الاية

Measurement of Normal Adult's Kidney Volume

Using Ultrasonography

قياس حجم الكلى للبالغين باستخدام الموجات فوق الصوتية

A thesis Submitted for Partial Fulfillment of the Requirements

M.Sc Degree in Medical Diagnostic Ultrasound

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بسم الله الرحمن الرحيم

(اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنسَانَ مَا لَمْ يَعْلَمْ (5)).

صدق الله العظيم

Dedication

To my mother god protect her, my father God rest his soul. To my husband, to my daughter Ayat, to my brother and my sister. Whom have been affected in every way possible by this quest. Thank you. My love for you all can never be quantified.

God bless you

Acknowledgements

First my gratitude goes to God who has provided all that was needed to complete this project and the program for which it was undertaken for. **Second** my appreciation also goes to my supervisor Dr. Mona Ahmed Mohamed, one of the simplest people I have met; for her patience, constant support and encouragement that has pushed me to expend the kind of efforts I have exerted to make this work as original as it can be Thanks to her I have experienced true research and my knowledge on the subject matter has been broadened. I will never forget you.

I won’t forget to thank the persons who helped me for analyzed the data Suhaib and Mohammed Mokhtar

Abstract

The renal size is a very useful diagnostic parameter in the practice of medicine, since is affected by various factors, it is necessary first to determine the normal value. This study was carried out on 50 adult patients (25 females, 25 males) who are found to be of unknown renal diseases were examined according to the age, sex & BMI, aging between 16 - 65 years, during the period from July to October, 2016 in Elehtiati Elmarkazi Hospital.

Measurement includes length, width and thickness estimation of the renal volume which is obtained by multiplying the three variables by 0.523, the factor age, sex, body mass index and right and left kidney side are statically analyzed.

The mean right kidney length is (10.16 ± 0.61cm) …. The mean right kidney width is (4.61 ± 0.30cm) …. The mean right kidney depth is (4.10 ± 0.25cm).

The mean left kidney length is (10.56 ± 0.53cm) …. The mean left kidney width is (4.83 ± 0.29cm) …. The mean left kidney depth is (4.41 ± 0.24cm).

The mean right kidney volume is (100.55 ± 12.29cm^3) and the mean left kidney volume is (116.95 ± 11.58cm^3), Length did not significantly differ between right and left. However, the kidney width in the right is smaller than the left one. The only significant factors affecting the renal volume is the sex, age, BMI and right or left side.

The study concludes that there was no relation between renal volume and BMI, also there was no relation between renal volume and age.

The volume in male (106.06, 122.39) is slightly more than in females (95.03, 111.50)… (RKV, LKV), with the left kidney volume lager than the right. The mean volume of kidney in the left side (116.95) is larger than the right one (100.55).

الملخص

حجم الكلية مهم جدا كعامل تشخيصى في مجال الطب، . بما ان حجم الكلية يتأثر بعوامل مختلفة ، فمن الضروري أولا تحديد القيمة الطبيعية. وقد أجريت هذه الدراسة على المرضى 50 من البالغين تم فحص (25 إناث و 25 ذكور) الذي وجد انهم دون اى من امراض الكلى ، تم فحصهم بناءا على العمر والجنس و بنية الجسم، واعمارهم بين 16- 65 عاما، خلال الفترة من يوليو الى اكتوبر ، 2016 في مستشفى الاحتياطى المركزى

شملت الدراسة قياس الطول والعرض والسمك لتقدير حجم الكلى التي يتم الحصول عليها عن طريق ضرب المتغيرات الثلاث فى 0.523 ، عامل السن، والجنس، ومؤشر كتلة الجسم وجانب الكلية الايمين والايسر وتحليلها بشكل ثابت.

وجدت الدراسة أن طول الكلية اليمين هو (0.61 ± 10.16سم) .... ومتوسط عرض الكلية اليمين (0.30 ± 4.61 سم) .... ومتوسط عمق الكلية اليمنى هو (0.25 ± 4.10سم). متوسط طول الكلية اليسرى (0.53 ± 10.56 سم) .... متوسط عرض الكلية اليسرى (0.29 ± 4.83سم) .... و متوسط عمق الكلية اليسرى هو (0.24cm ± 4.41سم). ووجدت أن متوسط حجم الكلية اليمنى هو (12.29 ± 100.55سم^3) و متوسط حجم الكلية اليسرى هو

(11.58± 116.95سم^3) ، و ايضا وجدت أن الطول لا يختلف كثيرا بين اليمين واليسار . ومع ذلك، فإن عرض الكلية اليمنى هو أصغر من اليسرى . العوامل المهمة الوحيدة التي تؤثر على حجم الكلى هو الجنس والعمر ومؤشر كتلة الجسم والجانب الكلية الأيمن أو الأيسر.

خلصت الدراسة الى أنه ليس هنالك علاقة بين حجم الكلية و مؤشر كتلة الجسم, و وكذلك ليست هنالك علاقة بين حجم الكلية و تقدم العمر.

و أن الحجم في الذكور (106.06، 122.39) سم^3 أكبر من الإناث (95.03، 111.50) سم^3 ... (حجم الكلية اليمنى، حجم الكلية اليسرى)، بينما في الجانب الأيسر (116.95) أكبر من الايمن (100.55) .

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List of Abbreviations

ADH antidiuretic hormone

BMI body mass index

BU blood urea

DCT Distal Convoluted Tubule

IVC inferior vena cava

LOP loop of henle

NCS nutcracker syndrome

PCT proximal convoluted tubule

RFT renal function test

RVT renal vein thrombosis

TGC time gain compensation

UG urine general

UPJ ureteropelvic junction

US ultrasound

Chapter One

Chapter one

1.1 Introduction

The kidney size of a patient is a valuable diagnostic parameter in urological and nephrological practice. While the leading anatomy text describes the adult kidney as 12 cm long, 6 cm wide and 3 cm deep (Gray, Henry, 1995), further review of the literature shows that renal size varies with age, gender, body mass index, pregnancy and co-morbid conditions. Renal size may be an indicator for the loss of kidney mass and therefore, kidney function. (Guzman RP, et al, 1994)

It is valuable in monitoring unilateral kidney disease through comparison with the other, compensatorily increased side (Yamaguchi S, et al, 1990) and for the discrimination between upper and lower urinary tract infections. (Dinkel E, et al, 1986)

Renal infections/inflammations, nephrologic disorders, diabetes mellitus and hypertension are the most important co-morbid conditions affecting renal size (Montague JP, et al, 1982) (Yamada-H, et al, 1992)

Since the renal size is affected by various factors, it is necessary to first establish the normal values. The information available may not be extrapolated to our population since the renal size may differ according to body size (Emamian Sa, et al, 1993)

While population-based studies are needed to establish the normal values for Sudanese individuals, in our study we determined the ultrasonography renal size in a group of individuals with no known renal disease and assessed the effect of age, gender, side and BMI.

1.2 Problem of the Study

The differ measurements of kidney size due to many causes either for normal or due to diseases but there is no study that shows the normal measurements of kidneys for Sudanese adults according to their body mass index, age and sex.

1.3 Objectives

1.3.1 General objective

Measurements of the kidneys volume in the normal adults person using ultrasonography.

1.3.2 Specific Objectives of the study

- To evaluate the different measurement of kidney volume between male and female
- To determine the relation between kidney volume and body mass index
- To assess the effects of age in the kidney volume
- To comparison between right and left kidney volume in individual

1.4 Overview of the study

- Chapter one: Introduction
- Chapter two: Theoretical Review
- Chapter three: Material and Method
- Chapter four: Results
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- References
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Chapter Two

Chapter Two

2.1Theoretical Review

2.1.1 Anatomy

2.1.1.1 Location and Description

The kidneys have a bean-shaped structure; they are located in the retroperitoneum, one on each side of the spinal column. Ribs extend forward and downward over the kidneys, covering the upper third of each organ. The longitudinal axes of the kidneys converge toward the spinal column at an acute angle when viewed from behind and from the side. Their transverse axes form an approximately 45° angle with the sagittal plane the right kidney. The right kidney lies posteriorly in an angle between the spinal column, musculature, and right lobe of the liver. The right hepatic lobe extends laterally to the lower third of the kidney. The kidney is covered anteriorly by the right lobe, and its lower half in particular is covered by the right colic flexure and duodenum. (Berthold Block, 2011)

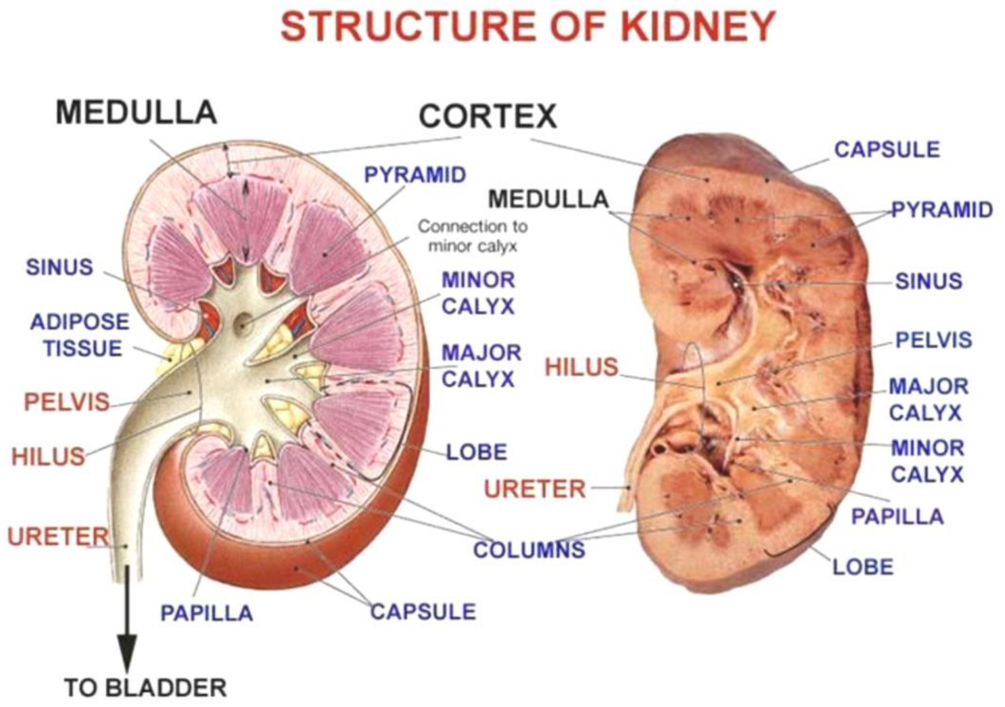

Fig (2.1) Left kidney anatomy. (Richart.S.Snell, 2005)

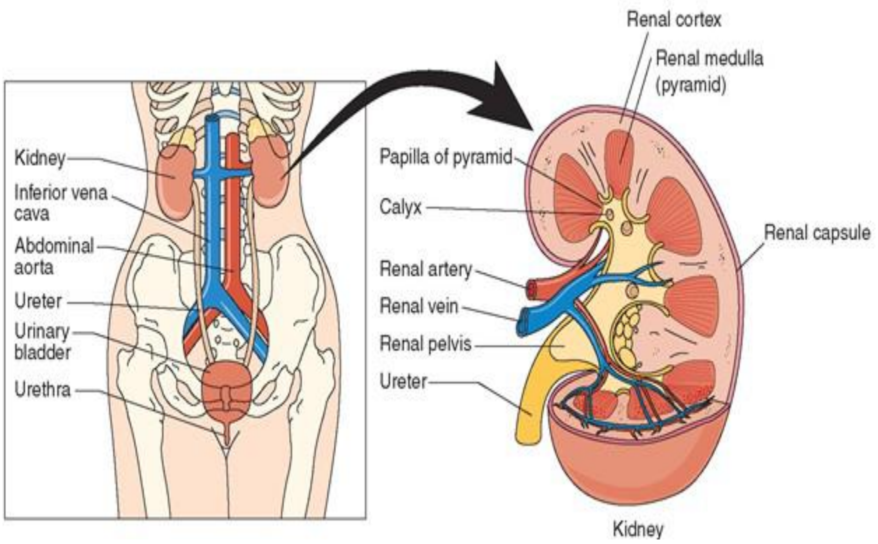

Fig (2.2) longitudinal section of the urinary system and relation with great vessels. (Richart.S.Snell, 2005)

The left kidney lies posteriorly in an angle between the spinal column, musculature, and spleen. The spleen extends laterally to about the middle of the left kidney. The lower half of the kidney is covered by the descending colon and left flexure. The left flexure passes around the anterior surface of the kidney and is in contact with it. The stomach overlies the front of the upper pole. The left kidney usually lies 1 to 2 cm higher than the right kidney. The kidneys are mobile and will move depending on body position. In the supine position, the superior pole of the left kidney is at the level of the 12^{th} thoracic vertebra, and the inferior pole is at the level of the third lumbar vertebra. The kidneys move readily with respiration; on deep inspiration, both kidneys move downward approximately 1 inch. In the adult, each kidney measures approximately 9 to 12 cm long, 5 cm wide and 2.5 cm thick and weights 120 to 170 grams. (Rumack, Carol M, et al, 2011)

2.1.1.2 Covering

The kidneys have the following coverings:

* Fibrous capsule; this surround the kidney and closely applied to its outer surface.
* Perirenal fat; it covers the fibrous capsule.
* Renal fascia; this is a condensation of connective tissue that lies outside the Perirenal fat.
* Pararenal fat; lie external to renal fascia and is often in the large quantity renal fat, perirenal fat. It supports the kidney and hold it in position. (Richart.S.Snell, 2005)

2.1.1.3 Renal Structure

Each kidney has a dark brown outer cortex and a light brown medulla. The medulla is composed of about 10 conical structures known as renal pyramids; each having its base facing towards the cortex and its apex is The renal papilla projecting medially, the cortex extends into the medulla between adjacent pyramids as the renal columns. The renal sinus, which is the space within the hilum, contains the upper expanded end of the ureter, the renal pelvis. This divided into two or three major calyces, each of which divided into two or three minor calyces. Each minor calyx is intended by apex of the renal pyramids, the renal papilla. (Richart.S.Snell, 2005)

2.1.1.4 Relationships

Anterior to the right kidney are the right adrenal gland, liver, Morison's pouch, second part of the duodenum, and right colic flexure. Anterior to the left kidney are the left adrenal gland, spleen, stomach, pancreas, left colic flexure, and coils of jejunum.

