Hemodialysis Definition Principles Indications & Complications

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I- Introduction:

Chronic renal failure which results from progressive deterioration of renal function is characterized by retention of substances that are ordinarily removed by the healthy kidneys. This condition is also associated with derangement in hormonal and metabolic homeostasis.
Chronic renal failure is associated with significant morbidity and is a life threatening condition if left untreated.
Several therapeutic options are available for the management of chronic renal feature.
These include dialysis and renal transplantation. These various modalities lead to marked improvement in the condition of the patients.
In this article, the various dialysis modalities are reviewed

II- Dialysis:

A- Definition:

Dialysis refers to the process in which fluid and solutes are removed from or added to the patient's blood outside the body.

B- History:

Although experiments with dialysis are said to have occurred thousands of years ago, dialysis as we know it today has its roots in the 20th century. This lifesaving treatment has been routinely applied for the treatment of patients with chronic renal failure only for the past 50 years.
In 1913, Abel and his colleagues from Johns Hopkins have shown, in experimental animals, that when blood was circulated through numerous collodion tubes surrounded by a jacket containing dialysis fluid, substances diffused from the blood to the dialysate.
These investigators have also shown that the composition of the dialysate fluid was a major determinant of what was removed or retained during the procedure. Based on these findings, Kolf developed the rotating drum artificial kidney and in 1945, he achieved a breakthrough when, for the first time, he successful dialyzed a patient with acute renal failure. Pioneering physicians such as Merrill, Scribner and Schreiner successfully supported patients through the oligoanuric phase of acute renal failure.
The adaptation of the acute procedure to the management of permanent, irreversible renal failure became possible with the development of permanent shunt connecting an artery and a vein in the wrist by Scribner in 1960 and later improved by subsequent investigators.
Mass production of disposable devices for the treatment of renal failure such as dialyzers, tubing and easily reconstituted dialysate facilitated widespread delivery for maintenance hemodialysis.

C- Classification:

There are 2 types of dialysis procedures: (1) hemodialysis; (2) peritoneal dialysis. The percentage of patients undergoing hemodialysis is much greater than those maintained on peritoneal dialysis

HEMODIALYSIS:

a. Definition:
Hemodialysis is an extracorporeal process that performs the work of healthy kidneys by using an artificial membrane to filter wastes, remove extrafluid from the blood, restore the proper balance of biochemicals in the blood and eliminate extrafluid (edema) from the body.

b. Components of the Extracorporal Circuit:
The extracorporal (hemodialysis) circuit includes the following components (a) hemodialyser, (b) dialysate fluid, (c) a permanent vascular access

i. Hemodialysers:
A hemodialyser, also called a dialyser, is an artificial kidney designed to provide controllable transfer of water and solutes across a semipermeable membranes which separates flowing blood and dialysis streams.
Structurally, the dialysis membranes may be cellulosic, semisynthetic or synthetic. Cellulose and its derivatives, cuprophane and cellulose acetate continue to be the most commonly used membranes worldwide.
Semisynthetic membranes are made up of compounds that contain cellulose such copper-ammonia cellulose complexes yielding a membrane with cupra-ammonium radicals. This modification yields greater diffusion and ultrafiltration capacities for cuprophane membranes

compared with straight cellulose.
Synthetic membranes differ from cellulose-based dialysis in several ways. Although thicker than cellulose membranes, synthetic membranes display enhanced intrinsic diffusion characteristics and maintain their thickness when wet.
In contrast, cuprophane and cellulose membranes swell when wet. However, a number of synthetic membranes also strongly bind blood proteins, causing decreases in their filtration efficiency.
There are 3 basic dialyzer designs: coil, parallel plate and hollow fiber configurations:

a- Coil dialyzer:

It is an early design in which the blood compartment consists of one or two long membrane tubes placed between support screens and tightly wound around a plastic core. This design has serious performance limitations which gradually restricted its use as better designs evolved. The coil design does not produce uniform dialysate flow distribution across the membrane.

