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Dialysis

In medicine, **dialysis** (from Greek διάλυσις, *diàlysis*, "dissolution"; from διά, *dià*, "*through*", and λύσις, *lỳsis*, "loosening or splitting") is the process of removing excess water, solutes and toxins from the blood in those whose native kidneys have lost the ability to perform these functions in a natural way. This is referred to as renal replacement therapy.

Dialysis may be used in those with rapidly developing loss of kidney function, called acute kidney injury (previously called acute renal failure); or slowly worsening kidney function, called Stage 5 chronic kidney disease, (previously called chronic kidney failure and end-stage renal disease and end-stage kidney disease).

Dialysis is used as a temporary measure in either acute kidney injury or in those awaiting kidney transplant and as a permanent measure in those for whom a transplant is not indicated or not possible.[1]

In Great Britain and the United States, dialysis is paid for by the government for those that are eligible. The first successful dialysis was performed in 1943.

Renal Dialysis

Patient receiving hemodialysis

Specialty	nephrology
ICD-9-CM	39.95
MeSH	D006435
MedlinePlus	00743

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 sample and the solution "dialysis bath" or "dialysate"[2] that the sample is in. For dialysis in a laboratory semipermeable membrane is used as a tube made of cellulose acetate or nitrocellulose[3] where pore size can vary according to the size separation required. Control over pore size allows a better separation between small molecules while leaving large molecules of interest inside. Solvents, ions diffuse easily through the pores while leaving the big molecules behind and separate. In protein purification technique dialysis is used to exchange buffers, loose smaller proteins that can pass through the pores, dilutions of concentrated salts, while leaving the protein of interest inside the semipermeable membrane separated.

Contents

Background


A hemodialysis machine

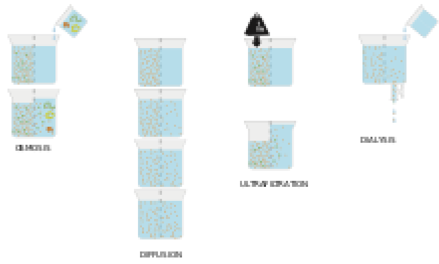
The kidneys have an important role in maintaining health. When the person is healthy, the kidneys maintain the body's internal equilibrium of water and minerals (sodium, potassium, chloride, calcium, phosphorus, magnesium, sulfate). The acidic metabolism end-products that the body cannot get rid of via respiration are also excreted through the kidneys. The kidneys also function as a part of the endocrine system, producing erythropoietin, calcitriol and renin. Erythropoietin is involved in the production of red blood cells and calcitriol plays a role in bone formation.[4] Dialysis is an imperfect treatment to replace kidney function because it does not correct the compromised endocrine functions of the kidney. Dialysis treatments replace some of these functions through diffusion (waste removal) and ultrafiltration (fluid removal).[5] Dialysis uses highly purified (also known as "ultrapure") water.[6]

Principle

Dialysis works on the principles of the osmosis of solutes and ultrafiltration of fluid across a semi-permeable membrane. Diffusion is a property of substances in water; substances in water tend to move from an area of high concentration to an area of low concentration.[7] 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 holes of various sizes, 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). This replicates the filtering process that takes place in the kidneys when the blood enters the kidneys and the larger substances are separated from the smaller ones in the glomerulus.[7]

The two main types of dialysis, hemodialysis and peritoneal dialysis, remove wastes and excess water from the blood in different ways.[1] 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 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.