Posterior to the right kidney are the diaphragm, costodiaphragmatic recess of the pleura, twelfth rib, psoas muscle, quadrates lumborum, and transverses abdominis muscles. The subcostal (T12), iliohypogastric, and ilioinguinal (L1) nerves run downward and laterally.

Posterior to the left kidney are the diaphragm, costodiaphragmatic recess of the pleura, eleventh and twelve ribs, psoas muscle, quadrates lumborum, and transverses abdominis muscles. The same nerves are seen near the left kidney as in the right. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.1.5 Vascular Supply and innervations of the Kidney

2.1.1.5.1 Renal Artery

One of the pair of large blood vessels that branch off from the abdominal aorta (the abdominal portion of the major artery leading from the heart) and enter into each kidney. (The kidneys are two bean-shaped organs that remove waste substances from the blood and aid in fluid conservation and in stabilization of the chemical composition of the blood.) At the inner concavity of each kidney there is an opening, known as the hilum, through which the renal artery passes. After passing through the hilum, the renal artery divides ordinarily into two large branches, and each branch divides into five. (Richart.S.Snell, 2005)

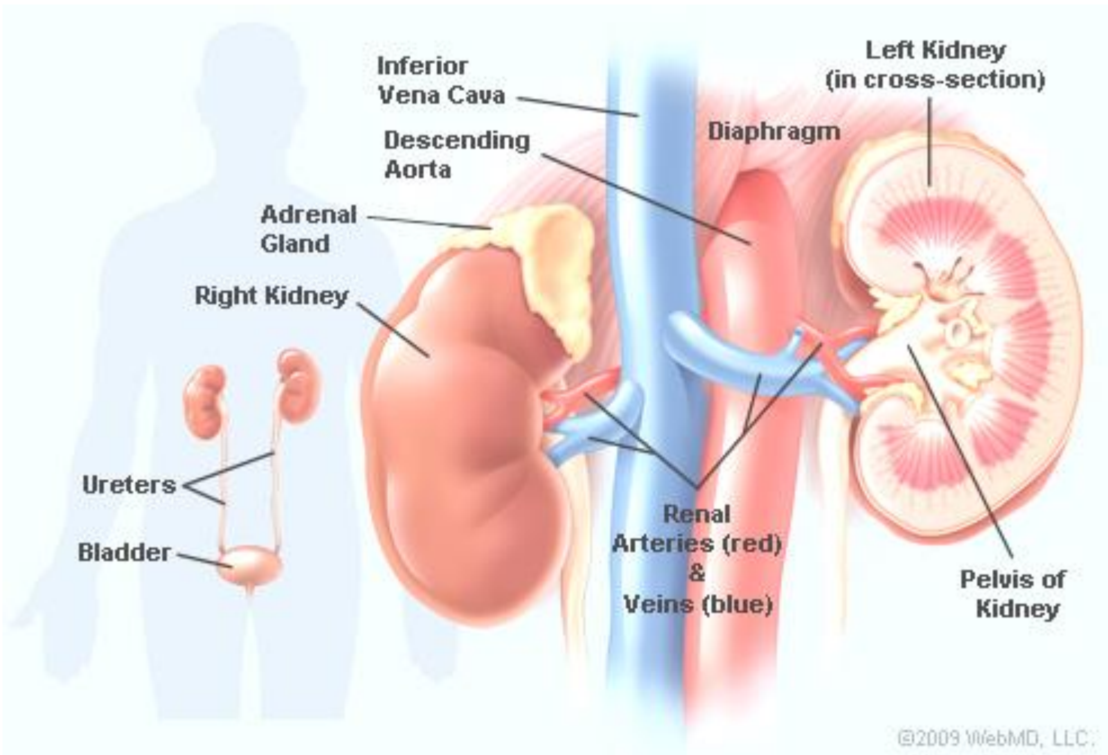

Fig (2. 3) shows longitudinal section of the urinary system and relation with great vessels. (http://www.medicinenet.com/image-collection/kidneys_picture/picture.htm, 2009)

2.1.1.5.2 Renal Vein

There are two renal veins, a left and a right. They branch off of the inferior vena cava and drain deoxygenated blood from the kidneys. As it enters the kidneys, each vein separates into two parts, each branch connects to a certain location. The posterior vein assists in draining the posterior section of the kidney, while the anterior assists the anterior part. These veins also are responsible for draining blood from the ureter, which moves urine away from the kidneys to the urinary bladder. These veins should not be confused with the renal aorta. Unlike veins, the renal aorta delivers oxygenated blood to the kidneys. To simplify, aorta carry blood to the kidneys while veins move the blood away. There are two main diseases often associated with renal veins. If a clot or a thrombus develops, a condition called renal vein thrombosis (RVT) results, symptoms include a diminished flow of urine while urine volume stays consistent. Treatment would require either anticoagulants and/or clot-removing surgery. Another issue includes nutcracker syndrome (NCS), which involves the one of the renal veins becoming compressed between abdominal aorta and the superior mesenteric artery. (Richart.S.Snell, 2005)

2.1.1.5.3 Lymphatic Vessels of the Kidney

Renal lymphatic plexuses among the tubules in both cortex and medulla are arranged around the blood vessels, especially the veins.

Lymphatic vessels run from the plexuses into a dense basal network over the base of the pyramids, where the channels from the cortex join with those from the medulla to reach the region of the calyceal fornix (From there, the lymphatics run with the blood vessels around the calyceal necks to the renal sinus, where they empty into several large valved collectors lying on the surface of the pelvis and accompany the renal vein out of the hilum to terminate in a few nodes along the renal vessels and in the aortic nodes. (Tarig Hakim, 2008)

2.1.1.5.4 Innervations of the kidney

A very large number of autonomic nerves, primarily with vasomotor activity, come from wide spread sources to a focus in the renal plexus. Four to eight renal branches arise from the celiac plexus on each side and, at first, run cephalad to the renal vessels and then pass ventral to them as the nerves approach the renal plexus and least splenic nerves provide nerve supply to the kidney, usually indirectly, partly via the aortorenal ganglion and partly through the celiac ganglion. Branches to the renal plexus also arise from the second lumbar sympathetic ganglion and run directly to the kidney or by way of the posterior renal ganglion. Other branches come from the upper parts of the aortic plexus.

Finally, branches pass from the lower part of the aortic plexus to the renal plexus, with or without communication with the superior hypogastric plexus. (Tarig Hakim, 2008)

2.1.1.6 Histology

Renal histology studies the structure of the kidney as viewed under a microscope. The functional renal unit is the nephron, which is composed of the following various distinct cell types occur in the kidney, including

- The renal corpuscle: glomerulus and Bowman capsule
- Proximal convoluted tubules (PCT, located in the renal cortex)
- Descending loop of Henle (LOH)
- Ascending limb (which resides in the renal medulla, leading to the thick ascending limb)
- Thick ascending limb
- Distal convoluted tubule (DCT)

- Collecting duct (which opens into the renal papilla). (Richart.S.Snell, 2005).

2.1.1.7 Embryology

Three sets of kidneys develop in human embryos: the pronephros, mesonephros and metanephros (definitive or permanent kidney). The pronephroi appear early in the fourth embryologic week and are rudimentary and nonfunctioning. The mesonephroi form late in the fourth week and function as interim kidneys until the developing metanephroi begin to function (ninth week). The metanephroi (permanent kidneys) develop from two sources: the ureteric bud and metanephrogenic blastema. The ureteric bud forms the ureter, renal pelvis, calices, and collecting ducts, interacting with and penetrating the metanephrogenic blastema. This interaction is necessary to initiate ureteric bud branching and differentiation of nephrons within the blastema. Initially, the permanent kidneys are found in the pelvis. With fetal growth, the kidneys come to lie in the upper retroperitoneum. With ascent, the kidneys rotate medially 90 degrees so that the renal pelvis is directed anteromedially. The kidneys are in their adult location and position by the ninth gestational week. As the kidneys ascend, they derive their blood supply from nearby vessels; adult blood supply is from the abdominal aorta. (Rumack, Carol M, et al, 2011)

2.1.1.8 Normal variants

Renal variants include slight alterations in anatomy that may lead the sonographer to suspect an abnormality is present when it really is a normal variation.

2.1.1.8.1 Columns of Bertin

The columns of Bertin are prominent invaginations of the cortex located at varying depths within the medullary substance of the kidneys. Hypertrophied columns of Bertin contain renal pyramids and may be difficult to differentiate from a vascular renal neoplasm. The columns are most exaggerated in patients with complete or partial duplication.

2.1.1.8.2 Dromedary Hump

A dromedary hump is a bulge of cortical tissue on the lateral surface of a kidney (usually the left), resembling the hump of a dromedary camel. It is seen in persons whose spleen or liver presses down. It is a normal variant but may resemble a renal neoplasm. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.1.8.3 Junctional Parenchymal Defect

A junctional parenchymal defect is a triangular, echogenic area typically located anteriorly and superiorly. It is a result of partial fusion of two embryonic parenchymal masses called renunculi during normal development. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.1.8.4 Fetal Lobulation

Fetal lobulation is developmental variation that is usually present in children up to 5 years old, and may be persistent in up to 51% of adults. The surfaces of the kidneys are generally indented in between the calyces, giving the kidneys a slightly lobulated appearance. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.1.8.5 Sinus Lipomatosis

Sinus lipomatosis is a condition characterized by deposition of a moderate amount of fat in the renal sinus with parenchymal atrophy. In sinus lipomatosis, the abundant fibrous tissue may cause enlargement of the sinus region with increased echogenicity and regression toward the center of the parenchymal. Occasionally, a fatty mass is localized in only one area; this is called lipomatosis circum scripta. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.1.8.6 Extrarenal Pelvis

The normal renal pelvis is a triangular structure. Its axis points inferiorly and medially. The intrarenal pelvis lies almost completely within the confines of the central renal sinus. This is usually small and foreshortened. The extrarenal pelvis tends to be larger with long major calyces. (Ansert, Sandra L. Hagen, et al, 2012)

2.1.2 Physiology

The kidneys play a major role in the control of the internal environment The blood flowing in the kidney is first filtered by the glomerulus, so that all the blood constituents, except blood cells and plasma protein, go into the microtubular system, in these tubules, filtration take place so that useful substances, including most of filtrate water, are quickly reabsorbed (tubular reabsorption) back into the blood unwanted substances that escaped filtration are actively secreted into tubular lumen (tubular secretion) the final concentration of electrolytes and other constituents of urine is adjusted according the requirement of the regulation of extra cellular fluid composition.

