ISSN 2321 – 2004

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 1, April 2013

# Functions of kidney & artificial kidneys

Raghavendra[1], Mallikarjun[2], Vidya M.J[3]

Student, Instrumentation Technology, R.V.C.E, Bangalore, India [1]

Student, Instrumentation Technology, R.V.C.E, Bangalore, India [2]

Assistant Professor, Instrumentation Technology, R.V.C.E, Bangalore, India [3]

**Abstract:** Renal failure is a term to describe a situation when the kidneys fail to work. This may be a permanent or temporary failure. When the kidneys fail, Wastes begin to accumulate in the blood (uremia) As homeostasis is upset within the body, other organs can also begin to shut down – heart, liver, etc. The end result of renal failure is usually death unless the blood is filtered by some other means. The ideal intervention is to replace the failed kidneys with a donor kidney (STSE).While a person waits for a donor kidney, they usually have to undergo dialysis, a method where their blood is filtered and cleaned on a regular basis using machines.

**Keywords**: uraemia, homeostasis, Palpation, Elasticity

## I. INTRODUCTION

The kidneys are organs that serve several essential regulatory roles in most animals, including vertebrates and some invertebrates. They are essential in the urinary system and also serve homeostatic functions such as the regulation of electrolytes, maintenance of acid–base balance, and regulation of blood pressure (via maintaining salt and water balance). They serve the body as a natural filter of the blood, and remove wastes which are diverted to the urinary bladder. In producing urine, the kidneys excrete wastes such as urea and ammonium, and they are also responsible for the reabsorption of water, glucose, and amino acids. The kidneys also produce hormones including calcitriol, erythropoietin, and the enzyme renin.
Located at the rear of the abdominal cavity in the retroperitoneum, the kidneys receive blood from the paired renal arteries, and drain into the paired renal veins. Each kidney excretes urine into a ureter, itself a paired structure that empties into the urinary bladder. Renal physiology is the study of kidney function, while nephrology is the medical specialty concerned with kidney diseases. Diseases of the kidney are diverse, but individuals with kidney disease frequently display characteristic clinical features. Common clinical conditions involving the kidney include the nephritic and nephrotic syndromes, renal cysts, acute kidney injury, chronic kidney disease, urinary tract infection, nephrolithiasis, and urinary tract obstruction.

Various cancers of the kidney exist; the most common adult renal cancer is renal cell carcinoma. Cancers, cysts, and some other renal conditions can be managed with removal of the kidney, or nephrectomy. When renal function, measured by glomerular filtration rate, is persistently poor, dialysis and kidney transplantation may be treatment options. Although they are not severely harmful, kidney stones can be painful and a nuisance. The removal of kidney stones involves ultrasound treatment to break up the stones into smaller pieces, which are then passed through the urinary tract. One common symptom of kidney stones is a sharp pain in the medial/lateral segments of the lower back.

## II. ANATOMY

### A. Location

In humans the kidneys are located in the abdominal cavity, more specifically in the paravertebral gutter and lie in a retroperitoneal position at a slightly oblique angle. There are two, one on each side of the spine. The asymmetry within the abdominal cavity caused by the liver typically results in the right kidney being slightly lower than the left, and left kidney being located slightly more medial than the right. The left kidney is approximately at the vertebral level T12 to L3, and the right slightly lower. The right kidney sits just below the diaphragm and posterior to the liver, the left below the diaphragm and posterior to the spleen. Resting on top of each kidney is an adrenal gland. The upper (cranial) parts of the kidneys are partially protected by the eleventh and twelfth ribs, and each whole kidney and adrenal gland are surrounded by two layers of fat (the perirenal and pararenal fat) and the renal fascia. Each adult kidney weighs between 125 and 170 grams in males and between 115 and 155 grams in females. The left kidney is typically slightly larger than the right.

### B. Structure

The kidney has a bean-shaped structure; each kidney has a convex and concave surface. The concave surface, the renal hilum, is the point at which the renal artery enters the organ, and the renal vein and ureter leave. The kidney is surrounded by tough fibrous tissue, the renal capsule, which is itself surrounded by perinephric fat, renal fascia ( Gerota) and paranephric fat. The anterior (front) border of these tissues is the peritoneum, while the posterior (rear) border is the transversalis fascia.