b- Parallel plate dialyzer:

Sheets of membrane are mounted on plastic support screen, and then starched in multiple layers ranging from 2 to 20 or more. This design allows multiple parallel blood and dialysate flow channels which a lower resistance to flow. Several modifications introduced into this design have improved its functional characteristics.

c- Hollow fiber dialyzer:

This is the most effective design for providing low-volume high efficiency devices with low resistance to flow. The fibers in the device are termed the fiber bundle. The fibers are sealed in polyurethane at each end of the fiber bundle in the tube sheet which serves as the membrane support.

ii- Vascular access:

Hemodialysis requires the creation of an adequate vascular access to provide large volumes of blood to the dialyzer.
For acute hemodialysis, a large vein, such as the femoral vein is often cannulated with a double- lumen catheter. One is for extracting blood from the patient (the so-called arterial) and the other returns blood to the patient (venous side). Femoral catheters are seldom left in place for more than one dialysis session unless the patient is nonambulatory, because they are prone to kinking, dislodgement and infection.
For usage for one to several weeks, an indwelling double lumen catheter is often placed in a central vein to minimize the risk of central vein stenosis and subsequent thrombosis. Central vein catheters should be inserted preferentially into the right jugular vein, regardless of whether they are being used for temporary or more permanent purposes. Improvement in catheter design and function combined with ease of insertion have increased use of central vein catheters in dialysis units.
Long-term vascular access for hemodialysis is usually established by the creation of an arteriovenous fistula in an upper extremity, a lower extremity or even an axillary vessel may sometimes be employed a fistula is established by connecting an artery to a nearby vein either by direct surgical anastonosis of the native vessels or with an artificial vascular graft, for example, one made of polytetrafluorothylene (PTFE). Native fistulae are preferred to PTFE grafts because of their relative longevity and lower susceptibility to infection.

iii- Dialysis machines:

Dialysis mechanisms have 3 basic functions: (a) circulation of blood from the patient's access through the dialyzer and back to the access using a blood pump and a disposable tubing set; (b) preparation of dialysate from purified water and one or more concentrates and circulation of that dialysate through the dialyzer using a system that also controls the rate of fluid removal; (c) monitoring for any loss of integrity in either blood or dialysate circuit or any excursion of an operating parameter outside a predefined range.

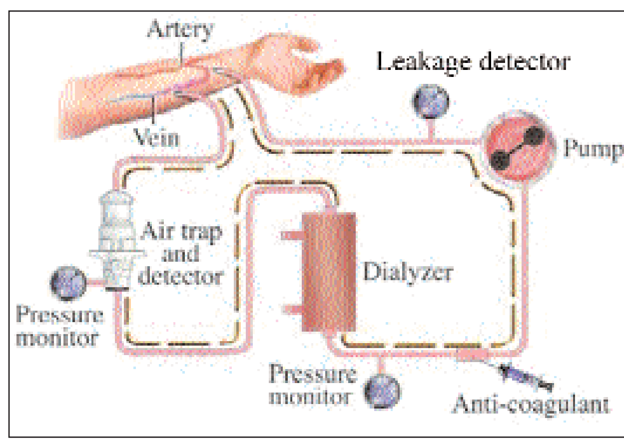

Figure 1: Dialysis Machines

To perform these functions properly and safely, the dialysis machine incorporates important features including a pump to deliver blood to the dialyzer at a constant rate, monitors to ensure that the pressure inside the extracorporal circuit are not excessive, a detector for leakage of red blood cells from the blood compartment into the dialysate compartment, an air detector and shut-off device to prevent air from entering the patient, a pump to deliver dialysate, a proportioning system to properly dilute the dialysate concentrate, a heater to warn the dialysate to approximately body temperature and conductivity monitors to check dialysate ion concentrations. (Figure 1) Modern dialysis machines also contain ultrafiltration control devices that precisely regulate the flow of fluid across the porous membrane of the dialyzer to prevent an excessively rapid decrease in intravascular volume.

