كلية الدراسات العليا

Sudan University of Science and Technology

College of Graduate Studies

# Measurement of Normal Kidneys Length and Volume in Sudanese Children using Ultrasound Imaging

## قياس طول وحجم الكلى الطبيعية في الأطفال السودانيين باستخدام التصوير بالموجات فوق الصوتية

**A thesis submitted for partial fulfillment of M.sc degree in medical diagnostic ultrasound**

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بسم الله الرحمن الرحيم

# *Abstract*

This was descriptive study concluded in Khartoum state and western Kurdufan state – Sudan, from December 2016 to January 2017. This study done to measure the normal kidneys length and volume in Sudanese children using B-mode ultrasound imaging**.** The problem of this study was to identify kidneys length and volume to lay the foundation for faster and easier diagnosis of renal pathological conditions and to revel if the growth kidney affected by geographic factors or not. The study aimed to measure and correlate the length and volume of the right and left kidneys and to correlate the body characteristics, gender and deferent areas to these measurements. The data collected from 104 volunteers using master data sheet in order to analyze it and calculate the mean normal value of kidneys measurements. The study found that the mean value of right and left kidneys length was 8.034 cm and 8.212 cm respectively, and the mean value of right and left kidneys volume was 55.935 $cm^3$ and 64.497$cm^3$ respectively. Left kidney was larger than right kidney in all measurements and the significant difference between the right and left kidneys found. Significant difference between right and left kidney measurements in different geographic areas (Khartoum and Western Kurdufan) also found. No significant difference found in respect to gender. Right kidney length correlated with height and BMI. Right kidney width correlated with body height and body weight. While left kidney width only correlated with body height. AP diameter for right and left kidney correlated with body height. The right kidney volume correlated with body weight and BMI while left kidney volume correlated with body height and BMI. The study recommended that further studies to overcome the limitations specially that related to age and number of volunteers.

# ملخص البحث

هذه دراسة وصفية تمت في ولايتي الخرطوم وغرب كردفان -السودان، من ديسمبر 2016 إلى يناير 2017. أجريت هذه الدراسة لقياس طول وحجم الكلى الطبيعية في الأطفال السودانيين باستخدام التصوير بالموجات فوق الصوتية. برزت أهمية الدراسة في تحديد طول وحجم الكلى لوضع الأساس لتشخيص أسرع وأسهل للحالات المرضية الكلوية ومعرفة أثر العوامل الجغرافية على تلك القياسات. هدفت الدراسة إلى قياس طول وحجم الكلى اليمين واليسار ومعرفة أثر خصائص الجسم واختلاف الجنس والمناطق على هذه القياسات. تم جمع البيانات من 104 متطوعا باستخدام ورقة البيانات الرئيسية وتم تصنيفها وتحليلها وحساب القيمة المتوسطة لقياسات الكلى الطبيعية عند الاطفال السودانيين. وجدت الدراسة أن متوسط قيمة طول الكلى اليمنى واليسرى كانت 8.034 سم و8.212 سم على التوالي، وكان متوسط قيمة حجم الكلى اليمنى واليسرى 55.935 سم مكعب و64.497 سم مكعب على التوالي. وجد فرق كبير بين قياسات الكلى اليمنى واليسرى حيث كانت الكلية اليسرى أكبر من الكلية اليمنى في جميع القياسات. ووجد أيضا فرق كبير بين قياسات الكلى اليمنى واليسرى في المناطق الجغرافية المختلفة (الخرطوم وغرب كردفان). لم يوجد فرق كبير بين قياسات الكلى اليمنى واليسرى فيما يتعلق باختلاف الجنس. طول الكلية اليمنى ارتبط مع طول الجسم ومؤشر كتلة الجسم. ارتبط عرض الكلية اليمنى مع طول الجسم ووزن الجسم. حين ارتبط عرض الكلى اليسار فقط مع ارتفاع الجسم. ارتبط سمك الكلى اليمنى واليسرى مع ارتفاع الجسم. حجم الكلية اليمنى ارتبط مع وزن الجسم ومؤشر كتلة الجسم في حين أن حجم الكلى اليسرى ارتبط مع ارتفاع الجسم ومؤشر كتلة الجسم. أوصت الدراسة بالمزيد من الدراسات للتغلب على المعوقات والصعوبات التي واجهتها خصيصا تلك المرتبطة بالعمر وعدد المتطوعين.

# DEDICATION

*To my beloved parents whom have raised me to become the person I am today, they have always been with me and generously supporting me.*

*To my wife who stood by me all the way and to my lovely daughter.*

*To my dear brothers.*

*And*

*To my friends.*

Acknowledgment

*Prayers are to Allah Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding.*

*My sincere gratitude to my supervisor Dr. Asmaa Ebrahim and Dr. Mohamed Al-Fadil for their continuous guidance and appreciable efforts during preparation of this thesis.*

*My deepest appreciation to all those how helped me in completion and improvement of this thesis.*

*Finally, I pay much gratitude to Sudan University of Science and Technology for being knowledge home.*

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## *Abbreviations:*

| | |
|---|---|
| AP | Antroposterior |
| ADH | Antidiuretic hormone. |
| BMI | Body mass index |
| CT | Computed Tomography |
| EPO | Erythropoietin |
| IVC | Inferior venacava |
| L1 | First Lumber vertebra |
| L3 | Third Lumber vertebra |
| RAS | Renin angiotensin system |
| $R^2$ | Regression factor |
| T1 | First Thoracic vertebra |
| T8 | Eighth Thoracic vertebra |
| UPJ | Ureteropelvic Junction |

# Chapter one
# Introduction

## 1-1 Introduction:

Abdominal pain is the most common indication for a renal ultrasound scan. However, doctors may also refer patients because they suffer from other symptoms or may be concerned about examination findings or blood and urine tests.

