedure cannot travel around because of supplies' availability
- Requires more supplies such as high water quality and electricity
- Requires reliable technology 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

Mechanism and technique: 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.^[16]

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 and is called dialysate. Urea and other waste products including 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. The concentration of electrolytes in the dialysate is adjusted depending on the

patient's status before the dialysis. If a high concentration of sodium is added to the dialysate, the patient can become thirsty and end up accumulating body fluids, which can lead to heart damage. On the contrary, low concentrations of sodium in the dialysate solution have been associated with a low blood pressure and intradialytic weight gain, which are markers of improved outcomes. However, the benefits of using a low concentration of sodium have not been demonstrated yet, since these patients can also develop cramps, intradialytic hypotension and low sodium in serum, which are symptoms associated with a high mortality risk.^[17]

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

What is in dialysis machine? The dialysis machine is made up of a series of membranes that act as filters and a special liquid called dialysate. The membranes filter waste products from your blood, which are passed into the dialysate fluid.

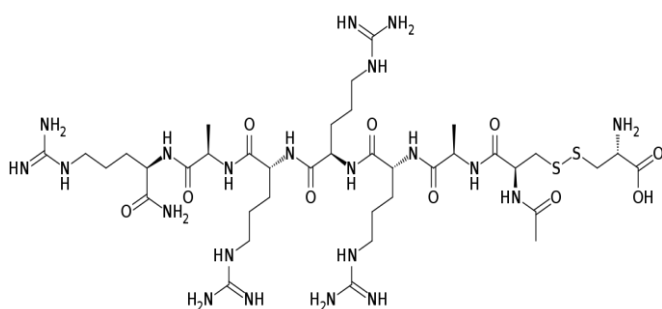
What does my dialysis machine do? The dialysis machine mixes and monitors the dialysate. Dialysate is the fluid that helps remove the unwanted waste products from your blood. It also helps get your electrolytes and minerals to their proper levels in your body. The machine also monitors the flow of your blood while it is outside of your body. You may hear an alarm go off from time to time. This is how the machine lets us know that something needs to be checked.^[18]

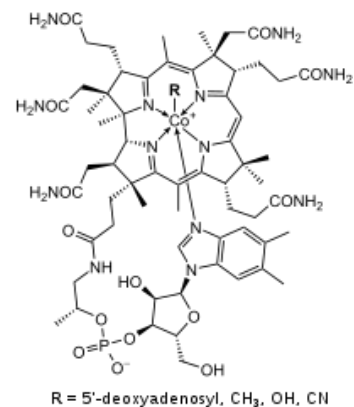
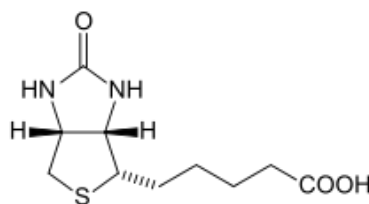
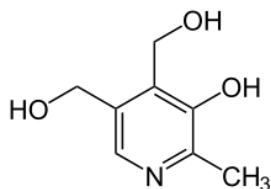
What are those plastic jugs sitting in front of my machine? The plastic jugs hold the liquids used to mix the dialysate. The machine mixes the dialysate, which is made up of an acidified solution, bicarbonate and purified water. The acidified solution contains electrolytes and minerals. You may hear it referred to as "acid." The other solution is bicarbonate or bicarb, which is like baking soda. Both are mixed inside the machine with purified water. While you are dialyzing, dialysate and your blood flow through the dialyzer (but they never touch). Fresh dialysate from the machine enters your dialyzer throughout your treatment. Impurities are filtered out of your blood into the dialysate. Dialysate containing unwanted waste products and excess

