Renal Replacement Therapy

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The kidneys work through transport, diffusion, and osmosis, and when this system fails, other means of filtration must be used. The management is primarily achieved through renal replacement therapy. Renal replacement therapy is divided into several modalities including hemodialysis, continuous renal replacement therapy, slow continuous therapy, ultrafiltration, and peritoneal dialysis. This article will give you an overview of the different procedures.

The Function of the Kidneys

The **urinary system** is our body's most vital function in terms of maintaining health and balance. Its organ of control is contributed by the renal system, specifically the kidneys. The kidneys are retroperitoneal organs found on the posterior left side and lower right (liver).

Blood supply and functions

Each kidney is made of up to 1.3 million nephrons that receive 25% of cardiac output to carry out the various functions. The supply is via the **renal arteries** and drained through the **renal veins**.

The artery branches into the interlobar arteries, arcuate arteries, and interlobular arteries that unite to form the afferent arteriole. The high-pressure input system flows against glomerular resistance to elicit the force needed for ultrafiltration, which is the kidney's main role.

Other functions of the kidneys include:

- Water and electrolyte balance
- Excretion of metabolic wastes
- Acid-base balance
- Secretion, metabolism, and elimination of hormones

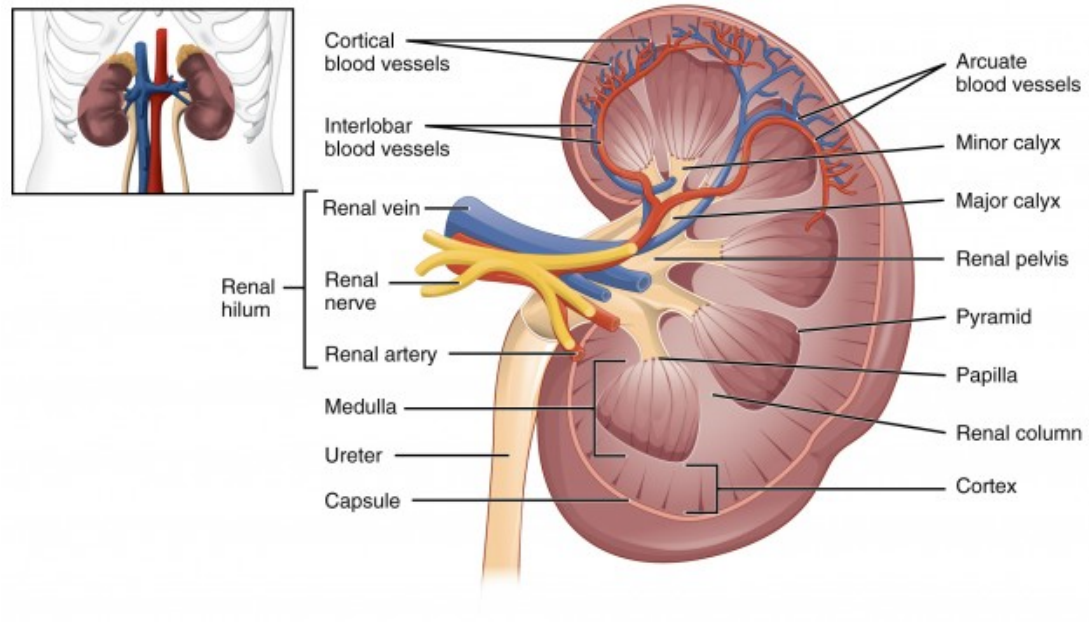

Image: "Internal Anatomy of the Kidney" by Philschatz. License: CC BY 4.0

The **nephron** is the kidney's primary functioning unit. Its purpose is to filter the blood and create urine within the tubular system. The tubular system, though highly efficient and calculated, is also prone to injury. The most common pathologies in the kidneys are due to **acute kidney injury and failure**, due to a decline in kidney filtration and perfusion.

Etiology of Acute Kidney Injury

Causes of acute kidney injury

Causes of acute kidney injury are classified as:

- Prerenal causes (30%of the cases)
- Burn injuries
- Sepsis
- Hemorrhage
- Dehydration
- Congestive heart failure
- Renal artery occlusion
- Hepatorenal syndrome

- Intrarenal causes(65% of the cases)
    - Acute tubular necrosis following medication overuse, such as NSAIDs, angiotensin receptor blockers, or chemotherapy medications
    - Acute glomerulonephritis/nephrosis following infections, ischemia, or toxic chemical ingestion
    - Acute interstitial nephritis after inflammatory and infiltrative conditions, such as lupus, multiple myeloma, scleroderma, and lymphoma
    - Other conditions such as nephrolithiasis
- Postrenal causes (5% of the cases)
    - Ureteral obstructions by stones, peritoneal fibrosis, or blood clots
    - Bladder neck obstruction
    - Urethral obstructions following strictures
    - Benign prostate hypertrophy and other tumors