Glomerulur filtration, tubular reabsorption, and tubular secretion are rightly described as renal mechanism that allows the kidney to undertake its various homeostatic functions. Several hormones especially anti diuretic hormones act on the kidney to enable it to adjust the final composition of the urine in response to internal environment. (Tarig Hakim, 2008)

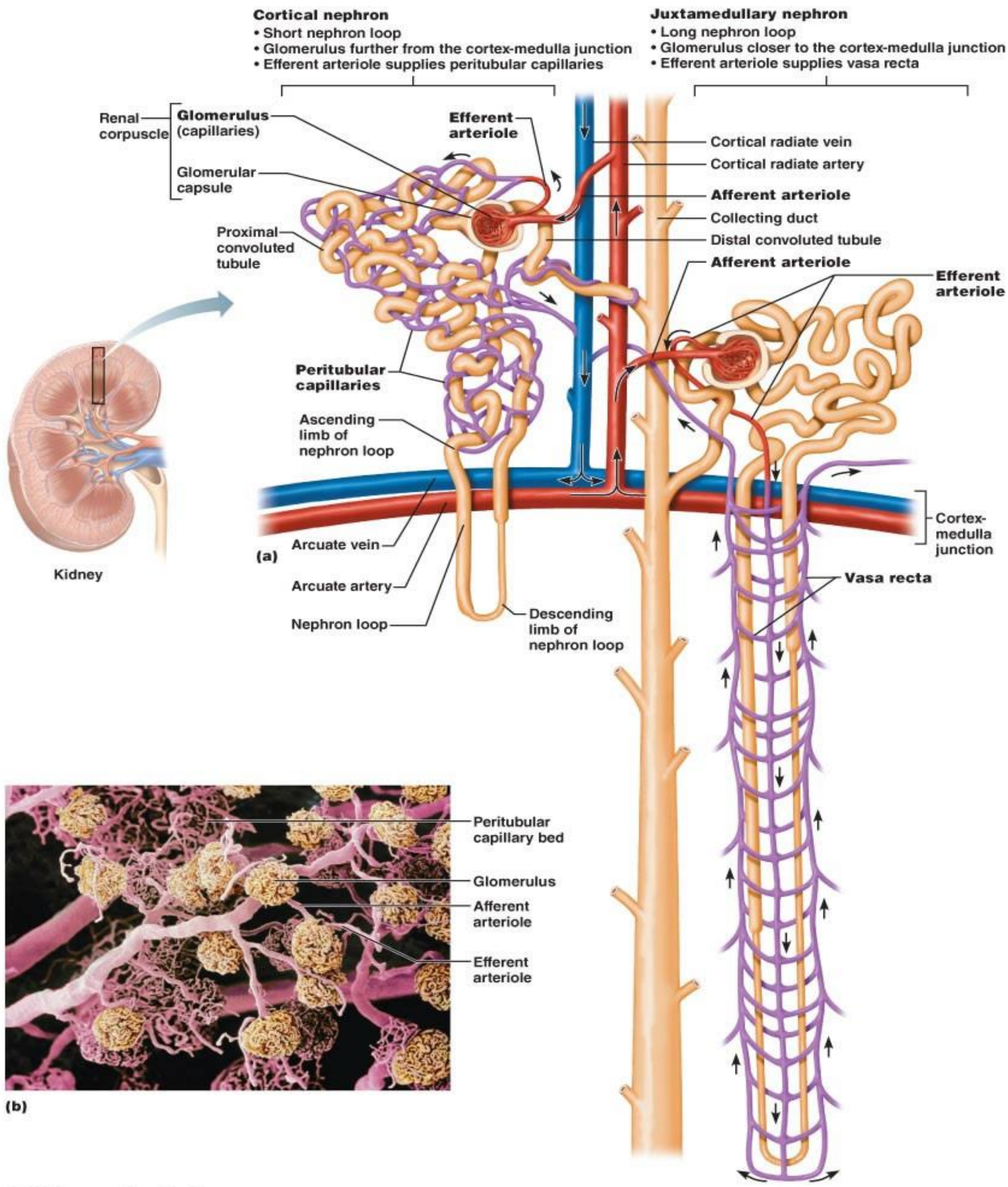

Fig (2.4) shows the nephron.

(http://classes.midlandstech.edu/carterp/Courses/bio211/chap25/chap25.htm, 2013)

2.1.2.1 The nephron

Are the functioning unites of the kidney, there are about 1.3 million nephrons in each kidney the glomerulus is a tuft of capillaries covered by fibrous capsule (Bowman s capsule). It s supplied by afferent arterioles and drainage efferent, its diameter is about 200um and its function is filtration. All glomeruli are found in the cortex, most of them are located in the juxtaposition to the medulla, and accordingly there are two types of nephrones: Cortical nephrons: is about 28% of all nephrons, their glomeruli are found higher up in the cortex, and characterized by short loop of henle. Juxtamedullary nephrons: about 15% of all nephrons, their glomeruli are located close to the medulla, and characterized by long loop of henle. They play important role in concentration of urine. The tubules are specialized for reabsorption and secretion, they include: proximal convoluted tubule, loop of henle, distal convoluted tubule, and collecting duct. (Tarig Hakim, 2008)

2.1.2.2 Function of the kidneys

The removal from the body of waste products of protein metabolism, such as urea uric acid, creatinine , phosphates and sulpher, Control of extra cellular fluid (by excretion of more or less water in the urine), Control of extra cellular fluid electrolytes (by regulation of electrolyte excretion in the urine), Control of extra cellular fluid osmolarity by regulation of sodium and water excretion), The maintenance of acid-base balance by the body (control of pH), The removal of toxic substances and drugs from the body, Metabolic functions including the maintenance of blood pressure (long term effect), red blood cell production and calcium metabolism and Endocrine function: synthesis and secretion of erythropoietin - activation of vitamin D - and release of refine enzyme.

The kidneys perform the first four of these functions by the production of urine. The urine consists mainly of water and contains urea, uric acid,

creatinine, sodium chloride, potassium, calcium, phosphates and sulphate. Normally 1-2 liter of urine is produced per day. The volume depends upon the fluid intake and 13 the amounts of fluid lost by sweating and in the stool. (Tarig Hakim, 2008)

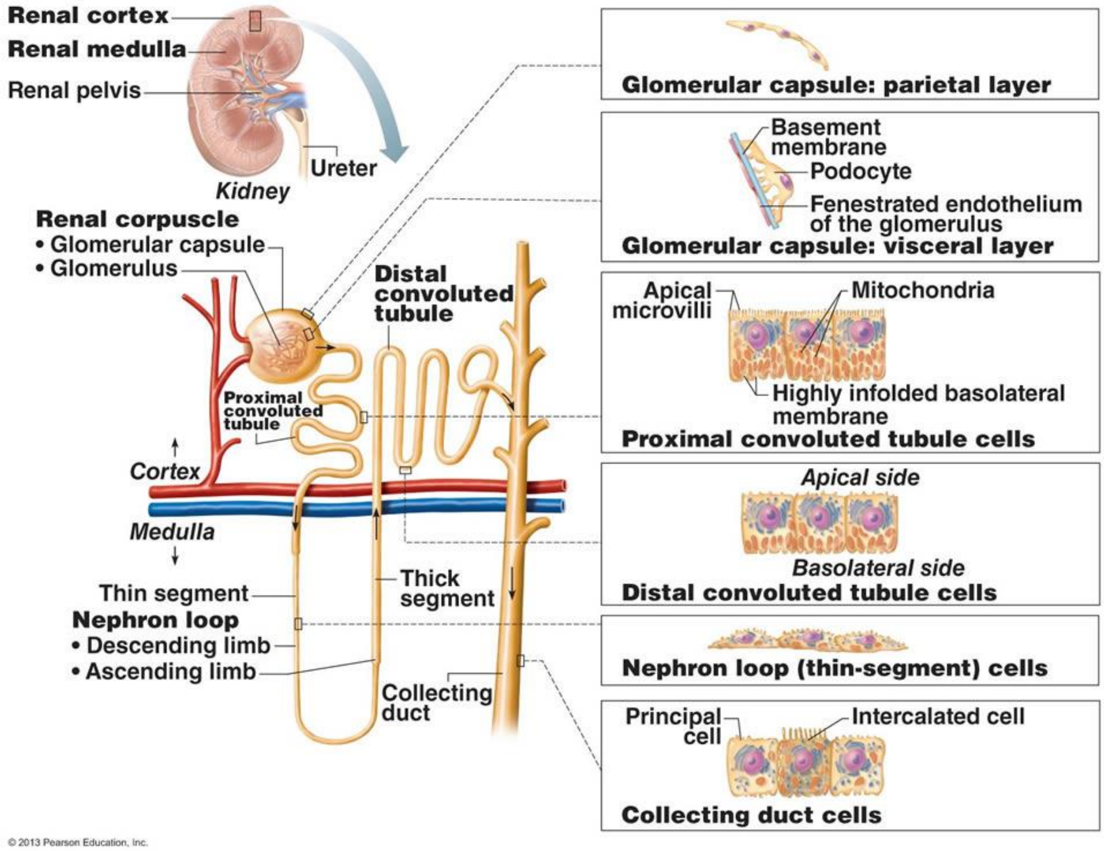

Fig (2.5) shows the histology of the renal unit

(http://classes.midlandstech.edu/carterp/Courses/bio211/chap25/chap25.htm, 2013)

The kidneys perform the first four of these functions by the production of urine. The urine consists mainly of water and contains urea, uric acid, creatinine, sodium chloride, potassium, calcium, phosphates and sulphate, normally 1-2 liter of urine is produced per day. The volume depends upon the fluid intake and the amounts of fluid lost by sweating

and in the stool, increased fluid loss due to increased sweat production or gastro intestinal losses diarrhea & vomiting. (Tarig Hakim, 2008)

2.1.2.3 Renal blood flow

The renal blood flow is 1-2 liter per minute this is about 20-25 % of the cardiac output; its directed mainly to the cortex (90% to the cortex and 10% to the medulla. This low blood flow to the medulla maintains its high osmolarity. The renal blood flow is autoregulated (i.e. it is maintained constant in spite of the change in main arterial pressure between 80-180 mmHg) this is due to myogenic response or hormonal factors (e.g. angiotensin). (Tarig Hakim, 2008)

2.1.2.4 Glomerulus filtration

It is the transportation of fluid and crystalloid from glomerular capillaries to bowman space. The blood entering the glomeruli is under high pressure and, at rest, up to 25% of the cardiac output flows through the kidneys, the fluid filtered in to the Bowman's capsule is plasma minus the plasma protein and cells. The fluid filtered at the glomerulus is altered during its passage down the tubules by removal of some of its constituents and by the addition of some others. The processes involved are, respectively, reabsorption and secretion .Thus the fluid which enters the ureter is very different in composition from that which was filtered at the glomerulus. By the processes of reabsorption and the secretion the composition of the extra cellular fluid is kept constant. (Sukkar, 2000)

2.1.2.5 Reabsorption

Some of the constituents of the fluid which is filtered at the glomerulus are reabsorbed into the blood stream. This process may be active or passive, active transport requiring energy expenditure. For example, 19

Glucose is present in the glomerular filtrate but is normally absent from the urine. The glucose is completely reabsorbed from the glomerular

filtrate and returned to the blood stream by the action of the cells of the proximal convoluted tubule, i.e. it is actively reabsorbed .Urea on the other hand, passes out of the tubule back in to the blood by diffusion, i.e. it is passively reabsorbed. Sodium chloride is actively and virtually completely reabsorbed by the renal tubule, the reabsorption in the distal tubule occurring under the control of aldosterone.

Approximately 5-6 liters of fluids are filtered at the glomerulus in each hour, but only 1-2 liters of urine are produced every 24 hours. Therefore nearly all the water filtered must be reabsorbed from the renal tubules.

The reabsorption of water occurs at such a rate as to keep the osmotic pressure (osmolality) of the body fluids constant. The rate of reabsorption of water from the tubule is controlled by the secretion of Antidiuretic hormone (ADH) from the posterior pituitary gland. The loop of henle dips deep in to the medulla of kidney, where there is a high osmotic pressure due to active transport of sodium out of the tubule at the point. ADH is increases the permeability of water to distal tubular cells and the cells lining the collecting ducts, water therefore passes in to the area of high osmotic pressure i.e. out of the renal tubule. (Sukkar, 2000)

2.1.2.6 Secretion

The cells of the tubules remove potassium and hydrogen ion from the venous blood and secrete them in to the tubules; the secretion of the hydrogen ions into the tubules causes the production of acid urine. Since Metabolic processes generate a great deal of hydrogen ions i.e. acidity, this function of the kidney is very important in maintaining the correct PH of extracellular fluids. Tubular secretion is the method by which the kidney rids the body of drugs such as penicillin. (Tarig Hakim, 2008)

2.1.2.7 The Kidney and the production of red blood corpuscles

The kidney is the main sources of the hormone Erythropoietin, which increases the rate of red cell production, patients with renal failure are anemic and patients with renal cell carcinoma have an increased number of thread cells.