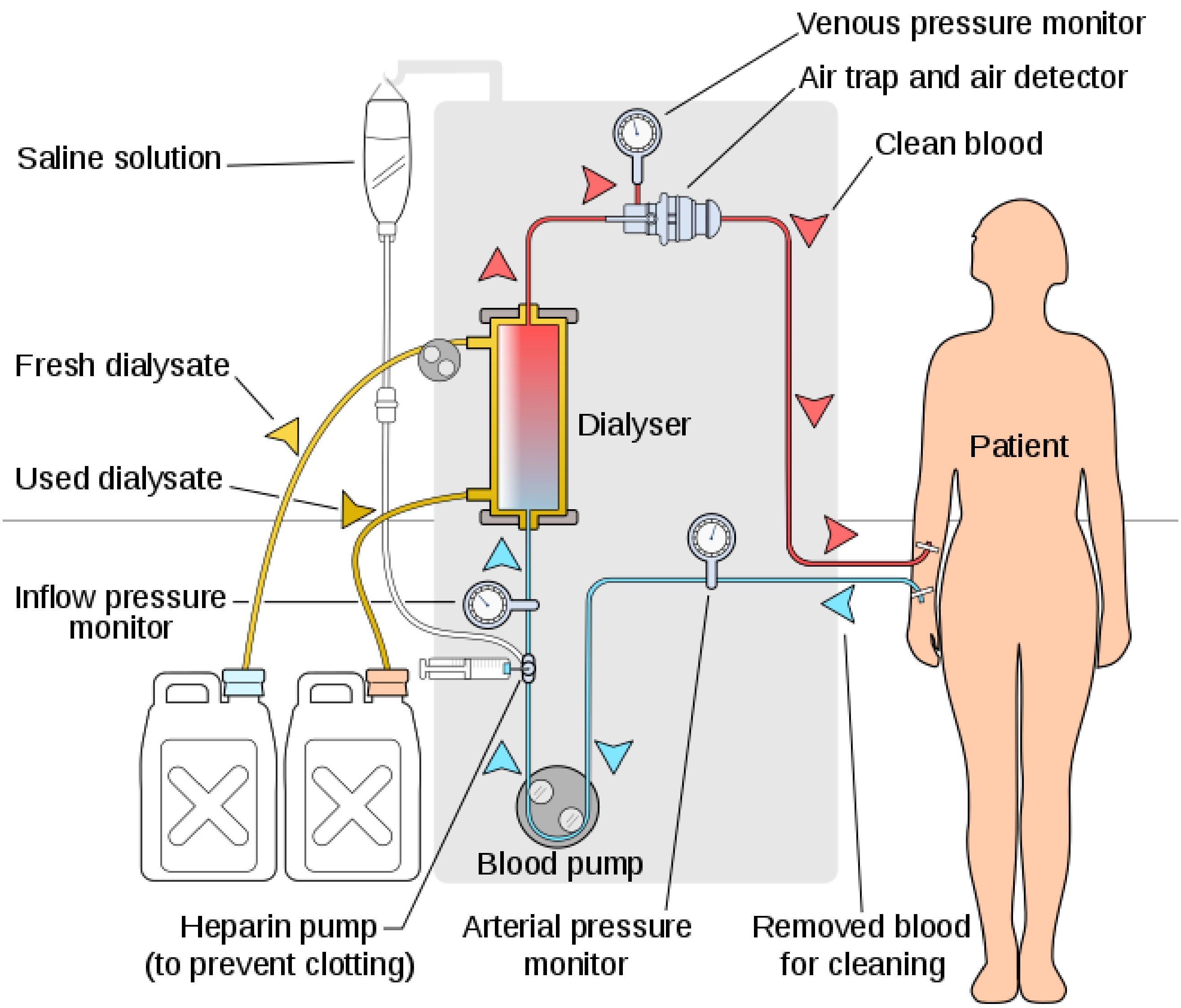


Osmosis diffusion ultrafiltration and dialysis

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

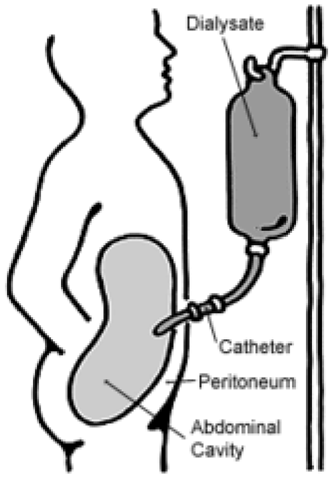


In hemodialysis, the patient's blood is pumped through the blood compartment of a dialyzer, exposing it to a partially permeable membrane. The dialyzer is composed of thousands of tiny hollow synthetic fibers. The fiber wall acts as the semipermeable membrane. Blood flows through the fibers, dialysis solution flows around the outside of the fibers, and water and wastes move between these two solutions.[8] 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 4-hour treatment. In the United States, hemodialysis treatments are typically given in a dialysis center three times per week (due in the United States to Medicare reimbursement rules); however, as of 2005 over 2,500 people in the United States are dialyzing at home more frequently for various treatment lengths.[9] 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[10] 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.[11]