These devices ensure the proper, safe, and reliable delivery of blood and dialysate to the dialyzer where exchange of water and solutes occurs.

iv- Dialysate:

The dialysate creates solute concentration gradients to drive diffusion across dialysis membranes. Dialysate sodium is usually kept at concentrations similar to or higher than plasma sodium concentration to avoid a decrease in plasma sodium concentration. In contrast, dialysate potassium concentration is often kept low in order to decrease plasma potassium concentration. Because dialysis patients are often acidemic, bicarbonate rather than acetate is often used in order to avoid complications associated with acetate buffers. Calcium and magnesium concentrations in the dialysate depend on the specific needs of the patient. Most dialysate solutions do not contain glucose.

D- Physiology of fluid transport across dialysis membranes:

Solutes are transported across this membrane by either diffusional or convective flux.

In diffusive solute transport, solutes cross the dialysis membrane in a direction dictated by the concentration gradient established across the membrane of the hemodialyzer (figure 2)

Blood	Diffusion	Dialysate
Initial Urea 100mg/dl	→	Initial Urea 0 mg/dl
Potassium 6 mm/l	→	Potassium 2 mm/l
Bicarbonate 15 mm/l	←	Bicarbonate 35 mm/l
	Dialysate membrane	

Figure 2: Diffusive transport

In this example, urea and potassium diffuse from blood to dialysate thereby decreasing the urea and potassium in the plasma conversely; the concentration gradient of bicarbonate favors the diffusion of this ion from the dialysate to the blood compartment. At a given temperature, diffusive transport is directly proportional to both the solute concentration gradient across the membrane and the membrane surface area and inversely proportional to membrane thickness.

During hemodialysis water moves from blood to dialysate driven by a hydrostatic gradient between the blood and dialysate compartments, a process referred to as ***ultrafiltration***. The rate of ultrafiltration is determined by the magnitude of this pressure gradient. Movement of water tends to drag solutes across the membrane, a process referred to as convective transport or solvent drag. ***Convective transport*** contributes mainly to transport of middle or to high molecular weight solutes.

Blood	Ultrafiltration	Dilaysate
Hydrostatic pressure 90mmHg		Hydrostatic pressure -150mmHg
Water/ Sodium	→ Dialysate membrane	Water/ Sodium

Figure3: Convective transport

F- Indications for hemodialysis:

(1) Acute hemodialysis:

Acute hemodialysis is primarily performed for renal failure and drug overdose. Indications for emergency dialysis in the acute renal failure setting include fluid overload, hyperkalemia, metabolic acidosis and signs and symptoms of uremia such as including acute psychosis, uremic encephalopathy, seizures, disorientation, and confusion.

(2) Chronic or maintenance hemodialysis

When to begin maintenance hemodialysis is a complex decision which is determined by many variables. The decision to initiate dialysis is easy when patients present with florid uremic symptoms and signs, laboratory values of high blood urea nitrogen (BUN) and serum creatinine, and ultrasonic findings of bilaterally small kidneys. However most patients are seen before the onset of florid manifestations of uremia. Patients often have incipient manifestations (table 1).

1- Florid uremic signs and symptoms

- a- Pericarditis
- b- Poorly controlled severe hypertension
- c- Fluid overload/pulmonary edema
- d- Neurologic manifestations
  - - Encephalopathy
  - - Neuropathy (seizures, disorientation, confusion, acute psychosis)
- e- Abnormal laboratory values
  - - Hyperkalemia
  - - Severe metabolic acidosis

2- Incipient uremic manifestations

- a. Persistent nausea, vomiting, anorexia
- b. Evidence of malnutrition
- c. Osteopenia
- d. Abnormal laboratory values
  - " High serum creatinine (above 10mg/dl) and BUN (above 100mg/dl)
  - " Poorly controlled serum calcium and phosphorous levels
  - " Low serum albumin concentrations