2.1.2.8 The kidneys and the blood pressure

Cells in the region of the glomerulus produce an enzyme rennin, which converts angiotensin2 in the blood to angiotensinl. A further enzyme causes the production of angiotensin2 from angiotensin1 .Angiotensin2 is powerful constrictor of blood vessels and arises the arterial blood pressure by this action, it also stimulates the production of aldosterone, the sodium retaining hormone from the zonaglomerulosa of the adrenal cortex. The secretion of rennin is stimulated by a fall in the blood pressure within the kidney or by a fall in the plasma sodium concentration. (Tarig Hakim, 2008)

2.1.2.9 The Kidney and calcium metabolism

The kidney is the site of formation of 1, 25.dihydroxycholecalciferol the most active of vitamin D, the most important of this renal metabolite is to increase calcium absorption from the intestine especially to meet the demands of growth, pregnancy and location. (Tarig Hakim, 2008)

2.1.2.10 Renal clearance

Defined as the volume of plasma, which is completely cleared of substance perunite time. The efficiency of the glomerulus may be investigated by studying the clearance of creatinine, a product of protein metabolism. Creatinine is filtered at the glomerulus and is then neither reabsorbed from nor secreted into renal tubule. Certain other substances such as the radiological contrast are not only filtered but are also secreted

Into the tubules. The high iodine content of these drugs makes them radio-opaque and this allows them to be used to visualize the renal tract on radiographs. The clearance of such substances is equal to the renal blood flow. So it can be used for Measurement of glomerular filtration, Measurement of renal blood flow and Assessment of renal function.

(Tarig Hakim, 2008)

2.1.3 Pathology

Approximately 10% of individuals have congenital abnormality of the urinary tract, some are hereditary. Congenital renal diseases may be malformation related to the volume of renal tissue formed or its differentiation. Anatomical abnormalities of position of vascular or ureteric connections. Metabolic lesions such as enzyme defects which affect tubular transport.

2.1.3.1 Congenital megacalices

Congenital megacalices develop as result of an abnormality in the number and timing of divisions in the ureteral bud. Calices are increases in size and number and medullary thickness is decreased, whereas cortical thickness is normal, except in mild reduction in concentration ability. However, patients may develop stones and infection as a result of stasis. The sonographic appearance of large, clubbed calices extending into medullary region may mimic hydronephrosis or renal papillary necrosis, contrast radiography and clinical finding will help differentiate between these entities. (David Sutton, 2002)

2.1.3.2 Uretropelvic junction obstruction

Uretropelvic junction obstruction is a common congenital anomaly that rarely result in renal failure, unless it is sever or bilateral. In many cases, UPJ obstruction may go undiagnosed until adulthood even if discovered late, surgical repair may preserve renal function. Other genitourinary tract anomalies are frequently associated with PUJ obstruction, particularly a contralateral multicystic dysplastic kidney.

Sonographically: early in life show pelvocalectasis with an abrupt cut off of the pelvis dilation at the PUJ. Long standing cases detected in adults may present as a cystic mass without discemable renal parenchyma. In some cases differentiation of severe long standing PUJ obstruction from multicystic dysplastic kidney may impossible. (David Sutton, 2002)

2.1.3.3 Bilateral agenesis of the kidney Patter Syndrome

Is not compatible with independent life, it occurs in 0.04% of all pregnancies. Children with this condition have characteristic appearance low set ears; there is always a reduced volume of amniotic fluid due to absent of fetal urine. The most likely cause is a failure of the ureteric bud to develop; there are developments abnormalities also of other tissues derived from the mesonephrous, e, g bladder and genetelia, however, the commonly associated spinal cord abnormalities and pulmonary hyperplasia suggest that the defect is more generalized. Unilateral agenesis of a kidney undergoes marked hypertrophy and is subsequently prone to infections and trauma. Children with this condition often do not survive long because of associated multiple developmental abnormalities, including congenital heart disease, spina bifida and menengomyocele. In renal hyperplasia the kidney is abnormally small but not otherwise malformed. Hypoplastic kidneys are prone to infection or stone formation. (David Sutton, 2002)

2.1.3.4 Disorders of differentiation

Renal dysplasia is a cause of cystic kidney which may present in child hood as an abdominal mass requiring surgical excision if only to exclude malignant tumor (e.g.Nephroplastoma). The lesion is characterized by islands of undifferentiated mesenchyme or cartilage within the parenchyma, if the lesion is unilateral the prognosis is good.

2.1.3.5 Anatomical abnormalities

Ectopic kidney forms in an abnormal site, usually the pelvis, and may be associated with intestinal mairotation. The principal clinical importance lies in their presenting as a suspicious pelvic mass, and in the risk of infection due to the ureteric kinking that often comprises this condition. Horse shoe kidney results from fusion of the two nephrogenic blastomas during fetal life the majority are fused at the lower pole. The condition is not rare and renal function is usually normal, there may be a susceptibility to infection and stone formation, the duplication of vessels or ureters is not uncommon, achieving clinical significance either when an anomalous polar artery passing anterior to the ureter causes ureteric obstruction or during renal transplantation.

2.1.3.6 Metabolic malformation

Cyst in urea results from defective tubular reabsorption of several amino acids including cystine , lysine , ornithine and arginine the precise enzyme defect is unknown but some patient also have impaired intestinal transport cystine crystal are found in the urine and calculi may develop the disease is inherited as an autosomal recessive.

Renal tubular acidosis type (1) is probably due to a defect in the enzyme system which enables hydrogen ions to be exchanged for bicarbonate in the proximal tubule, there is loss of bicarbonate and failure to acidity and concentrate the urine, renal function is otherwise but there is a tendency to form stones and develop infections this condition is inherited as autosomal dominant gene, although an identical deficiency may be acquired as a result of tubular damage. Abnormalities in the kidney that can be detected by sonography include parenchyma or medical disease, obstructive uropathy, space, occupying lesions and renal vein thrombosis, abnormalities for size, shape and position are easily detected. Renal agenesis is suspected after through search in the abdomen and pelvic for ectopic organ, Duplication and mairotation can be shown. (David Sutton, 2002)

2.1.3.7 Space occupying lesions

Ultrasound is most common investigation performed to diagnosis masses suspected in sonographic examination. Its accuracy in detecting cystic versus solid lesions is nearly 100%.

2.1.3.8 Renal cysts and cystic disease

A simple and benign cyst is thin, walled and anechoic with distal enhancement. Cyst may be cortical or central in passion, when central they should be differentiated by their discrete shadow as compared to confluent shadows of hydronephrosis in poly cystic disease, the cyst are multiple and the kidney is large, there is often similar involvement of the liver, spleen, or pancreas. The symptoms of this abnormality usually renal failure do not develop before middle age. Medullary cystic disease is an autosomal recessive disease that remains silent until renal failure, cyst is confined to medulla and the kidney is small, Dysplastic multi cystic disease. Is unilateral the affected kidney in non functioning and there for bilateral disease is fatal, Hemorrhagic cyst and hematomas show both echo free and echogenic features with debris, fluid level.

2.1.3.9 Renal abscess

Has variable echogenicity, generally hypoechoic with internal echoes there may be gas pocket within the abscess causing distal shadows. The development of renal or perinal abscess is an uncommon complication of renal infection.

2.1.3.10 Renal mass

Renal cell carcinoma willims tumor and transitional cell carcinoma gives focal lesions lymphomas and leukemic infiltration, generalized enlargement of the kidney with an increase in echogenicity and diminished pelvicaliceal shadows.

2.1.3.11 Diffuse parenchymal lesion and renal failure

Small kidneys with parenchymal abnormalities occur in echogenic glomerulonephritis, chronic pyelonephritis and renal vascular disease. Renal failure due to mechanical renal disease increase the cortical echogenisity to level similar to or higher than those of adjacent liver or spleen, both acute and chronic glormerulonephritis give higher echogenicieties the later is characterized by small kidney loss of corticomedulary differentiation.

2.1.3.12 Hydronephrosis

Is the separation of renal sinus echoes by interconnected fluid filled areas. In patient with progressive obstruction the renal parenchyma is compressed. If the hydronephrosis is suspected, on the ultrasound we should evaluate the bladder. If it's full, post void longitudinal scan of each kidney should be done to show that hydronephrosis has disappeared or remained the same; at the level of the obstruction we should sweep the transducer back and forth, in two planes to see if a mass or stone can be distinguished. There are three grades of hydronephrosis grade 1 entails small separation of the calceal pattern, also known as splaying. So we have to rule out a Parapelvic cyst The septation may be numerous or renal vessels in the Parapelvic area color flow is extremely useful. An extrarenal pelvis would protrude outside of the renal area, so we would not confuse this pattern probably with hydronephrosis. (David Sutton, 2002)

2.1.4 Physics and equipment

2.1.4.1 Understanding the physics behind the use of US

US waves are a form of sound waves. Its frequencies exceed the upper limit of audible human hearing. Medical US frequencies are in the range of 1-20 MHz. Each US wave is characterized by a specific frequency and wavelength, which are inversely related (2.6). Frequency is the number of cycles per second and is measured in Hertz.

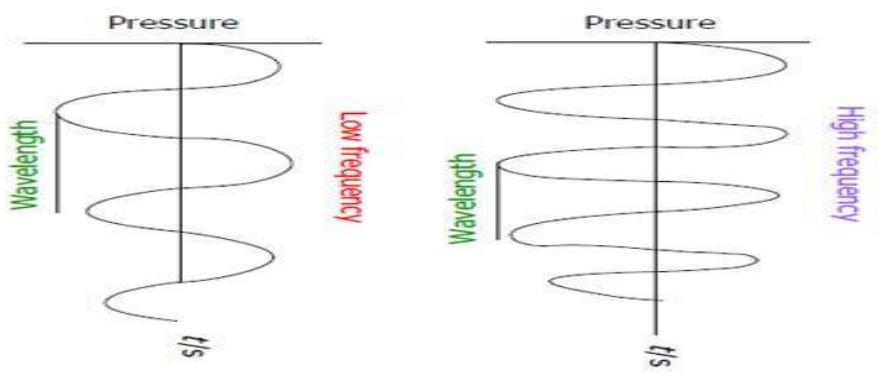

Fig (2.6) Ultrasound waveform. (Shanthanna H, 2014)

Wavelength is the distance between two consecutive, similar positions in the pressure wave. It is determined by the frequency of the wave, and the speed of propagation in the medium it is passing through. Actually the speed of sound is different based on the tissues through which it propagates. However it is averaged as approximately 1540 m/s for the entire body and is referred to as propagation velocity or acoustic velocity

The US waves are produced by piezoelectric effect, which was discovered by Curie brothers in 1880. It involves the generation of an electrical charge, by a piezoelectric material, when subjected to mechanical stress and the reverse piezoelectric effect involves such an electrical charge being converted to mechanical vibration. In the available US machines the transducer holding the piezoelectric material acts both as a generator and receiver of such signals. US used in medical imaging are referred to as B-mode (2D), meaning brightness mode display. This means the brightness of the pixel on the image is a representation of the strength of reflection. A source of alternating current makes the piezoelectric crystals to vibrate at high frequency producing US waves. This is then transmitted to the patient through a conductive gel. (Shanthanna H, 2014)

2.1.4.2 US equipment

Medical US utilizes a transducer attached to a display monitor which also holds the operating console. A transducer (also known as probe) contains a damping material, piezoelectric crystals, a matching layer and a protective layer (2.6). Each crystal is isolated and hence transmits its own US wave. The damping layer, present just behind the crystals acts to reduce their resonance so that they are sensitive to the returning signal. The matching layer in front acts to reduce the impedance mismatch and is covered by a protective layer.

