Dialysis: Types, Indications and Complications

Dialysis is a medical procedure that acts as an artificial replacement for lost kidney function. It filters the blood to remove metabolic waste products (such as urea and creatinine), excess salts, and extra fluid from the body when the kidneys are no longer able to do so effectively. This therapy is crucial in patients with **kidney failure**, whether sudden (**acute kidney injury, AKI**) or progressive (**chronic kidney disease, CKD**).

When is Dialysis Needed? (Indications)

Dialysis becomes necessary when the kidneys lose most of their function, typically when 85% to 90% of kidney function is lost. This corresponds to a **glomerular filtration rate (GFR)** — a measure of how well the kidneys filter blood — of less than 15 milliliters per minute (mL/min).

Dialysis is also a lifesaving intervention in severe acute kidney injury cases while the kidneys recover, although some patients may require dialysis long term if kidney function does not return.

Specific clinical indications for dialysis include:

- **Uremic pericarditis or pleuritis:** Inflammation of the heart's covering (pericardium) or lung lining (pleura) due to toxin buildup in the blood.
- **Progressive uremic encephalopathy or neuropathy:** Neurological symptoms caused by toxin accumulation, such as confusion, decreased consciousness, abnormal muscle movements (asterixis), seizures, or muscle twitches (myoclonus).
- **Bleeding diathesis:** Increased tendency to bleed because toxins interfere with blood clotting.
- **Fluid overload:** Excess fluid in the body causing swelling or breathing difficulty that does not respond to diuretics (water pills).
- **Metabolic disturbances resistant to medical treatment:** This includes high potassium (hyperkalemia), acid-base imbalances (metabolic acidosis), abnormal calcium or phosphate levels, all of which can be life-threatening.
- **Severe nausea, vomiting, weight loss, or malnutrition:** Symptoms due to toxin accumulation affecting digestion and appetite.
- **Poisoning or overdose with dialyzable toxins:** Certain drugs (like lithium) or poisons (such as ethylene glycol) can be removed quickly via dialysis.

Goals of Dialysis

Dialysis has two primary therapeutic goals:

1. **Solute Clearance** – Removal of waste products and toxins dissolved in the blood, achieved through:
    - **Diffusion:** Movement of solutes from an area of higher concentration in the blood to a lower concentration in the dialysis fluid.
    - **Convection:** Movement of solutes dragged along with fluid removal (solvent drag), especially in techniques involving ultrafiltration.

2. **Fluid Removal** – Removal of excess water from the bloodstream to prevent swelling, high blood pressure, and heart failure.

Types of Dialysis Modalities

1. Peritoneal Dialysis (PD):
This method uses the body's own **peritoneal membrane**—a thin lining inside the abdomen—as a natural filter. A sterile fluid called **dialysate** is infused through a catheter into the peritoneal cavity (the abdominal space surrounding the intestines). The peritoneal membrane allows waste products and excess fluids to move from the blood vessels in the abdomen into the dialysate by diffusion and osmosis. After a dwell time (usually a few hours), the fluid containing wastes is drained and discarded.

- The catheter is surgically inserted through the abdominal wall and usually becomes usable about two weeks after insertion.
- The dialysate solution used in PD is **hypertonic**, meaning it has a higher concentration of solutes than the blood, which helps pull excess fluid from the bloodstream into the abdomen.

Two main types of PD:

- **Continuous Ambulatory Peritoneal Dialysis (CAPD):**
  - Does not require a machine. The patient manually fills and drains the dialysate using gravity and sterile technique, typically performing 3-5 exchanges daily.
  - Patients can remain ambulatory (mobile) during the dwell periods when dialysate is inside the abdomen.
- **Continuous Cyclic Peritoneal Dialysis (CCPD) or Automated Peritoneal Dialysis (APD):**
  - Uses a machine called a **cycler** to automate dialysate exchanges, usually overnight while the patient sleeps.
  - The cycler pumps dialysate in and out in programmed cycles, reducing the need for multiple daytime exchanges.

2. Intermittent Hemodialysis (IHD):
In hemodialysis, blood is drawn directly from the patient's circulation and passed through an **artificial kidney** machine called a **dialyzer**, which removes waste and extra fluid before returning the cleaned blood to the body.

- Typically performed 3 to 6 times per week, with sessions lasting 3 to 4 hours.
- Blood flows at rates over 250 mL/min; dialysate flows at 500 to 800 mL/min.
- Waste removal occurs mainly by diffusion; fluid removal by ultrafiltration (applying pressure to pull fluid out).

Advantages:

- Rapid correction of electrolyte imbalances (e.g., high potassium) and fluid overload.
- Useful for rapid clearance of drugs or toxins in poisonings.
- Lower anticoagulation requirements due to shorter treatment time and high blood flow.

Disadvantages:

- Risk of **systemic hypotension** (low blood pressure) due to rapid fluid shifts.
- Rapid solute removal can cause **cerebral edema** and increased intracranial pressure, which makes IHD unsuitable for patients with brain injuries or severe liver disease.

3. Continuous Renal Replacement Therapy (CRRT):
A slower, continuous form of dialysis used mainly in critically ill patients who are unstable or unable to tolerate the rapid fluid and solute shifts of IHD. CRRT allows more gradual removal of toxins and fluid over 24 hours.

Hemodialysis Equipment

- **Dialyzer (Artificial Kidney):** Contains a semi-permeable membrane made of cellulose or synthetic material, separating blood from dialysate.
- **Dialysate:** Special fluid free of contaminants such as aluminium, chloramine, and bacteria.
- **Tubing and Machine:** Circulate blood and dialysate, monitor pressure, flow rates, and detect air bubbles.

Hemodialysis Vascular Access

Effective hemodialysis requires reliable access to the bloodstream to allow sufficient blood flow.

Types of vascular access:

1. **Central Venous Catheters (CVCs):**
    - Large bore catheters (usually 11-13 French gauge) inserted into large veins such as the internal jugular or femoral veins.
    - Allow rapid blood flow required for hemodialysis.

    Subtypes:

    - **Non-tunneled Catheters:**
        - Also called “temporary dialysis catheters” or “Quinton catheters.”
        - Used short-term, primarily in acute kidney injury.
        - Secured with sutures and dressings.
        - Higher risk of infection and bleeding if dislodged.
        - Not suitable for long-term use or discharge from hospital.
    - **Tunneled Catheters:**
        - Also called “Hickman catheters” or “permacaths.”
        - Surgically tunneled under the skin before entering the vein, with a cuff that reduces infection risk by promoting tissue growth around it.
        - Intended for longer-term use while waiting for permanent vascular access.
2. **Permanent Access (Not detailed here):**
    - Includes **arteriovenous fistulas (AV fistulas)** and **arteriovenous grafts**, which are surgically created to provide durable access for long-term hemodialysis.