electrolytes leave the dialyzer and are washed down the drain. How does my blood get in and out of my body? Blood tubing carries your blood from your access to the dialyzer. The blood tubing is threaded through the blood pump. You'll see the blood pump turning in a circular motion. The pumping action of the blood pump pushes your blood through the dialyzer and back into your body. What's in the syringe that's attached to my machine? Blood tends to clot when it moves through the blood tubing. To prevent this the nurse will give you a drug called "heparin." Your doctor orders the amount of heparin you get at each treatment. That amount of heparin is drawn up into a syringe then placed on the machine into the "heparin pump." The heparin pump is programmed to release the right amount of heparin into your blood tubing during your treatment. The heparin prevents your blood from clotting. How does the machine keep me safe? One problem that may occur during dialysis is that air gets into the blood tubing. To prevent this from happening, blood tubings have two air traps built into them. One trap is before the dialyzer and the other is after it. These traps catch any air that may get into the system. If air does get past these traps an internal machine air sensor shuts down the blood pump and an alarm will sound. All blood flow is stopped until the air is removed. Why are there so many alarms? The machine continuously monitors the pressures created by your blood inside the blood tubing and dialyzer. It also monitors the blood flow, temperature and proper mixture of the dialysate. If any of these go out of range, the machine lets us know by sounding an alarm, blinking lights and shutting down blood or dialysate flow. It also lets us know if your blood pressure is too low or high. Oh yes, it also alarms when it's time to go home.

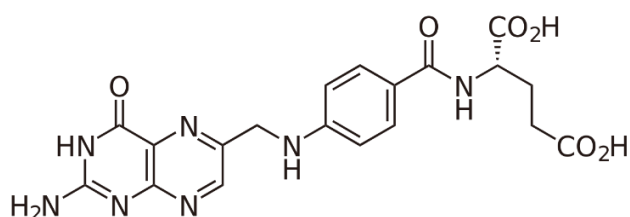
Which injection is used for dialysis patients?

Etelcalcetide [CAS: 1262780-97-1; IUPAC: 6R,9R,12R,15R,18R,21R,24S,29R)-24-Acetamido-1,29-diamino-12,15,18-tris(3-carbamimidamidopropyl)-6-carbamoyl-1-imino-9,21-dimethyl-8,11,14,17,20,23-hexaoxo-26,27-dithia-2,7,10,13,16,19,22-heptaazatriacontan-30-oic acid] injection comes as a solution (liquid) to inject intravenously (into a vein). It is usually given 3 times a week at the end of each dialysis session by a doctor or nurse at the dialysis center.

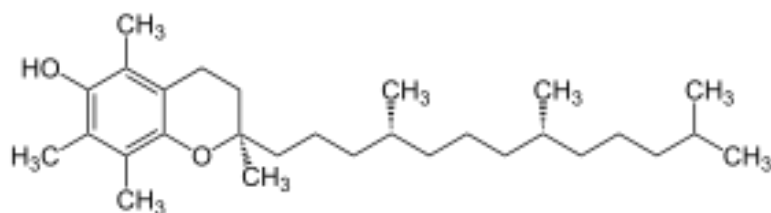




- *Folic Acid* [CAS: 59-30-3; IUPAC: (2S)-2-[[4-[(2-Amino-4-oxo-1H-pteridin-6-yl)methylamino]benzoyl]amino]pentanedioic acid]



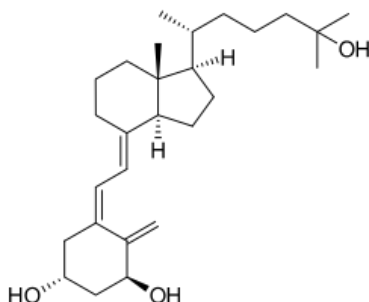
- *Topical creams & antihistamines.*
- *Vitamin E: Tocopherol*



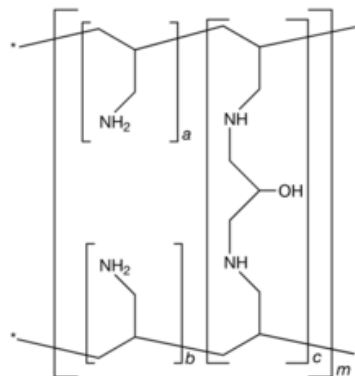
What emergency medicine are required during hemodialysis?