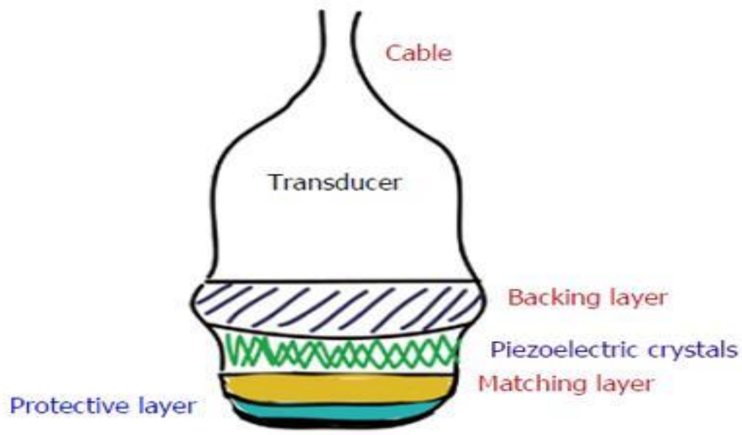

Fig (2.7) Typical transducer. (Shanthanna H, 2014)

There are several types of transducers and it is necessary to choose the right one for the procedure. Some others give 3 varieties, based on the range: high- (8-12 MHz), medium- (6-10 MHz), and low- (2-5 MHz). The smaller one with a straight contact surface is called a linear array transducer due to the linear arrangement of crystals. It also produces high frequency waves in the range of 8-12 MHz. Its penetration, and hence resolution is usually good for structures within 3-4 cm. The larger one with a curved contact surface is called a curved array or curvilinear

transducer because of the curved arrangement of crystals. It creates a wedge shaped US beam and produces a much broader view with the image of deeper structures being wider than the footprint of the probe. It is used to visualise deeper structures, beyond 4 cm. It is important to know that the width of the image is equal to the probe footprint size only at the uppermost part of the image and hence any determination of depth is tricky. (Shanthanna H, 2014)

2.1.4.3 US tissue interaction

Once generated the wave passes through various tissue structures and thereby interacts with them. US waves are primarily influenced by physical changes involving reflection, refraction and attenuation. The reflected wave, which gives rise to the resulting signal, is dependent upon the underlying structures the waves encounter. This property is called acoustic impedance. It is unique to each tissue type and is defined as the density of the medium times the velocity of US wave transmitted through it. Less dense organs such as lungs have lower impedance in contrast to bones which would have higher impedance. The greater the differences in acoustic impedance between 2 adjacent tissues, more waves are reflected back. So it is not individual acoustic impedances but the relative difference of it among adjacent tissues that control the amount of energy reflected back.

Specular reflection involves a large smooth surface, such as a needle. Depending upon the incident angle, a large amount of US waves is reflected back to the transducer. Scattered reflection involves an irregular surface giving rise to scattering and hence loss of signal. Refraction involves changes in the direction of US waves due to an interface of tissues with different speeds of sound transmission. It is related to the depth of beam penetration. (Shanthanna H, 2014)

2.1.4.4 Understanding the controls and improving the image quality

A good use of US guidance can only be made when one understands how to operate the equipment and also how to modify the variables to get the best possible image. The following section gives an understanding of these elements.

Resolution: It describes the ability to separately identify to individual structures. Axial resolution refers to the possible differentiation between the 2 objects in the plane of US beam. Higher frequencies and superficial structures give better axial resolution. Temporal resolution refers to the rate at which consecutive images are visualised. It depends on the frame rate or pulses. A transducer emits the next pulse only after it has received the previous pulse. Increasing the depth of US beam affects the temporal resolution. Similarly, using Doppler has the same effect as it requires more time to process the incoming signals and hence lower temporal resolution. Lateral resolution refers to separation of structures lying side by side. Inappropriate use of focus zone-as explained below can decrease the lateral resolution. Contrast resolution is referred to the optimal visualisation achieved in terms of hyper and hypoechogenic structures displayed on the screen. To enhance visualisation and to improve resolution there are 3 important settings which can be altered.

Gain: This simply refers to the strength of the signal. The brightness of the image is proportional to the strength of the signal received by the transducer.

Focus: The sound waves converge to a point called focal zone and then diverge. The divergence of these waves beyond the focal zone can allow for missed information in a horizontal plane. To minimise this loss, it is important to set the focal zone at the same level as the target of interest.

Time gain compensation: As the name suggests there is an increase in gain (signal strength) which is restricted to a set field of depth. Attenuation increases with increasing depth. To compensate for this time gain compensation (TGC) allows for stepwise increase in gain which can be adjusted for a particular depth.

Frequency: Waves of higher frequency are more attenuated. One should choose a higher frequency probe for superficial structures, and low frequency probe for deeper structures.

Color Doppler : This function helps to detect structures with movement, like blood flow. It is based on the doppler principle. Structures moving away from the probe appear blue and those towards the probe appear red. One important thing to remember is that the angle of incidence should be as less as possible. With an angle of incidence of 90°, no flow is detected and might provide a false negative implication. To help visualise even smaller vessels and also to be independent of the incident angle, newer machines have power Doppler. (Shanthanna H, 2014)

2.1.4.5 Artifacts associated with US imaging

The image produced on the monitor is a 2 dimensional image obtained from converting mechanical energy into electrical signals. The actual conversion of signals into images involves several assumptions on the part of equipment’s software. These give rise to artifacts: could be a distortion in the image brightness, duplication, absence of echoes, etc. Commonly understood artifacts are described below.

Acoustic shadowing: This happens when a superficial structure has greater attenuation coefficient than the structures deep to it. Due to this the underlying structure appears less echogenic than normal.

Posterior acoustic enhancement: This is almost the opposite of shadowing. Due to the presence of a less attenuating structure superficially, the region behind that structure produces stronger echoes than the surrounding structures.

Reverberation: It is the multiple representation of the same structure at different depths of display. It is usually caused by a specular reflector such as a needle. It reflects a strong signal back to the tranducer, some of which is again reflected back to cause a repeat of the shadow at a different depth, because of the time delay involved.

Mirror image: It is a type of reverberation artifact, commonly produced due to a significant mismatch in the acoustic impedance between 2 adjacent structures such as air-bone, soft tissue-lung etc. appears in all modes including doppler.

Refraction: This is also called as bayonet effect. This appears as a subtle bend in the length of the needle due to refraction.

Dealing with artifacts: (1) Have a high degree of suspicion; (2) Confirm in 2 views, longitudinal and cross-sectional; (3) Change the position of transducer-move proximal or distal; (4) Reduce gain; and (5) Move the patient. (Shanthanna H, 2014)

2.1.5 Ultrasonography of the Kidney and techniques

Ultrasonography is used for anatomy, intra venous urography for anatomy and function, and nuclear medicine for function. Evaluation the kidney with u/s is noninvasive approach. It delineates retroperitoneal masses or fluid collection such as hematomas or abscesses, it's also rules out the hydronephrosis and fluid filled structure like cysts. It determines the renal size and parenchymal details, detect also upper ureter and renal congenital abnormalities. (B.Breyer; et al, 1995), (Gratton, Denis, 2005)

2.1.5.1 Patient Preparation

Patient fasting six hours prior exam with drinking water to fill the bladder before examination. When the patient is over hydrated, the internal collecting system will become distended but if the patient is dehydrated renal pelvic will be collapsed. (Gratton, Denis, 2005)

2.1.5.2 Patient Position

The examination begins with the patient in the supine position or decubitus position scans are performed in the sagittal and transverse planes from the anterior approach using the liver and spleen as acoustic windows for the right and left kidney respectively. Scanning is also done in deep suspended aspiration. Start with longitudinal scan over the right upper abdomen and then follow with transverses scan. Next, rotate the patient to the left lateral decuibitus position to visualize the right kidney in the coronal view. To visualize the left kidney, scan the left upper abdomen in a similar sequence, if the left kidney cannot be seen usually due to excess bowel gas; try the right lateral decubitus position. If the kidney cannot be imaged adequately, scan through the lower intercostals spaces. Turn the patient prone and apply enough gel to the left and right renal areas and perform longitudinal and transverses scan. Both kidneys can be also examined with the patient sitting or standing erect, when examining any part of kidney, compare both kidneys in different projection. Variations in size counter and internal echogenicity may indicate abnormality. For adults use 3.5 MHZ transducer, children and thin adults use a 5.0 MHZ start by placing the transducer over the right upper abdomen, then angle the beam as necessary and adjust the time gain compensation (TGC) with adequate sensitivity setting to allow uniform acoustic pattern, thus obtaining the best image of renal parenchyrna. Gain is amplification of the reflective ultrasound waves by the unit. The near gain control amplifies echoes returning from tissue above the focal point of the beam. While the far gain control amplifies echoes returning from beyond the focal point of the beam. E.g. echoes coming from deeper tissues need more amplification. These controls can be adjusted to allow the proper comparison of echogenicity at different level.

Renal detail may be obscured if there is significant amount at perirenal Fat, hepatocellular diseases, gall bladder stones, rib interface or other abdominal masses, or collection of fluid between the liver and kidney. When scanning the kidney it is better to identify the renal capsule, the cortex, the medulla sinus, upper ureter, renal arties and vein.

The kidneys are imaged by U/S as organs with smooth outer contours surrounded by highly echogenic perirenal fat. The renal capsule appears as a bright echogenic line surrounding the cortex which is homogonous with smooth counter, its echogenicity is moderated (mid to lower level echoes). In an even texture that is less echogenic than the normal liver or spleen but more echogenic than the adjacent renal medullary pyramids. The renal contains the pyramids which appear as triangular or blunted hypo echoic to an echoic area (it should not be mistaken for renal cyst or tumors). (B.Breyer; et al, 1995), (Gratton, Denis, 2005)

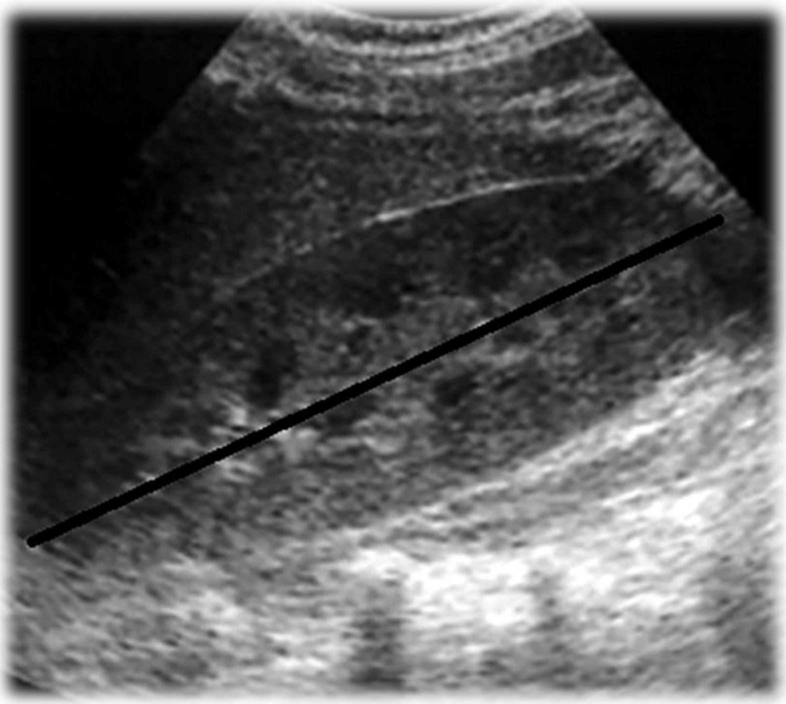

Fig (2.8) shows the normal kidney ultrasound longitudinal of the right kidney. (Maaji SM, et al, 2015)

2.1.5.3 Ultrasound of Normal kidney

It is easier to visualize the pyramids in children and young adults; the central echo complex (the renal sinus) is imaged as a very highly hyper echoic (very echogenic) area, normally occupying about one third of the kidney and includes the collecting system (pelvis and calyces) and renal vessel. It is the most part of the kidney and has greater echogenicity due to the fat deposition. The sinus is surrounded by the parenchyma (the area from the renal sinus to outer renal surface) whose thickness is 11-18mm in male and 11-16 mm in female. The pelvis is not visualize unless there is urine filled when it appear anechoic it is scanned through the renal sinus in an anterior transverses vein. (Gratton, Denis, 2005)

Fig (2.9) shows the normal longitudinal & cross-section of the kidney

(http://www.ultrasoundpaedia.com/normal-kidney/ , 2014)

The renal arteries and veins are best seen at hilum. They enter the kidney at different levels and may be multiple. The accurate vessels are demonstrated as intense specular echoes in cross section or oblique section at the corticomedullary junction. The renal arteries are best seen in supine and lateral decubitus views. The right renal artery can be seen in a longitudinal scan as a circular structure posterior to the inferior vena cava. The right renal vein extends from the central renal sinus directly in to the IVC. Both vessels appear as tubular structures in the transverse plane the renal arteries have an echo free central lumen with highly echogenic borders that consist of vessel wall and the surrounding retroperitoneal fat and connective tissue. They lie posterior to the veins and can be demonstrated with certainly if their junction with the aorta is seen. The left renal artery flows from the posterior-lateral wall of the aorta to the central renal sinus. An extra renal pelvis may be seen as a fluid filled structure medial to the kidney on transverse scans.