ISSN 2321 – 2004

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The superior border of the right kidney is adjacent to the liver; and the spleen, for the left kidney. Therefore, both move down on inhalation. The kidney is approximately 11–14 cm in length, 6 cm wide and 4 cm thick. The substance, or parenchyma, of the kidney is divided into two major structures: superficial is the renal cortex and deep is the renal medulla. Grossly, these structures take the shape of 8 to 18 cone-shaped renal lobes, each containing renal cortex surrounding a portion of medulla called a renal pyramid (of Malpighi).Between the renal pyramids are projections of cortex called renal columns (of Bertin). Nephrons, the urine-producing functional structures of the kidney, span the cortex and medulla. The initial filtering portion of a nephron is the renal corpuscle, located in the cortex, which is followed by a renal tubule that passes from the cortex deep into the medullary pyramids. Part of the renal cortex, a medullary ray is a collection of renal tubules that drain into a single collecting duct.

The tip, or papilla, of each pyramid empties urine into a minor calyx; minor calyces empty into major calyces, and major calyces empty into the renal pelvis, which becomes the ureter.

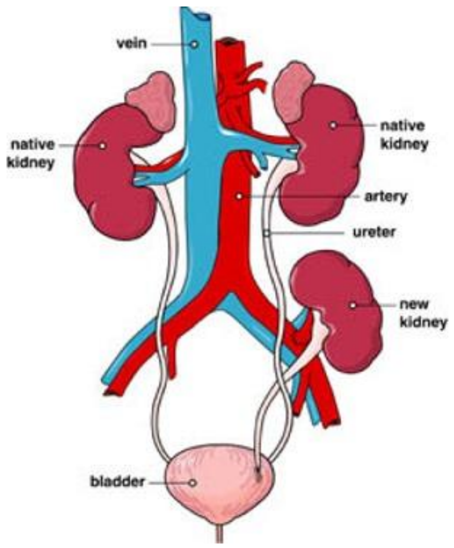



Fig 1: structure of kidney.

### C. *Blood supply*

The kidneys receive blood from the renal arteries, left and right, which branch directly from the abdominal aorta. Despite their relatively small size, the kidneys receive approximately 20% of the cardiac output. Each renal artery branches into segmental arteries, dividing further into interlobar arteries which penetrate the renal capsule and extend through the renal columns between the renal pyramids. The interlobar arteries then supply blood to the arcuate arteries that run through the boundary of the cortex and the medulla. Each arcuate artery supplies several interlobular arteries that feed into the afferent arterioles that supply the glomeruli. The interstitum (or interstitium) is the functional space in the kidney beneath the individual filters (glomeruli) which are rich in blood vessels. The interstitum absorbs fluid recovered from urine. Various conditions can lead to scarring and congestion of this area, which can cause kidney dysfunction and failure. After filtration occurs the blood moves through a small network of venules that converge into interlobular veins. As with the arteriole distribution the veins follow the same pattern, the interlobular provide blood to the arcuate veins then back to the interlobar veins which come to form the renal vein exiting the kidney for transfusion for blood.

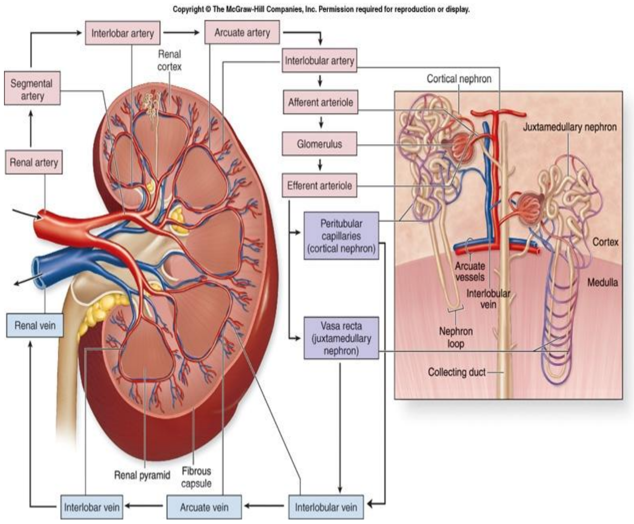



Fig 2: Blood supply in kidney

## III. FUNCTIONS OF KIDNEY

The kidney participates in whole-body homeostasis, regulating acid-base balance, electrolyte concentrations, extracellular fluid volume, and regulation of blood pressure. The kidney accomplishes these homeostatic functions both independently and in concert with other organs, particularly those of the endocrine system. Various endocrine hormones coordinate these endocrine functions; these include renin, angiotensin II, aldosterone, antidiuretic hormone, and atrial natriuretic peptide, among others.

Many of the kidney's functions are accomplished by relatively simple mechanisms of filtration, reabsorption, and secretion, which take place in the nephron. Filtration, which takes place at the renal corpuscle, is the process by which cells and large proteins are filtered from the blood to make an ultrafiltrate that eventually becomes urine. The kidney generates 180 liters of filtrate a day, while reabsorbing a large percentage, allowing for the generation of only approximately 2 liters of urine. Reabsorption is the transport of molecules from this ultrafiltrate and into the blood. Secretion is the reverse process, in which molecules are transported in the opposite direction, from the blood into the urine.