Hemo-dialysis was one of the most common procedures performed in U.S. hospitals in 2011, occurring in 909,000 stays (a rate of 29 stays per 10,000 population).[12]

Peritoneal dialysis

In peritoneal dialysis, a sterile solution containing glucose (called dialysate) is run through a tube into the peritoneal cavity, the abdominal body cavity around the intestine, where the peritoneal membrane acts as a partially permeable membrane. (eluma,2017)

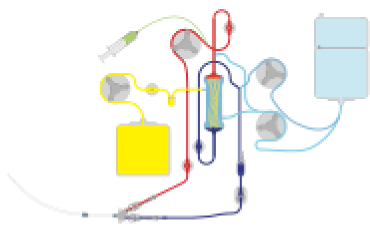


Schematic diagram of peritoneal dialysis

This exchange is repeated 4–5 times per day; automatic systems can run more frequent exchange cycles overnight. 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, often without help. This frees patients from the routine of having to go to a dialysis clinic on a fixed schedule multiple times per week. Peritoneal dialysis can be performed with little to no specialized equipment (other than bags of fresh dialysate).

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, including ones with large molecular weights, which are not cleared as 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.


Continuous veno-venous haemofiltration with pre- and post-dilution (CVVH)

Hemodiafiltration

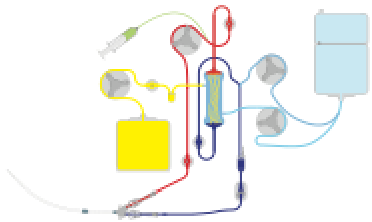
Hemodiafiltration is a combination of hemodialysis and hemofiltration, thus used to purify the blood from toxins when the kidney is not working normally and also used to treat acute kidney injury (AKI).

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.[13][14][15] An alternative approach utilizes the ingestion of 1 to 1.5 liters of non-absorbable solutions of polyethylene glycol or mannitol every fourth hour.[16]

Indications

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



Continuous veno-venous haemodiafiltration (CVVHDF)

Acute indications

Indications for dialysis in the patient with acute kidney injury are summarized with the vowel acronym of "AEIOU":[17]

1. Acidemia from metabolic acidosis in situations in which 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. 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.
4. Overload of fluid not expected to respond to treatment with diuretics
5. Uremia complications, such as pericarditis, encephalopathy, or gastrointestinal bleeding

Chronic indications

Chronic dialysis may be indicated when a patient has symptomatic kidney failure and low glomerular filtration rate (GFR $<$ 15 mL/min).[18] Between 1996 and 2008, there was a trend to initiate dialysis at progressively higher estimated GFR, eGFR. A review of the evidence shows no benefit or potential harm with early dialysis initiation, which has been defined by start of dialysis at an estimated GFR of greater than 10ml/min/1.73^2. Observational data from large registries of dialysis patients suggests that early start of dialysis may be harmful.[19] The most recent published guidelines from Canada, for when to initiate dialysis, recommend an intent to defer dialysis until a patient has definite kidney failure symptoms, which may occur at an estimated GFR of 5-9ml/min/1.73^2.[20]

Dialyzable substances

Characteristics

Dialyzable substances, substances which can be removed using dialysis, have following properties:

1. low molecular mass
2. high water solubility
3. low protein binding capacity
4. prolonged elimination (long half-life)
5. small volume of distribution

Substances

- Ethylene glycol
- Procainamide
- Methanol
- Isopropyl alcohol
- Barbiturates
- Lithium
- Bromide
- Sotalol
- Chloral hydrate
- Ethanol
- Acetone

- Atenolol
- Theophylline
- Salicylates

Pediatric dialysis

Over the past 20 years, children have benefited from major improvements in both technology and clinical management of dialysis. Morbidity during dialysis sessions has decreased with seizures being exceptional and hypotensive episodes rare. Pain and discomfort have been reduced with the use of chronic internal jugular venous catheters and anesthetic creams for fistula puncture. Non-invasive technologies to assess patient target dry weight and access flow can significantly reduce patient morbidity and health care costs.