Differentiation of the normal variant from obstruction is made by noting the absence of intra sinus distention of the renal pelvis and infundibula. Dilatation of the collecting system has also been noted in pregnancy (the right kidney is generally involved with mild degree of hydronephrosis which reverts to normal after delivery). Normally in the non hydrated subject the renal pelvis is collapsed and therefore not demonstrated on the scan. (Gratton, Denis, 2005)

The renal pelvis is influenced by bladder distention, diuretics and the state of hydration. Distention of the renal pelvis is seen in 50% of non hydrated and in 90% in hydrated subjects examined with a full bladder. The normal renal pelvis in the hydrated patients is between 2-14 mm. If two separated collection of renal sinus fat are identified a double collecting system should be suspected ability to visualize the kidney close not mean that it is functioning. To assess renal function use contrast urography, Arachio nuclide study or laboratory test, injury to kidney may result in temporary loss of function.

Normal ureters are not always seen. They should be sought where they leave the kidney at the hilum. They may be multiple and are often seen in the coronal projection generally, echogenicity from higher to decreasing order is: renal sinus, spleen, liver, renal cortex renal medulla in adult fig (2-9). The thickness of the renal parenchyma decrease at about 10% per decade after 20 years of age. The corticomedullary ratio is 1:1.6 up to 30 years old; 1:1.2 up to 50 years old 1:1 above 50 years old with thinning of cortex with age. The overall size decreases with age and only apparent in the elderly. The fetal kidney size in cm. equals the gestational age in weeks plus or minus 3mm. infantile kidneys are large compared to overall body size typically 4-5cm long at birth and may be imaged from 12-14 weeks on wards but clearly seen after 16 weeks. (Gratton, Denis, 2005)

In transverse section they appear hypoechogenic, circular structures on either side of the spine. Within them can be seen the strongly echogenic renal pelvis, the capsule is also echogenic; The renal papilla is hypoechoic and can appear large. Some dilatation of the renal pelvis less than 5 mm may sometimes be seen but it is normal finding. It is important to assess renal size by comparing the renal circumference with the abdominal circumference; the normal ratio being 0.27-0.3 the fetal urinary bladder can be recognized as a small avoid cystic structure within the fetal pelvis as early as 14-15 weeks. The normal urinary production at 22 weeks in 2m1 per hour, whereas at full term it is 26ml per hour until the age of 6 month. (Gratton, Denis, 2005)

Neonatal kidney differs acoustically from adult kidneys in that, the difference between cortex and medulla is less marked in the infant pyramids are relatively, hypoechoic and may resemble cysts cortex is less echogenic than Liver parenchyma. For the first 3 years of life; its pyramid appear large because the cortex is relatively thin and hyperechoic. During the first year of life the cortex gradually develops to assume the adult corticomedullary proportion. The pediatric renal sinus is poorly echogenic because it contains little fat. (Gratton, Denis, 2005)

Fat deposition and accumulation occurs gradually to achieve adult proportions by about age 10 years, the majority of infants have a slight separation of the central echo complex reflecting the presence of a small amount of urine of unknown cause. There is no absolute measurement to separate normal distension from hydronephrosis 10mm separation is considered the upper limit of normal. “Unlike in adult practice detection of children with vesicoureteric reflux is important and may only be reflected by minor separation the central sinus echoes without renal scarring”. Normal renal length of pediatric kidney is determined using this guide: Renal length (over one year) in cm 6.79+ (0.22* age in years).

In those less than one year=4.98+ (0.155*age in months). “Asymmetry in renal lengths exceeding 5 mm in infants and 10 mm in older children should raise the suspicion of an underlying problem even if both kidneys are within the normal range.” (Gratton, Denis, 2005)

2.1.6 Laboratory tests related to kidney function

2.1.6.1 Serum creatinine

Is nitrogenous compound formed as an end product of muscle metabolism. It is formed in small amount in the muscle, passed into the blood stream and excreted in the urine. Blood creatinine level measure renal function, normally it is produced in regular consistently small amount, therefore an elevation means a disturbance in renal function, so renal impairment is virtually the only cause of creatinine elevation.
(Tarig Hakim, 2008)

2.1.6.2 Blood urea nitrogen (BUN)

Urea is the end product of protein metabolism and is readily excreted by the kidney; there for the blood urea concentration normally is fairly low. Blood urea nitrogen level, measures renal function, the BUN level raises when the kidneys ability to excrete urea is impaired, it is also rises with reduced renal blood flow as with dehydration and urinary tract obstructions, elevated level of BUN may lead to mental confusion, disorientation and coma. (Tarig Hakim, 2008)

2.2 Previous Studies

Northwestern Nigeria study done in Bayero University, in a tertiary Hospital between January and December 2013, Study of the renal size in individuals without known renal disease, performed on 104 consecutive volunteers. There were 50 females and 54 males. Study show a mean length of 11.6 cm and 11.3 cm left and right, respectively. These values are slightly higher when compared with the Indo-Asian average length of 10.4 cm and is probably a reflection of the relatively small body size of most of the Indo-Asians, that left kidney is larger than the right (The renal volume was 109.6 ± 29.3 and 119.7 ± 32.8 for right and left kidney), with the findings that males have larger kidney volume, with volume of 206 cm^3 and 205 cm^3 for both right and left kidneys, respectively, however, there were no gender-related differences in renal length. The strongest correlation with renal volume is age, the correlation coefficient was 0.997, with positive correlations between renal volume and height, and body mass index. (Maaji SM, et al, 2015)

Iraqi study done in Sulimaniya University in 2013 - 2014 study of the renal size in ultrasound of unknown renal diseases. The study includes 450, 239 females 211 males. They found the results are nearer to the studies done in other nearby countries. They come to a conclusion that the BMI, ethnic, and environment are the main factors affecting the renal size. There was a positive correlation between the size of the right and left kidney, with the left kidney size which is larger (The mean of the left kidney size was 89031.0296 mm^3 with a standard deviation of 22025.83057, while the mean of the right kidney size was 72210.9842 mm^3 with a standard deviation of 18681.46873). There was also a positive correlation between renal size and age, as renal size increased with age till the 5th decade of life. While the male renal size was greater than the female renal size with the same age group, there was a positive correlation between renal size and body mass index (BMI). (Karim, Shilan Hussein et al, 2015)

A study done in Pakistan, ultrasonographic renal size in individuals without known renal disease. The study population were (194) male 98, females were 96, they come to find, Mean renal size in Pakistani population are significantly smaller than reference values available in literature from American and European population; the findings: A direct relationship between BMI and the renal size is in Pakistani population, the mean renal size correlated with age, female kidneys were significantly smaller than the male kidneys, with Left kidney is significantly larger than the right. (Buchholz, N., et al, 2000)

Chapter Three

Chapter Three

Material and Method

3.1 Material

3.1.1 Patient

The study was including 50 persons; out of which (25) were females and (25) were males at the Elehtiati Elmarzi Hospital; ranging between 16-65 years old during the period from July to October, 2016. The study population consisted of outpatients and in patients undergoing US examination due to common clinical complaints such as weight loss, unexplained abdominal pain, nausea and constipation.

3.1.1.1 Inclusion criteria

- Adults with normal renal laboratory findings (RFT include BU and S creatinine, UG and electrolyte)
- No symptoms related to renal impairment such as lower limbs, periorbital swelling or abdominal ascites.
- Normal ultrasound findings (normal renal echogenicity, cortical thickening and corticomedullary differentiation)

3.1.1.2 Exclusion criteria

- Patients less than 16 years old with abnormal laboratory findings were excluded
- Abnormal ultrasound findings such as increased parenchymal echogenicity, abnormal cortical thickening and corticomedullary differentiation , renal cysts, hydronephrosis, single kidney, kidney stone and mass, extreme obesity or pregnancy
- Symptoms related to renal impairment

Patients' age, sex, weight, height was recorded. The body mass index BMI (kg/m^2) is calculated by this formula:

$$\textbf{BMI} = \boldsymbol{weight\ (kg)\ /\ [height\ (m)]^2}$$

(Karim, Shilan Hussein et al, 2015)

3.1.2 Machine used

Alpinion medical systems; model E-CUBE 7 ultrasound machine. E-CUBE 7; ranged in frequency, we use 3.5 for adults and 5 for thin patients.

3.2 Methods

3.2.1Technique

The examination is performed on all patients. The subject lay in supine, lateral and prone positions; however, renal length, width and thickness of both kidneys for each individual were taken by ultrasound. Then, the renal size for each kidney was calculated automatically by the machine or by multiplying the three variables by 0.523 according the equation below:

$$\textbf{Renal size } (mm)^3 = \textbf{Length x Width x thickness x 0.523}$$

(Okur, Aylin, et al, 2014)

3.2.2 Data Source

From direct ultrasound scanning of the population of study, from data sheet and request forms.

3.3 Data Analysis

The data were analyzed by the computer and protected by a pass word. The data collected during the study were stored in the computer and protected by a pass word. All data collection sheets were protected in a private cabinet.

3.4 Consideration

There is no any patients name or individual patient`s details throughout the study.

Chapter Four

Chapter Four

Results

The following tables and graphs show summary of the results presented the data including the age, sex and BMI to the volume of the kidneys and also between the volumes of the person's kidneys in the left and the right side.

Table (4.1) Characteristics of subjects

Descriptive Statistics

	Total (Males + Females) ± SD	**Minimum**	**Maximum**	**Males ± SD**	**Females ± SD**
Age	38.68 +/- 14.12	16	65	39.80 +/-13.55	37.56 +/- 14.86
L	164.54 +/- 5.05	152	176	167.20 +/- 4.67	161.88 +/- 3.93
W	69.70 +/- 11.00	36	90	73.88 +/- 7.12	65.52 +/- 12.65
BMI	25.73 +/- 3.97	15.60	33.50	26.48 +/- 2.63	24.99 +/- 4.91
RKL	10.16 +/-0.61	9.10	12.60	10.27 +/- 0.71	10.05 +/- 0.47
RKW	4.61 +/-0.30	4.00	5.40	4.74 +/- 0.29	4.49 +/- 0.26
RKD	4.10 +/- 0.25	3.40	4.70	4.17 +/- 0.30	4.02 +/- 0.17
RKV	100.55 +/- 12.29	73.20	133.00	106.06 +/- 12.41	95.03 +/- 9.52
LKL	10.56 +/-0.53	9.60	12.60	10.68 +/- 0.60	10.43 +/- 0.43
LKW	4.83 +/-0.29	4.30	5.70	4.94 +/- 0.29	4.73 +/- 0.25
LKD	4.41 +/-0.24	3.90	5.40	4.50 +/- 0.28	4.32 +/- 0.17
LKV	116.95 +/-11.58	89.00	142.30	122.39 +/- 11.08	111.50 +/- 9.46

ns ± standard deviation

(L height, **W** Weight, **BMI** Body Mass Index, **RKL** Right Kidney Length, **RKW** Right Kidney Width, **RKD** Right Kidney Depth, **RKV** Right Kidney Volume, **LKL** Left Kidney Length, **LKW** Left Kidney Width, **LKD** Left Kidney Depth, **LKV** Left Kidney Volume, **SD** Standard Deviation **)**

Table (4.2) shows the Characteristics of subjects per age group

Descriptive Statistics

Age	BMI ± SD	RKL ± SD	RKW ± SD	RKD ± SD	RKV ± SD	LKL ± SD	LKW ± SD	LKD ± SD	LKV ± SD
10- 20	19.65 +/- 3.22	10.40 +/- 1.18	4.63 +/- 0.45	4.03 +/- 0.23	101.77 +/- 19.81	10.71 +/- 0.99	4.78 +/- 3.87	4.22 +/- 0.18	113.60 +/- 18.68
21- 30	23.36 +/- 1.50	10.30 +/- 0.68	4.60 +/- 0.28	4.12 +/- 0.26	102.02 +/- 11.37	10.68 +/- 0.59	4.83 +/- .024	4.46 +/- 0.40	118.19 +/- 11.5
31- 40	25.27 +/- 2.38	9.97 +/- 0.52	4.54 +/- 0.28	4.10 +/- 0.16	97.16 +/- 9.81	10.37 +/- 0.51	4.87 +/- 0.22	4.40 +/- 0.13	116.00 +/- 6.18
41- 50	28.44 +/- 2.58	10.03 +/- 0.422	4.75 +/- 0.33	4.15 +/- 0.34	103.65 +/- 14.36	10.41 +/- 0.37	4.98 +/- 0.36	4.47 +/- 0.20	120.88 +/- 13.22
51- 60	29.00 +/- 3.33	10.20 +/- 0.37	4.51 +/- 0.18	4.07 +/- 0.28	97.94 +/- 10.18	10.62 +/- 0.26	4.67 +/- 0.19	4.40 +/- 0.17	112.89 +/- 9.27
61- 70	28.50 +/- 1.65	10.20 +/- 0.20	4.63 +/- 0.32	4.07 +/- 0.05	100.43 +/- 5.92	10.77 +/- 0.15	4.77 +/- 0.29	4.47 +/- 0.12	119.97 +/- 11.93

ns ± standard deviation;