### A. *Excretion of waste*

The kidneys excrete a variety of waste products produced by metabolism. These include the nitrogenous wastes called "urea", from protein catabolism, as well as uric acid, from nucleic acid metabolism. Formation of urine is also the function of the kidney. The concentration of nitrogenous wastes, in the urine of mammals and some birds, is dependent on an elaborate counter current multiplication system. This requires several independent nephron characteristics to operate: a tight hair pin configuration of the tubules, water and ion permeability in the descending limb of the loop, water impermeability in the ascending loop and active ion transport out of most of the ascending loop. In addition, counter current exchange by the vessels carrying the blood supply to the nephron is essential for enabling this function.

*B. Acid Balance*

Two organ systems, the kidneys and lungs, maintain acid-base homeostasis, which is the maintenance of pH around a relatively stable value. The lungs contribute to acid-base homeostasis by regulating carbon dioxide (CO2) concentration. The kidneys have two very important roles in maintaining the acid-base balance: to reabsorb bicarbonate from urine, and to excrete hydrogen ions into urine.

*C. Osmolability*

Any significant rise in plasma osmolality is detected by the hypothalamus, which communicates directly with the posterior pituitary gland. An increase in osmolality causes the gland to secrete antidiuretic hormone (ADH), resulting in water reabsorption by the kidney and an increase in urine concentration. The two factors work together to return the plasma osmolality to its normal levels. ADH binds to principal cells in the collecting duct that translocate aquaporins to the membrane, allowing water to leave the normally impermeable membrane and be reabsorbed into the body by the vasa recta, thus increasing the plasma volume of the body. There are two systems that create a hyperosmotic medulla and thus increase the body plasma volume: Urea recycling and the 'single effect.' Urea is usually excreted as a waste product from the kidneys. However, when plasma blood volume is low and ADH is released the aquaporins that are opened are also permeable to urea. This allows urea to leave the collecting duct into the medulla creating a hyperosmotic solution that 'attracts' water. Urea can then re-enter the nephron and be excreted or recycled again depending on whether ADH is still present or not.

The 'Single effect' describes the fact that the ascending thick limb of the loop of Henle is not permeable to water but is permeable to NaCl. This allows for a countercurrent exchange system whereby the medulla becomes increasingly concentrated, but at the same time setting up an osmotic gradient for water to follow should the aquaporins of the collecting duct be opened by ADH.

*D. Sensing*

Although the kidney cannot directly sense blood, long-term regulation of blood pressure predominantly depends upon the kidney. This primarily occurs through maintenance of the extracellular fluid compartment, the size of which depends on the plasma sodium concentration. Renin is the first in a series of important chemical messengers that make up the renin-angiotensin system. Changes in renin ultimately alter the output of this system, principally the hormones angiotensin II and aldosterone. Each hormone acts via multiple mechanisms, but both increase the kidney's absorption of sodium chloride, thereby expanding the extracellular fluid compartment and raising blood pressure. When renin levels are elevated, the concentrations of angiotensin II and aldosterone increase, leading to increased sodium chloride reabsorption, expansion of the extracellular fluid compartment, and an increase in blood pressure. Conversely, when renin levels are low, angiotensin II and aldosterone levels decrease, contracting the extracellular fluid compartment, and decreasing blood pressure.

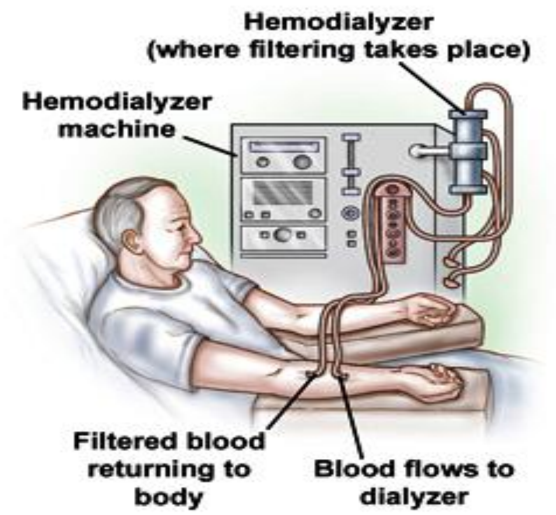
*E. Hormone Secretion*

The kidneys secrete a variety of hormones, including erythropoietin, and the enzyme renin. Erythropoietin is released in response to hypoxia (low levels of oxygen at tissue level) in the renal circulation. It stimulates erythropoiesis (production of red blood cells) in the bone marrow. Calcitriol, the activated form of vitamin D, promotes intestinal absorption of calcium and the renal reabsorption of phosphate. Part of the renin-angiotensin-aldosterone system, renin is an enzyme involved in the regulation of aldosterone levels.