Symptoms of Acute Kidney Injury

Manifestations of acute kidney injury

Signs and manifestations of acute kidney injury and failure include but are not limited to the ones listed in the following table:

Organ System	Manifestation
Integumentary	Purpura, allergic nephritis rash, vasculitis, ischemia
Ophthalmology	Keratitis, jaundice, uveitis
Cardio	**Endocarditis**, a fib from emboli
Musculoskeletal	Rhabdomyolysis
Renal	Hematuria, granular casts(red, white, muddy brown)<0.5 ml per kg per hour of urine output for >12 hours.
Neuro	**Encephalopathy**

The necessity for Renal Replacement Therapy

Management of acute kidney and chronic injuries is performed for patients with **severe and morbidity inducing kidney injuries**. The different methods of therapy for these patients are subdivided into:

- **hemodialysis** (the most common)
- **continuous renal replacement therapy**
- **renal transplant** (if all fails)

The purpose of renal replacement therapy is to prevent mortality due to **uremia** and **renal failure**. Therefore, renal replacement therapy is indicated for patients in the following cases:

- Refractory fluid overload
- Acidosis (metabolic) with a PH <7.1
- Hyperkalemia
- Uremia
- Drug intoxication
- Patients with GFR <60, especially <30 with underlying chronic kidney disease

It is suggested that renal replacement therapy be initiated before renal failure and the first signs of acute renal injury. These signs are usually complicated uremia (encephalopathy and metabolic acidosis). The **BUN** (**b**lood **u**rea **n**itrogen) is also a factor of when to initiate therapy. Generally, when the BUN reaches 80-100 mg/dl, dialysis is initiated. The rate and mechanism of renal replacement therapy are through **diffusion and ultrafiltration**.

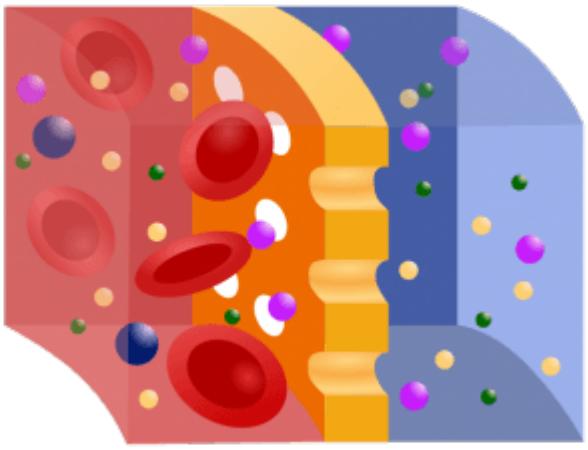

Image: “Plugged into dialysis” by Freemesm. License: CC BY-SA 3.0

The rate of solute diffusion depends on the solute **permeability of the dialysis membrane, blood flow rates, and duration**. If rate or duration is increased, a maximum concentration gradient may be achieved for continued diffusion. Solute removal by ultrafiltration is influenced by the transmembrane.

Quick-Hits for determining the need for renal replacement therapy

- Uremia/plasma urea > 30 mmol/L
- Creatinine > 600 mmol/L
- Chronic hyperkalemia
- Hypervolemia (refractory)
- Acute renal failure (ARF)
- Chronic uncontrolled renal failure with ARF

Different Methods Used for Renal Replacement Therapy

Hemodialysis

Hemodialysis allows a means of replacement for those with declining or lost renal function. It removes toxins, wastes, and substances hemodynamically in patients with acute kidney injury or **stage 5 chronic kidney disease** (end-stage renal disease). Ultrafiltration and diffusion through a semipermeable membrane are common fluid replacement methods.

Image: “Plugged into dialysis” by Dan. License: CC BY 2.0

Hemodialysis dosing and intervals are case dependent. Standard treatment is performing dialysis every other day for 3 – 4 hours for those who are hemodynamically stable. Usually, dialysis is performed in the hospital or a dialysis center and now even at home. The patient is hooked up to a hemodialysis machine in which blood is pumped out of the patient’s arm through an **external filter dialyzer** that contains the **dialysis fluid dialysate**.