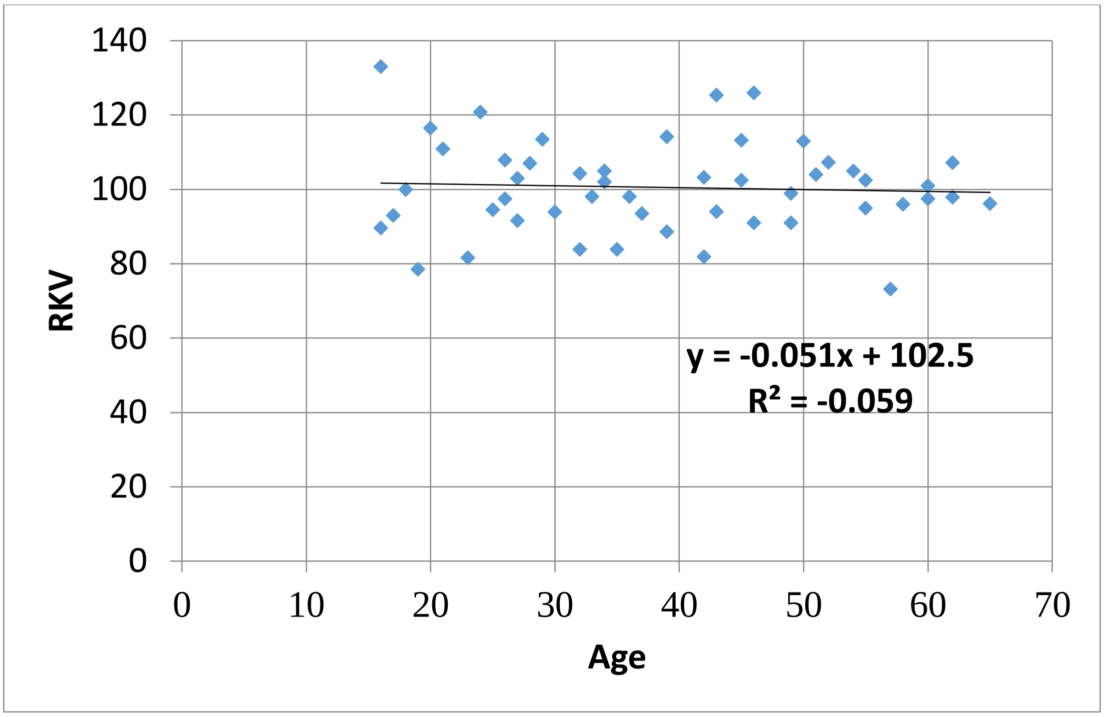

Fig (4.1) A scatter plot diagram shows relationship between the RKV and the Age of the subjects, $R^2 = -0.059$.

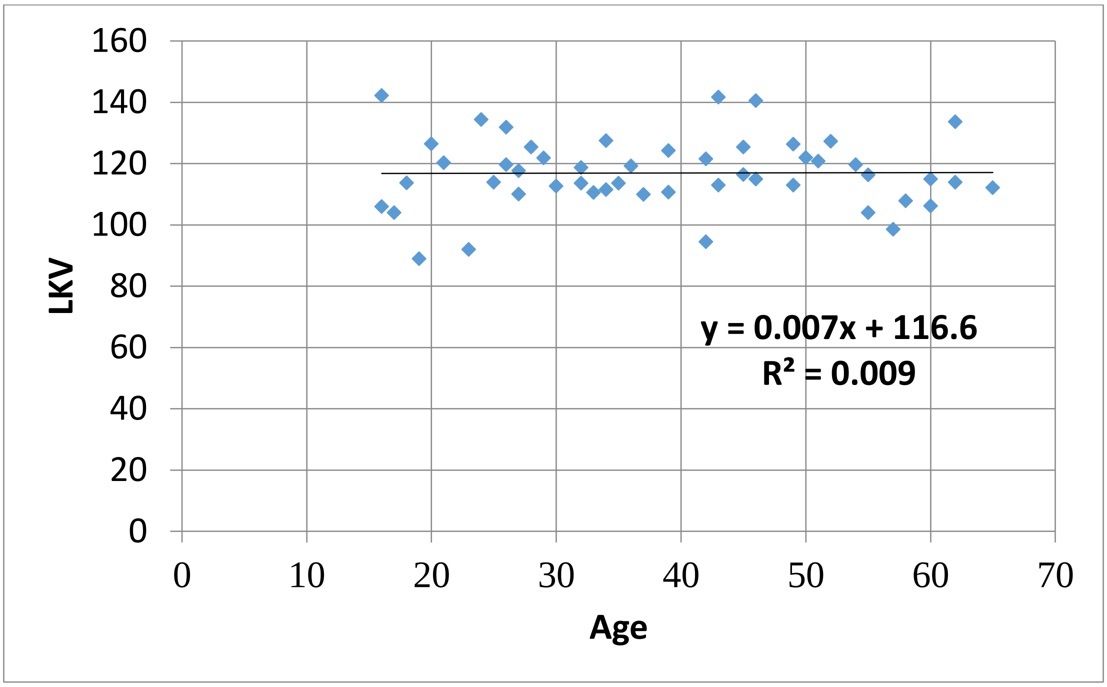

Fig (4.2) A scatter plot diagram shows relationship between the LKV and the Age of the subjects, $R^2 = 0.009$

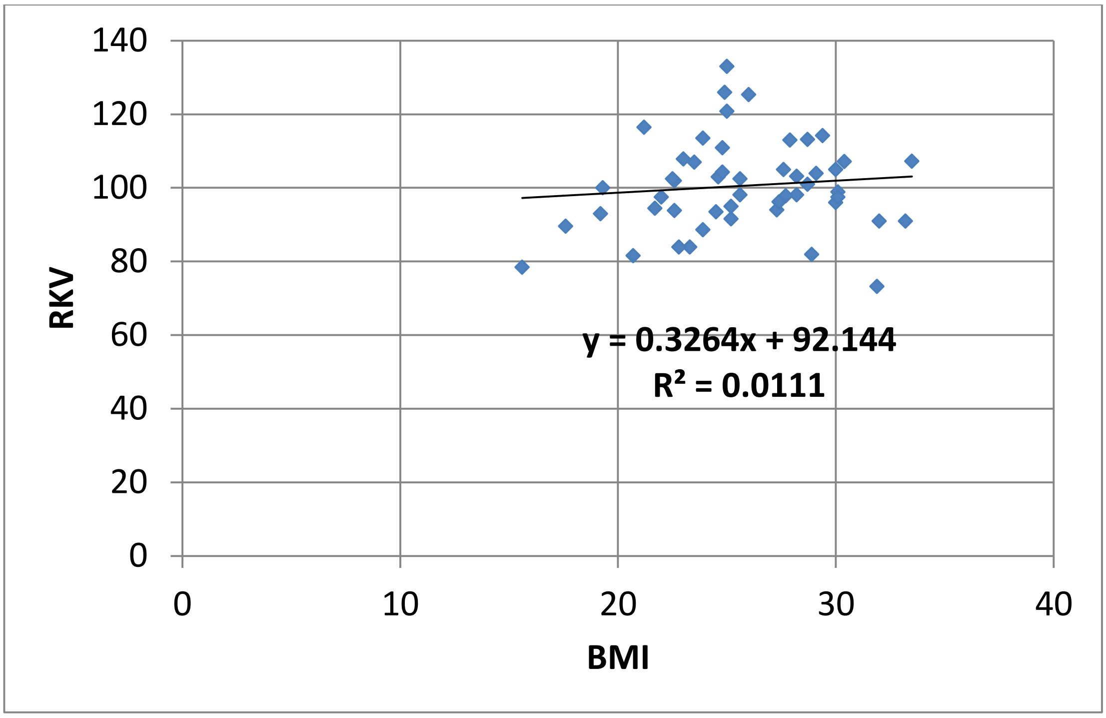

Fig (4.3) A scatter plot diagram shows relationship between the RKV and the BMI of the subjects, R^2 *= 0.011.*

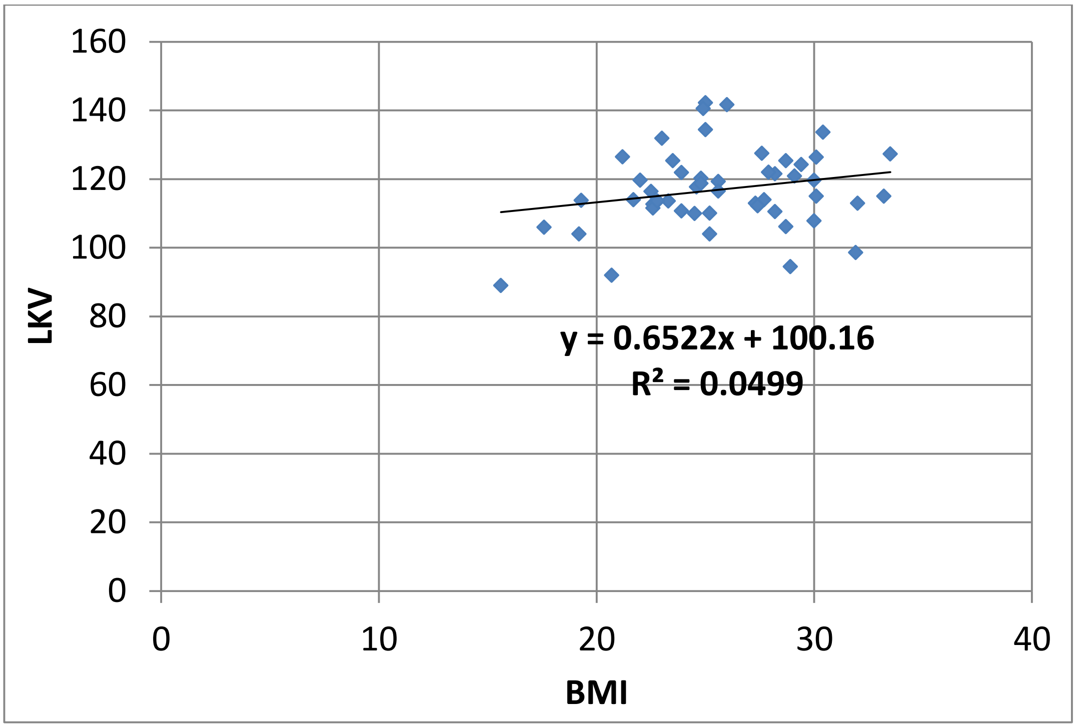

Fig (4.4) A scatter plot diagram shows relationship between the LKV and the BMI of the subjects, R^2 *= 0.049.*