## IV. ARTIFICIAL KIDNEYS

*Introduction*

Renal failure is a term to describe a situation when the kidneys fail to work. This may be a permanent or temporary failure. When the kidneys fail, Wastes begin to accumulate in the blood (uremia) As homeostasis is upset within the body, other organs can also begin to shut down – heart, liver, etc.The end result of renal failure is usually death unless the blood is filtered by some other means. The ideal intervention is to replace the failed kidneys with a donor kidney (STSE).While a person waits for a donor kidney, they usually have to undergo dialysis, a method where their blood is filtered



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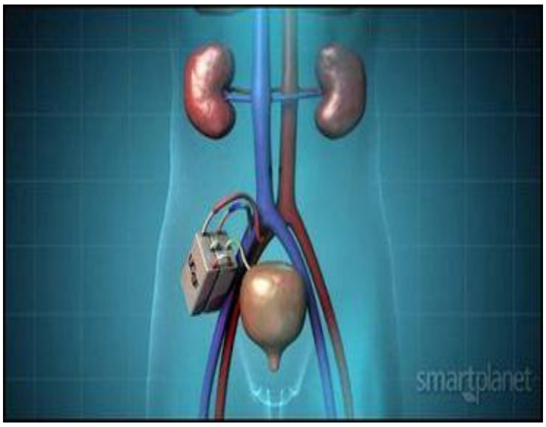


Fig 3: hemodialysis method and hemodialysis machine.

*F. What Does Dialysis Do?*

Like healthy kidneys, dialysis keeps the body in balance. Dialysis does the following:
Removes waste, salt and extra water to prevent them from building up in the body keeps a safe level of certain chemicals in the blood, such as potassium, sodium and bicarbonate. helps to control blood pressure.

*G. Types of Dialysis*

1. Hemodialysis (machine)

2. Peritoneal dialysis (no machine)

*1. Hemodialysis*

An artificial kidney called a hemodialyzer is used to remove waste and extra chemicals and fluid from the blood.
To get the blood into the artificial kidney, the doctor needs to make an access (entrance) into the blood vessels. This is done by minor surgery to the arm or leg. Sometimes, an access is made by joining an artery to a vein under the skin to make a bigger blood vessel called a fistula.
Usually, each hemodialysis treatment lasts about four hours and is done three times per week. The blood is slowly fed through the hemodialyzer, where it passes through a tube with a semi-permeable membrane.
This tube is bathed in a solution known as dialysate. Waste particles move across the membrane, by diffusion, into the dialysate. At the same time, essential materials, are diffusing from the dialysate into the blood (i.e. bicarbonate ions).

*2. Peritoneal Dialysis*

In peritoneal type of dialysis, the blood is cleaned inside the body. The doctor will operate to place a plastic tube called a catheter into the abdomen (belly) to make an access. During the treatment, the abdominal area (called the peritoneal_cavity) is slowly filled with dialysate through the catheter.

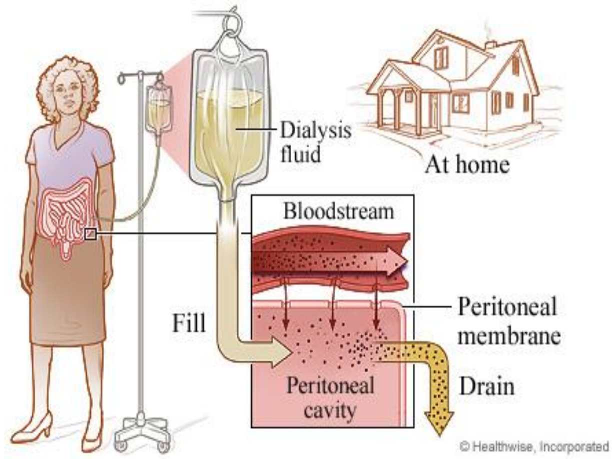


Fig 4: Peritoneal dialysis method.