Drugs for Dialysis

- *Calcitriol*. Calcitriol [CAS: 32222-06-3; IUPAC: (1R,3S)-5-[2-[(1R,3aR,7aS)-1-[(2R)-6-hydroxy-6-methyl-heptan-2-yl]-7a-methyl-2,3,3a,5,6,7-hexahydro-1H-inden-4-ylidene]ethylidene]-4-methylidene-cyclohexane-1,3-diol] is a synthetic vitamin D analog, prescribed for hypocalcaemia in patients undergoing chronic renal dialysis.



- *Iron Sucrose*. Iron Sucrose is a mineral iron, prescribed for iron deficiency anemia especially for kidney failure patients.
- *Lanthanum Carbonate* [La₂(CO₃)₃; CAS: 587-26-8].
- *Sevelamer* [CAS: 52757-95-6; IUPAC: poly(allylamine-co-N,N'-diallyl-1,3-diamino-2-hydroxypropane)]



How is emergency dialysis done? Each needle is attached to a flexible plastic tube that connects to a dialyzer. Through one tube, the dialyzer filters your blood a few ounces at a time, allowing wastes and extra fluids to pass from your blood into a cleansing fluid called dialysate. The filtered blood returns to your body through the second tube.

Dialysis through neck: A piece of synthetic tubing is used to connect the artery to the vein. As a short-term measure, or in an emergency, you may be given a neck line. This is where a small tube is inserted into a vein in your neck.

What is dialysis port in neck called?

Central Venous Catheter (CVC): Why do they put a catheter in your neck for dialysis?

If you need hemodialysis right away and you do not have time to wait for a fistula or graft to work, the surgeon can put in a catheter. The catheter is put into a vein in the neck, chest, or upper leg. This catheter is temporary. It can be used for dialysis while you wait for a fistula or graft to heal.

What are the different types of fistulas for dialysis?

There are 3 basic types of AVF [Arterio Venous Fistula] dialysis: Radial Cephalic fistula. Brachial Cephalic. Brachial Basilica Transposition. For chronic hemodialysis, the ideal permanent vascular access is the arteriovenous fistula (AVF). Temporary catheters should be reserved for acute dialysis needs. The AVF is associated with lower infection rates, better clinical results, and a higher quality of life and survival when compared to temporary catheters.

What is a permanent dialysis catheter? A permcath (Also known as a permacath) is a long, flexible tube (catheter) that is inserted into a vein most commonly in the neck (internal jugular vein) and less commonly in the groin (femoral vein) but that is actually tunneled under the skin and exits usually on the leg or mid-thigh. The research assessed the frequency of complications occurring during dialysis. Patients receiving hemodialysis usually pointed to muscle spasms (very often: 18%, often: 21%), skin dryness and itching (very often: 21%, often: 22%) and an increase or decrease in blood pressure (very often: 29%, often: 27%) Can we improve quality of life of patients on dialysis? Rigorously examined HRQOL in incident HD and PD patients in a prospective multi-center observational study and found that after 1 year of dialysis, overall HRQOL outcomes improved for both modalities, but there were some distinct advantages for both HD (physical functioning, sleep, sexual functioning) and PD. When people learn they need to begin dialysis, they typically experience a flurry of emotions. Often, the first reaction is shock or denial. People may feel numb or fail to accept the reality of the

situation. Anger, sadness, worry, and guilt are also common.

What is the average life expectancy of someone on dialysis? Life expectancy on dialysis can vary depending on your other medical conditions and how well you follow your treatment plan. Average life expectancy on dialysis is 5-10 years, however, many patients have lived well on dialysis for 20 or even 30 years.

CONCLUSION

Acute poisoning is treated with extracorporeal dialysis (ECTR) to eliminate poisons. If acute poisoning is severe and no other treatment is available, dialysis or other ECTR is necessary. It may also be used in individuals with altered elimination pathways, such as those with renal or hepatic failure. Additionally, intermittent hemodialysis offers the benefit of being able to correct acid-base imbalances and remove extra fluid, if necessary. ECTR aids in limiting symptoms and duration of toxicity. Toxins with low molecular weight, low protein binding, and modest volume of distribution are most responsive to dialysis; For the elimination of toxins that have a large volume of distribution or a high rate of endogenous clearance (> 4 mL/minute/kg), ECTR is less effective.