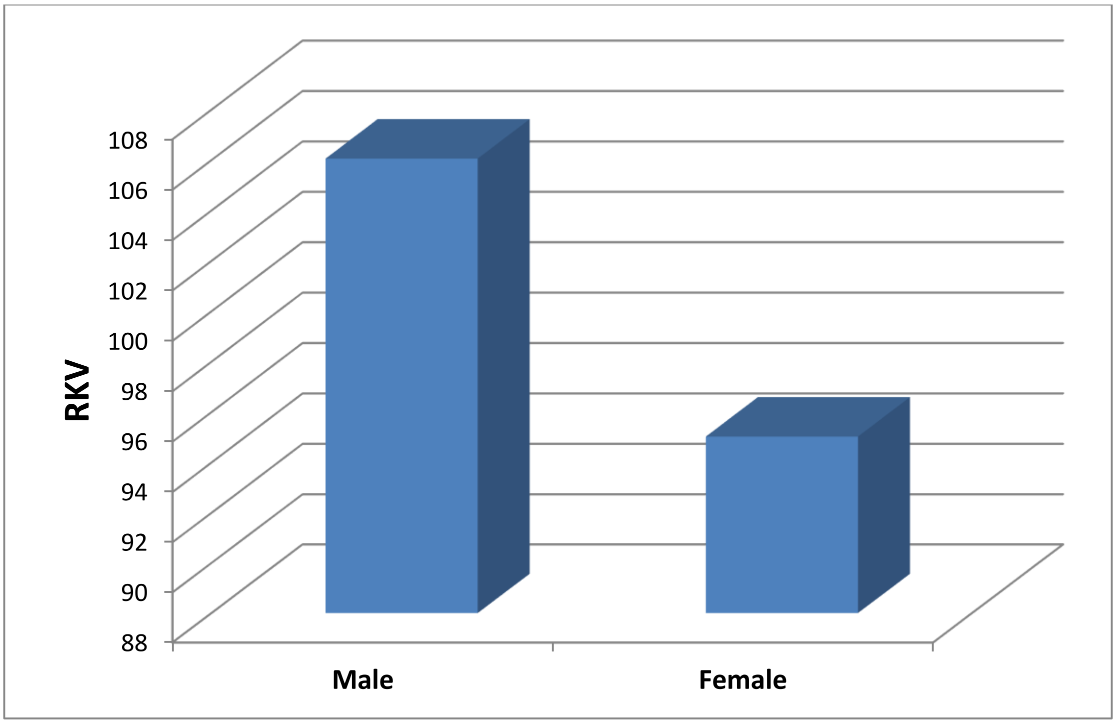

Fig (4.5) comparison between males and females in RKV

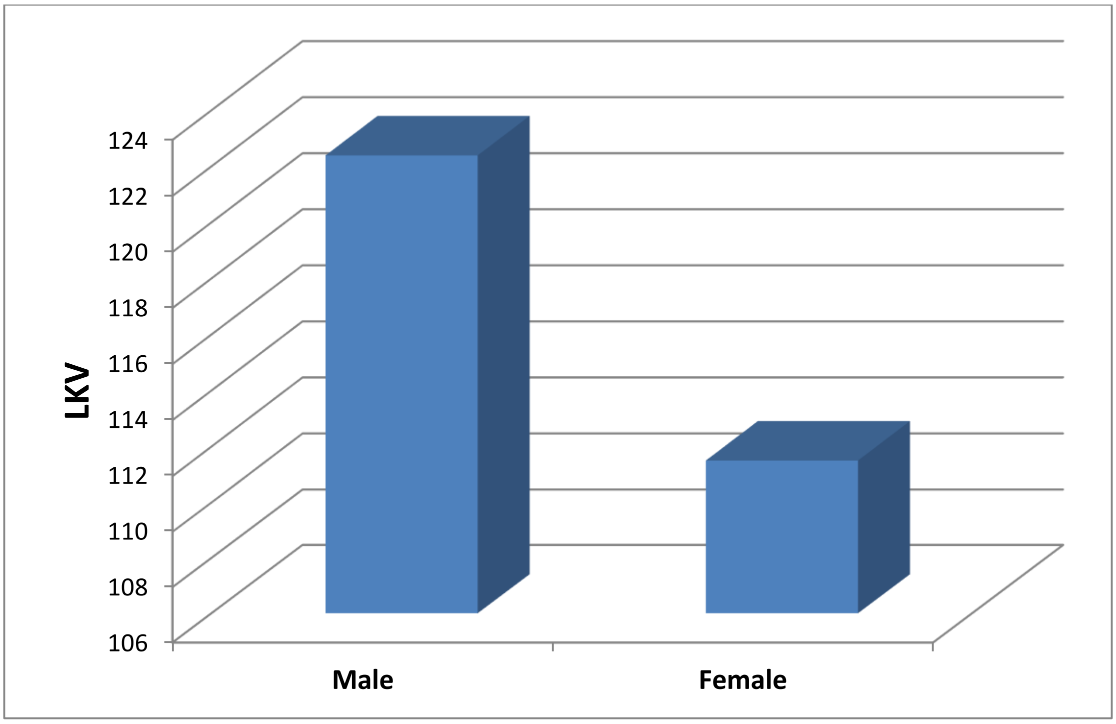

Fig (4.6) comparison between males and females in LKV

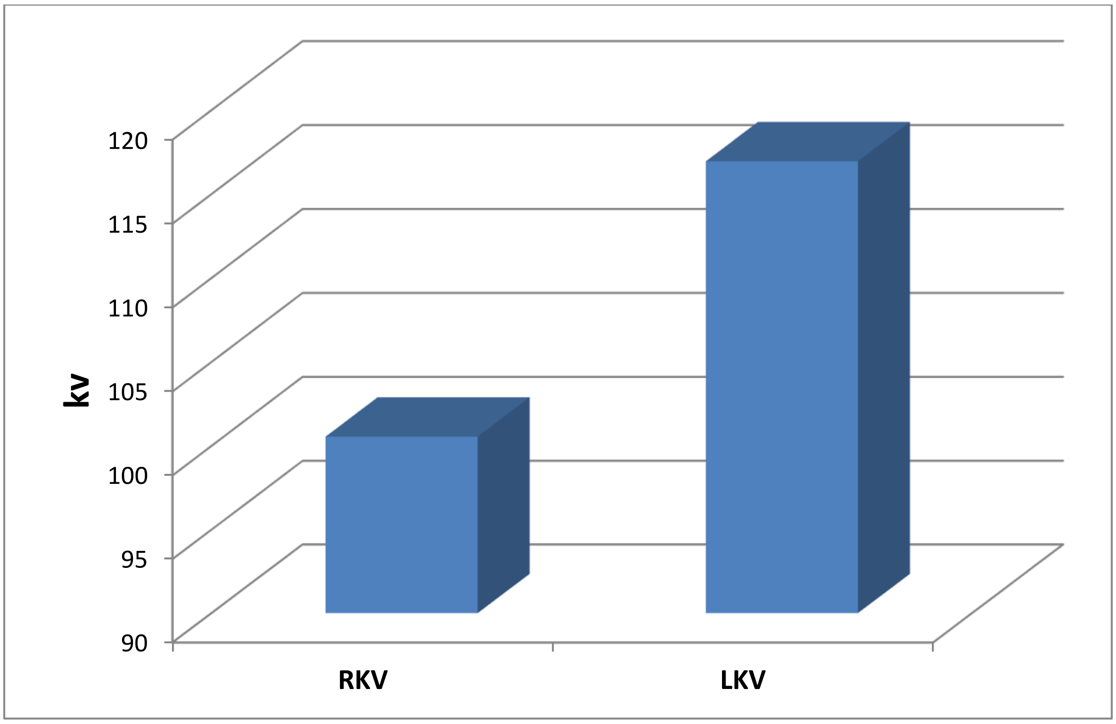

Fig (4.7) comparison between right and left Kidney Volume

Chapter Five

Chapter Five

Discussion, Conclusion & recommendation

5.1 Discussion

The mean age was 38.68 years. Hence, both kidney sizes are shown in table (4.1), (4.2). Calculation of correlation for both kidneys with age was done separately. The result showed that there was no correlation between age and kidney size, as shown in Fig (4.1) (4.2). Age is also important as both physiology and anatomy of the human body alters with age, not agree with previous study (Karim, Shilan Hussein et al, 2015) (Buchholz, N., et al, 2000)

The correlation between the body mass index and both kidney size. However, the mean of the body mass index was 25.73. The correlation coefficient between BMI and the size of both kidneys showed that there was no correlation between BMI and the size of both kidneys. Thus, this was shown in Fig (4.3), (4.4). Not agree with previous Studies done by (Buchholz, N., et al, 2000) (Karim, Shilan Hussein et al, 2015)

Renal size for both kidneys has been measured separately for both sexes. The mean of the right renal size in male was 106.06mm^3, while the mean of the left renal size was 122.39mm^3. In females, the mean of the right renal size was 95.03mm^3, while the mean of the left renal size was 111.50mm^3. The mean of the right renal size in both sexes and also the mean of the left renal size in both genders were compared so as to find whether there is a difference in the size or not. Hence, the correlation was significant. The right and left kidney sizes were larger in males than the right and left kidney sizes in females as can be seen in Fig(4.5) (4.6). Probably because of the difference in height or body mass index , renal size have been found to be slightly larger in males in most studies, this agree with previous study (Karim, Shilan Hussein et al, 2015) (Buchholz, N., et al, 2000).

Correlation between the right and left kidney size. The mean renal size for the right kidney was 100.55 mm^3 and that of the left kidney was 116.95 mm^3**.** The correlation was significant with the left kidney larger than the right kidney regarding age and gender, as shown in Fig (4.7), the left renal size in this study was greater when compared with the right (Buchholz, N., et al, 2000) (Karim, Shilan Hussein et al, 2015)

Table (5.1) Comparison of renal parameters with other studies

		NO	Right kidney		Left kidney		All
			Length (mm)	**Size (mm) 3**	**Length (mm)**	**(mm)3 Size**	Length (mm)
Saudi's population			103.2 ±6.9		107.7 ±8.7	74468.08 8±18	
Malaysian population			97±7.9		99±9.6		
Korea			102±12		105±8		
Isfahanian Adults			109 ± 8.4		111 ± 9.8		
Nigerian adults	**Male**		107 ±10		110 ±9		
	Female		104 ±9		108 ±9		
Mexican adults	**Male**		105.74 ±5.74		107.16 ± 6.97		
	Female		102.99 ±6.85		104.6 ± 7.96		
Brazil			120.25±7		126.5±7		
Turkish	**Male**		104.9125 ± 10.4		105.245 ± 10.25		
	Female		102.4425 ± 9.6		101.8825 ±10.37		
Pakistan			104 ±9		105±9	80640±12	
North-East India			89±9		91±9	80700 ±26.0	
Denmark			109±11		112±11	96790.4 ±30	
2013 Nigeria		104	11.3	110	11.6	119	
Iran	**Male**	400	110		113		109
	Female		107		109		111
USA			107				111

(Karim, Shilan Hussein et al 2015)

5.2 Conclusion

The study concluded that

- There was no correlation between age and volume of the kidneys
- There was no correlation between BMI and volume of the kidneys
- The kidney volume in males is slightly more than females

  With the left kidney volume larger than the right

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5.3 Recommendation

- Further study increase sample gives standard number (Some of the limitations in our study are the smaller sample size. The sample size must be large enough to detect the clinically important effect.)
- Use other modality like CT, MRI to confirm the accurate normal measurements

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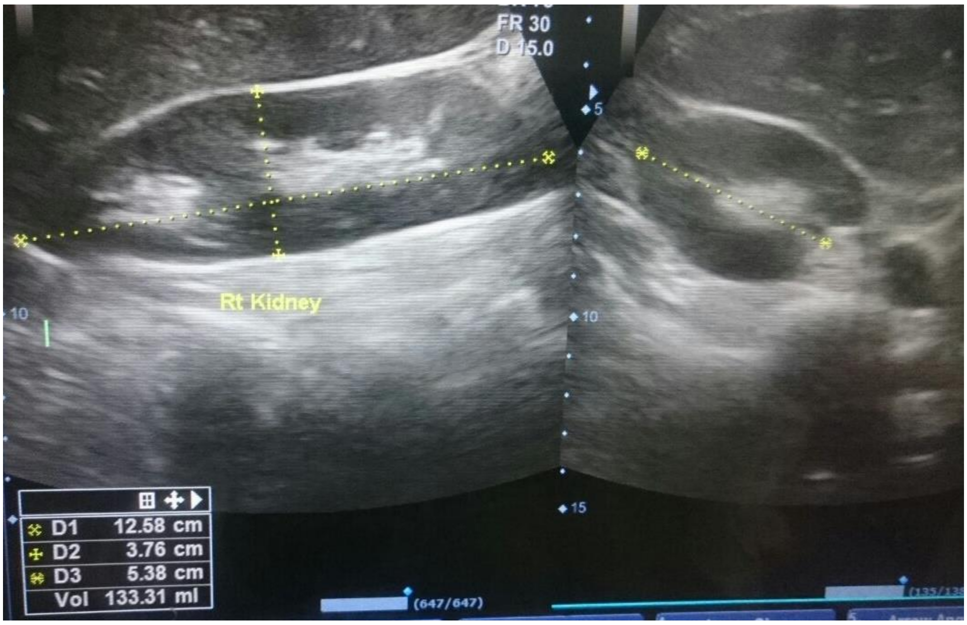
Appendices

Table (A.1) Data Sheet

NO	Sex	Age	L	W	BMI	RKL	RKW	RKD	RKV	LKL	LKW	LKD	LKV

Images of the study

(Image -1). Male – 57 years, 9.84 L, 4.19 W, 3.39 D, Volume 73.18cc



(Image -2). Female –16 years, 12.58 L, 5.38 W, 3.76 D, Volume 133.31cc

(Image -3). Male –43 years, 10.34 L, 4.77 W, 4.41 D, Volume 111cc

(Image -4). Female –42 years, 10.5 L, 4.26 W, 4.04 D, Volume 94cc

(Image -5). Male –37 years, 9.65 L, 5.20 W, 4.20 D, Volume110cc

(Image -6). Female –43 years, 10.45 L, 5.65 W, 4.59 D, Volume 141cc

(Image -7). Male –27years, 11.69 L, 4.16 W, 3.60 D, Volume 91cc

(Image -8). Male –39 years, 9.14 L, 4.41 W, 4.22 D, Volume 83cc