The blood stays in the arteries and veins that line your peritoneal cavity. Extra fluid and waste products are drawn out of your blood and into the dialysate. There are two major kinds of peritoneal dialysis:

1) Continuous Ambulatory Peritoneal Dialysis
2) Continuous Cycling Peritoneal Dialysis

1 .*Continuous Ambulatory Peritoneal Dialysis*

This method is done by the patient himself, usually four or five times a day at home and/or at work. Patient has to put a bag of dialysate (about two litres) into the peritoneal cavity through the catheter. The dialysate stays there for about four or five hours before it is drained back into the bag and thrown away. Patient needs to use a new bag of dialysate each time. While the dialysate is in the peritoneal cavity, patient can go about his usual activities at work, at school or at home.

2. *Continuous Cycling Peritoneal Dialysis*

This method is also done at home but uses a special machine called a cycler. This is similar to the previous method except that a number of cycles (exchanges) occur. Each cycle usually lasts 1-1/2 hours and exchanges are done throughout the night while you sleep.

*Cost of Dialysis*

Dialysis costs about $50,000 per year, the bulk of which is picked up by Medicare.

*Dialysis & Quality of Life*

1) Many patients live normal lives except for the time needed for treatments.
2) People on dialysis usually have very restrictive diets to reduce the buildup of toxic wastes.
3) People on dialysis often have to make complicated travel plans.
4) People on dialysis often have disruptions to their careers & personal lives.

ISSN 2321 – 2004

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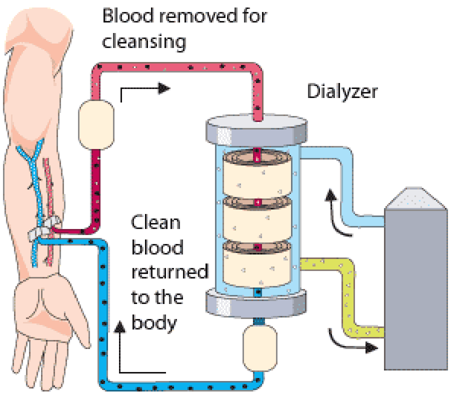


Fig 5: continuous cycling peritoneal dialysis.

*5. Implantation*

A bio-artificial tubule device was applied for the treatment of 10 acute renal failure and multiple organ failure patients by Humes et al. A bio-artificial kidney for chronic renal failure patients, however, has never been applied. In order to develop a bio-artificial kidney for preventing and treating long-term complications of maintenance dialysis patients, we have to overcome difficulties such as antithrombogenic issue of hemofilters and development of long functioning tubule devices in the context of economical and easy treatment. Continuous hemofilters should modify with an antithrombogenic material on the inner surfaces of membranes to get more hemocompatible characteristics. We are developing an antithrombogenic continuous hemofilter coating with methacryloyloxyethyl phosphorylcholine polymer which will mimic phospholipid layers of human cell membrane on the inner surface of a hemofilter. The transportability of $H_2O$, $Na^+$, and glucose of bio-artificial tubule devices using polysulfone hollow fiber modules and porcine proximal tubular epithelial cells LLC-$PK_1$ were evaluated using two kinds of circuits of different medium inside and outside of the cell-attached hollow fiber membrane. Transport of $H_2O$, $Na^+$, and glucose were significantly increased when 2.5 g/dL of albumin was added, and plateaued on the eight day and then decreased thereafter until the 13th day.

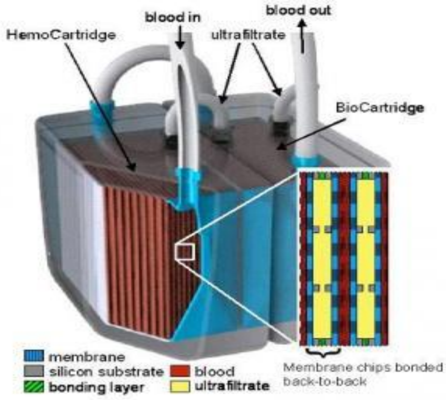


Fig 6: Portable kidney machine

## V. CONCLUSION

After studying the functions of kidney and artificial kidney, the kidneys are very important part of a human body and we got to know the various functions of kidney like excretion of water, purification of blood , hormone secretion etc., According to this report, haemodialysis is the best method for dialysis as it reduces the cost and has a better efficiency.

## ACKNOWLEDGMENT

We here by acknowledge and thank the authors listed in the references for their valuable information.

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## BIOGRAPHY

**RAGHAVENDRA**, V$^{th}$ SEMESTER STUDENT, DEPT OF INSTRUMENTATION TECHNOLOGY, RVCE, BANGALORE-59

**MALLIKARJUN**, V$^{th}$ SEMESTER STUDENT, DEPT OF INSTRUMENTATION TECHNOLOGY, RVCE, BANGALORE-59

**VIDYA M.J,** ASSISTANT PROFESSOR, DEPT OF INSTRUMENTATION TECHNOLOGY, RVCE, BANGALORE-59