Biocompatible synthetic membranes, specific small size material dialyzers and new low extra-corporeal volume tubing have been developed for young infants. Arterial and venous tubing length is made of minimum length and diameter, a <80ml to <110ml volume tubing is designed for pediatric patients and a >130 to <224ml tubing are for adult patients, regardless of blood pump segment size, which can be of 6.4mm for normal dialysis or 8.0mm for high flux dialysis in all patients. All dialysis machine manufacturers design their machine to do the pediatric dialysis. In pediatric patients, the pump speed should be kept at low side, according to patient blood output capacity, and the clotting with heparin dose should be carefully monitored. The high flux dialysis (see below) is not recommended for pediatric patients.

In children, hemodialysis has to be individualized and viewed as an "integrated therapy" considering their long-term exposure to chronic renal failure treatment. Dialysis is seen only as a temporary measure for children compared with renal transplantation because this enables the best chance of rehabilitation in terms of educational and psychosocial functioning.long-termchronic dialysis, however, the highest standards should be applied to these children to preserve their future "cardiovascular life" which might include more dialysis time and on-line hemodiafiltration online hdf with synthetic high flux membranes with the surface area of 0.2sq.m to 0.8sq.m and blood tubing lines with the low volume yet large blood pump segment of 6.4/8.0mm, if we are able to improve on the rather restricted concept of small-solute urea dialysis clearance.

Funding sources

In the United Kingdom

The National Health Service provides dialysis in the United Kingdom. In England the service is commissioned by NHS England. About 23,000 patients use the service each year.[21]

In the United States

Since 1972, the United States has covered the cost of dialysis and transplants for all citizens. By 2014, more than 460,000 Americans were undergoing treatment, the costs of which amount to 6 percent of the entire Medicare budget. Kidney disease is the ninth leading cause of death, and the U.S. has one of the highest mortality rates for dialysis care in the industrialized world. The rate of patients getting kidney transplants has been lower than expected. These outcomes have been blamed on a new for-profit dialysis industry responding to government payment policies.[22][23][24] A 1999 study concluded that "patients treated in for-profit dialysis facilities have higher mortality rates and are less likely to be placed on the waiting list for a renal transplant than are patients who are treated in not-for-profit facilities", possibly because transplantation removes a constant stream of revenue from the facility.[25] The insurance industry has complained about kickbacks and problematic relationships between charities and providers.[26]

In China

The Government of China provides the funding for dialysis treatment. There is a challenge to reach everyone who needs dialysis treatment because of the unequal distribution of health care resources and dialysis centers.[27] There are 395,121 individuals who receive hemodialysis or peritoneal dialysis in China per year. The percentage of the Chinese population with chronic kidney disease is 10.8%.[28] The Chinese Government is trying to increase the amount of peritoneal dialysis taking place in order to meet the needs of the individuals with chronic kidney disease in their country.[29]

History

Arm hooked up to dialysis tubing.

A Dutch physician, Willem Johan Kolff, constructed the first working dialyzer in 1943 during the Nazi occupation of the Netherlands.[30] 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 that were available at the time. Over the following two years (1943–1945), Kolff used his machine to treat 16 patients suffering from acute kidney failure, but the results were unsuccessful. Then, in 1945, a 67-year-old comatose woman regained consciousness following 11 hours of hemodialysis with the dialyzer and lived for another seven years before dying from an unrelated condition. She was the first-ever patient successfully treated with dialysis.[30] Nils Alwall modified a similar construction to the Kolff dialysis machine by enclosing it inside a stainless steel canister. This allowed the removal of fluids, by applying a negative pressure to the outside canister, thus making it the first truly practical device for hemodialysis. Alwall treated his first patient in acute kidney failure on 3 September 1946.

See also

Materials and methods

- Thomas Graham (chemist) the founder of dialysis and father of colloid chemistry
- Dialysis tubing
- List of US dialysis providers

Medical applications

- Apheresis, also known as plasmapheresis, is another extracorporeal technique that selectively removes specific constituents from blood
- Hemodialysis
- Peritoneal dialysis
- Acute kidney failure
- Kidney failure
- Nephrology
- Chronic kidney disease
- Hepatorenal syndrome

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Further reading

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External links

- Machine Cleans Blood While You Wait—1950 article on early use of dialysis machine at Bellevue Hospital New York City—i.e. example of how complex and large early dialysis machines were
- Home Dialysis Museum—History and pictures of dialysis machines through time
- Introduction to Dialysis Machines—Tutorial describing the main subfunctions of dialysis systems.
- First Nations man conducts own dialysis treatments to avoid move to the city—CBC News (November 30, 2016)

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