REFERENCES

1. Daugirdas JT, Black PG, Ing TS Handbook of Dialysis (4th ed.). Philadelphia, PA: Lippincott Williams & Wilkins, a Wolters Kluwer Business, 2007.
2. Van Waelegheem JP, Chamney M, Lindley EJ, Pancírová J "Venous needle dislodgement: how to minimise the risks" (PDF). *Journal of Renal Care*, 2008; 34(4): 163–8.
3. Cronin RE, Reilly RF "Unfractionated heparin for hemodialysis: still the best option". *Seminars in Dialysis*, 2010; 23(5): 510–5.
4. Davenport A. "Review article: Low-molecular-weight heparin as an alternative anticoagulant to unfractionated heparin for routine outpatient haemodialysis treatments". *Nephrology*, 2009; 14(5): 455–61.
5. Dutt T, Schulz M. "Heparin-induced thrombocytopenia (HIT)—an overview: what does the nephrologist need to know and do?". *Clinical Kidney Journal*, 2013; 6(6): 563–7.
6. Davenport A. "What are the anticoagulation options for intermittent hemodialysis?". *Nature Reviews. Nephrology*, 2011; 7(9): 499–508.
7. Kishimoto TK, Viswanathan K, Ganguly T, et al. "Contaminated heparin associated with adverse clinical events and activation of the contact system". *N Engl J Med*, 2008; 358(23): 2457–67.
8. Ayus JC, Mizani MR, Achinger SG, Thadhani R, Go AS, Lee S. "Effects of short daily versus conventional hemodialysis on left ventricular hypertrophy and inflammatory markers: a

- prospective, controlled study". *Journal of the American Society of Nephrology*, 2005; 16(9): 2778–88.
9. Weinreich T, De los Ríos T, Gauly A, Passlick-Deetjen J. "Effects of an increase in time vs. frequency on cardiovascular parameters in chronic hemodialysis patients". *Clinical Nephrology*, 2006; 66(6): 433–9.
 10. Pirklbauer M. "Hemodialysis treatment in patients with severe electrolyte disorders: Management of hyperkalemia and hyponatremia". *Hemodialysis International*, 2020; 24(3): 282–289.
 11. Misra, Madhukar "The basics of hemodialysis equipment". *Hemodialysis International*, 2005; 9(1): 30–36.
 12. Kashiwagi, Tetsuya; Sato, Kazuto; Kawakami, Seiko; Kiyomoto, Masayoshi; Enomoto, Miho; Suzuki, Tatsuya; Genei, Hirokazu; Nakada, Hiroaki; Iino, Yasuhiko; Katayama, Yasuo "Effects of Reduced Dialysis Fluid Flow in Hemodialysis". *Journal of Nippon Medical School*, 2013; 80(2): 119–130.
 13. Cheung AK. "Biocompatibility of hemodialysis membranes". *Journal of the American Society of Nephrology*, 1990; 1(2): 150–61.
 14. Eknoyan G, Beck GJ, Cheung AK, et al. "Effect of dialysis dose and membrane flux in maintenance hemodialysis". *New England Journal of Medicine*, 2002; 347(25): 2010–9.
 15. Cheung AK, Levin NW, Greene T, et al. "Effects of high-flux hemodialysis on clinical outcomes: results of the HEMO study". *Journal of the American Society of Nephrology*, 2003; 14(12): 3251–63.
 16. Paskalev DN "Georg Haas (1886–1971): The forgotten hemodialysis pioneer" (PDF). *Dialysis and Transplantation*, 2001; 30(12): 828–32.
 17. Kolff WJ, Berk HT, ter Welle M, van der Ley AJ, van Dijk EC, van Noordwijk J "The artificial kidney: a dialyser with a great area. *Journal of the American Society of Nephrology*, 1944; 8(12): 1959–65.
 18. McKellar S. "Gordon Murray and the artificial kidney in Canada". *Nephrology, Dialysis, Transplantation*, 1999; 14(11): 2766–70.