Dialysate contains different concentration levels to allow for diffusion of products from the blood to remove wastes and preserve essential substances that will return to the blood (blood cells and proteins). Dialysate and its concentration levels are dependent on the patient and nephrologist. **Solutes** are passed through a concentration gradient as blood leaves the arm. **Urea, creatinine, and other wastes** are removed from the blood into the dialysate. However, **calcium, bicarb, and red blood cells** are left unfiltered and move back from the dialysate to the blood returning to the patient’s arm. The dialysate flows countercurrent to blood flow through the dialyzer to maximize the concentration gradient between the compartments and, therefore, to maximize the solute removal rate. The result is a reduction in wastes and an elevation in essential proteins and products.

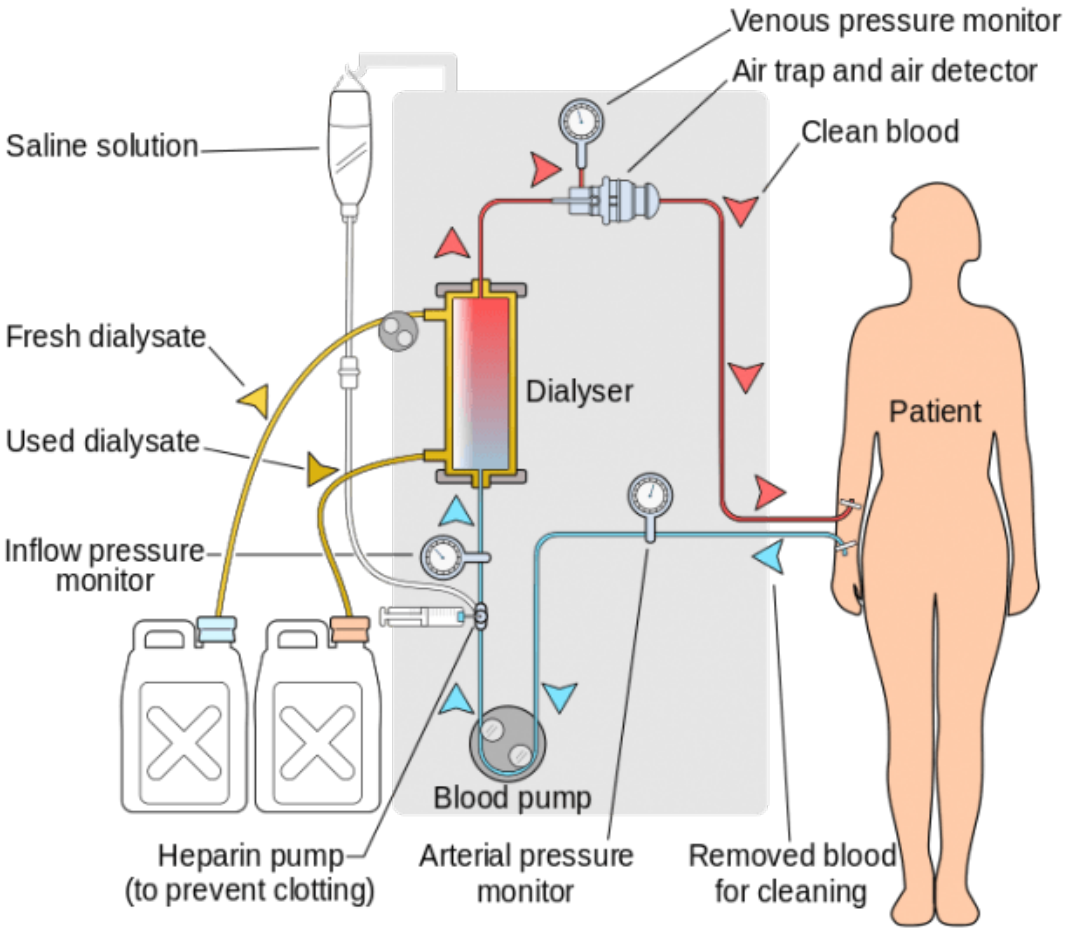

Image: “Simplified hemodialysis circuit.” by YassineMrabet. License: CC BY 3.0

Continuous Renal Replacement therapy

Continuous renal replacement therapy is used when standard hemodialysis is not enough. It is usually given to severely sick patients, the **hemodynamically unstable,** and those needing greater solute and/or fluid removal. Removing solutes over a daily course of 24 hours allows greater concentrations to be filtered.

Slow continuous ultrafiltration

This process allows for minimal solute removal. It is performed for those with **volume overload** and allows 7 l of fluid to be removed per day.

Continuous arteriovenous hemofiltration

The fluid is filtered in greater amounts, requiring fluid replacement and preventing **volume depletion**. The filtration is driven by the arteriovenous pressure difference. Usually, 1 l of filtrate is replaced per hour. To allow for better solute filtration, replacement fluid is pre-administered to allow for wastes to diffuse from within the red blood cells into the plasma for removal.

Continuous venovenous hemofiltration

This method requires the same concept as continuous arteriovenous hemofiltration. However, it requires a **blood pump** for flow rate control.

Continuous arteriovenous hemodialysis

This method allocates dialysis fluid to flow within the filter, separate from the patient's blood in the dialysis machine. Ultrafiltration is enhanced beyond normal to ensure solute clearance. The patient then receives replacement fluid to prevent **hypovolemia** and restore **euvolemia**.

Peritoneal dialysis

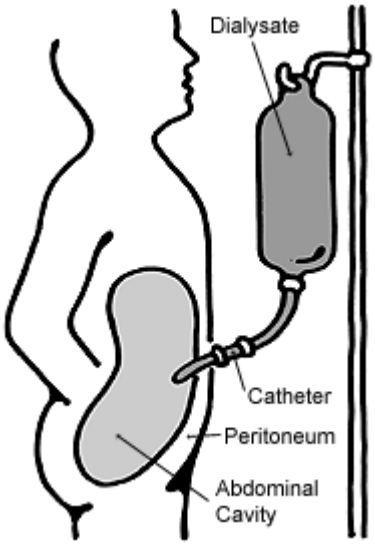

Image: "Peritoneal dialysis" by National Kidney and Urologic Diseases Information Clearinghouse. License: Public Domain.

This method is less complicated and efficient. Peritoneal dialysis allows the removal of large amounts of fluid. It is slow functioning, so disequilibrium and gradual correction can be achieved. The dialysis is performed in the OR or at the bedside by implanting a catheter into the **abdominal wall** via a superficial cuff that is placed in the subcutaneous abdominal wall. It is usually medial than midline, below the rectus muscle, to provide better tissue ingrowth around the cuff for better vascularization. Prophylactic antibiotics are given to decrease wound infections. The abdominal cavity is dialyzed by filling it with the dialysate fluid and maintaining it for a period of time. The peritoneum acts as a membrane to allow for solutes to diffuse out of the blood into the solution to be drained. This process can be repeated up to five times a day.

Disadvantages of Treatment

Side effects of renal replacement therapy

Hemodialysis comes with acute, intermediate, and long term adverse effects as follows:

- Acute complications include
    - Hypotension due to excessive fluid loss. The sudden filtration, volume loss, and restoration may be accompanied by syncope, dyspnea, cramping, nausea, and emesis
    - Air emboli
    - Cardiac arrhythmias
    - Muscle cramps due to redistribution of blood

- Intermediate complications include
    - Dialysis disequilibrium syndrome
    - Hemorrhage from the access due to anticoagulant use
- Chronic complications
    - Amyloidosis due to β_2 microglobulin accumulation that isn't removed by dialysis
    - Dialysis dementia due to aluminum toxicity. Aluminum is found in dialysate and may penetrate into the patient's system

Socially and economically, dialysis can be expensive and a barrier for those without a means of transportation. It forces patients to travel or stay idle for long periods, rendering them unable to work or carry out daily activities.

Peritoneal dialysis poses a risk for abdominal hernias, weight gain, and constipation, as well as sepsis from an infection.

Preparing for Renal Replacement Therapy

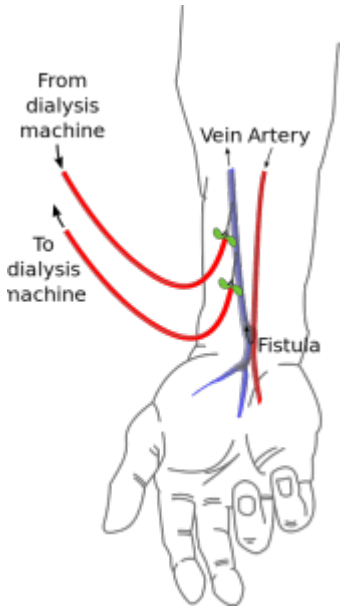

Image: "Radiocephalic fistula" by kbk. License: CC BY-SA 3.0

This form of therapy depends on personal preference, the extent of disease, and medical advice. Before one can start hemodialysis, the patient must undergo surgery. Usually, this is the **Cimino fistula**, an anastomosis between the arteria radialis and the vena cephalica in the distal forearm. This is access created in the patient's distal forearm to allow blood to flow in and out. The main aim of this procedure is to arteriorize the vein, making it stronger to handle a large amount of blood flow and withstand multiple venipunctures without undergoing changes.

Other modalities include an **AV graft** and a **central venous catheter**. Maintaining access is vital for preventing infection. Accesses should be cleansed and untouched. Blood pressure and vaccines, IV's should be avoided in the arm access. Patients should also be instructed to follow low sodium and low potassium diet to reduce the burden on the kidneys.

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Notes