Among other conditions, a renal ultrasound scan can detect kidney stones, cysts, tumors, congenital abnormalities of the renal tract (these are abnormalities that have been present from birth), problems of the prostate, effects of infection and trauma of the kidneys and renal tract.

Childhood is an important period of growth for many organ systems. Among various growth parameters, kidney size is an important parameter used for the clinical evaluation of renal growth and renal abnormalities, including atrophy, hypoplasia, and hypertrophy in children. Therefore, having a reliable reference for kidney size in children is valuable. Renal length and volume measurements are clinically relevant, serving as surrogates for renal functional reserve, and used frequently as the basis for making clinical decisions. Serial measurements also can provide information regarding disease progression or stability.

Several studies suggest that kidney’s length and volume strongly correlated with a patient's height, weight and body mass index (BMI). The prevalence of obesity has increased within children globally over the past decade, and this issue has raised concerns for health of the pediatric population.

There are several methods measuring renal size, including abdominal CT and MRI. However, these approaches have disadvantages such as radiation exposures and high costs. In comparison, ultrasonography (US) is a safe, noninvasive and a simple method for evaluating renal length and volume.

## 1-2 Problem of the study:

Kidneys are vital organs that need accurate findings to diagnosing specially in children. Ultrasound imaging is comfortable, low cost and most important safe for scanning kidneys and other internal organs. Identifying kidneys length and volume will lay the foundation for faster and easier diagnosis of renal pathological conditions, also Studies are needed to revel if the growth of vital organ as kidney is affected by geographic factors or not.

## 1-3 General objectives:

To Measure the normal kidneys length and volume in Sudanese children using ultrasound

### 1-3-1 Specific objectives:

- To measure the length and volume of the right and left kidneys in Sudanese children
- To correlate the length and volume of the right and left kidneys in Sudanese children
- To correlate the body characteristics with renal length and volume. in Sudanese children
- To correlate the values of length and volume with gender. in Sudanese children
- To correlate the length and volume of normal kidneys in Khartoum state children Western Kurdufan state children.

### 1-3-2 Significance of the study:

The study will determine the normal value of both right and left kidneys length and volume among Sudanese pediatric and if there is difference due to geographic distribution. This will facilitate diagnosis of any changes due to pathologic conditions.

## 1-4 Over view of the study:

This study consist of five chapters, where chapter one is an introduction of the study and give a view about chapter two include the previous study talking about the same subject, chapter three mentioned the study area and time and study sample and data collection method and analysis, chapter four including the result of the analyzing the data and lastly chapter five is the discussion of the results and the recommendations given for the further studies made.

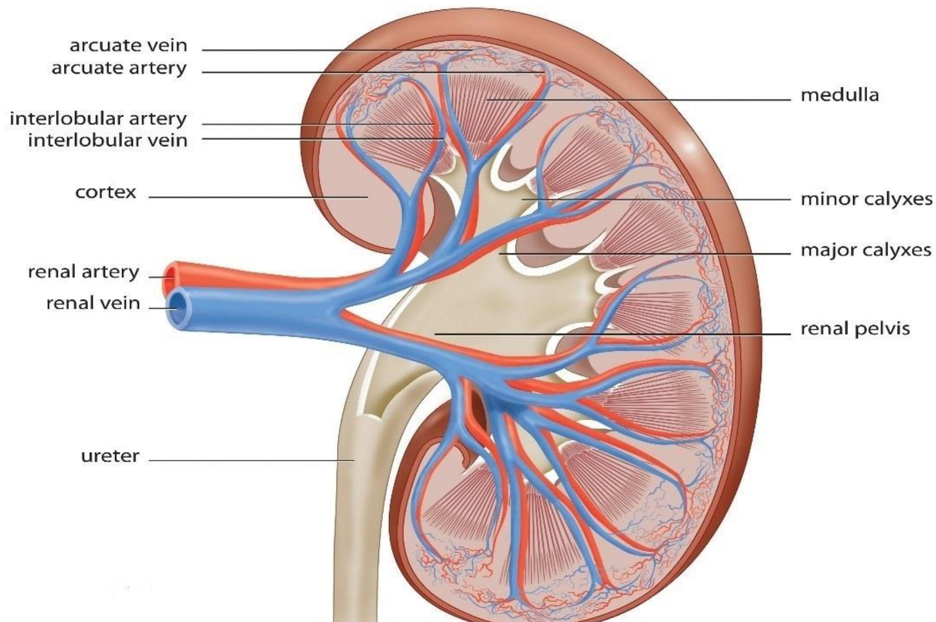
# Chapter Two

# Literature review and previous studies

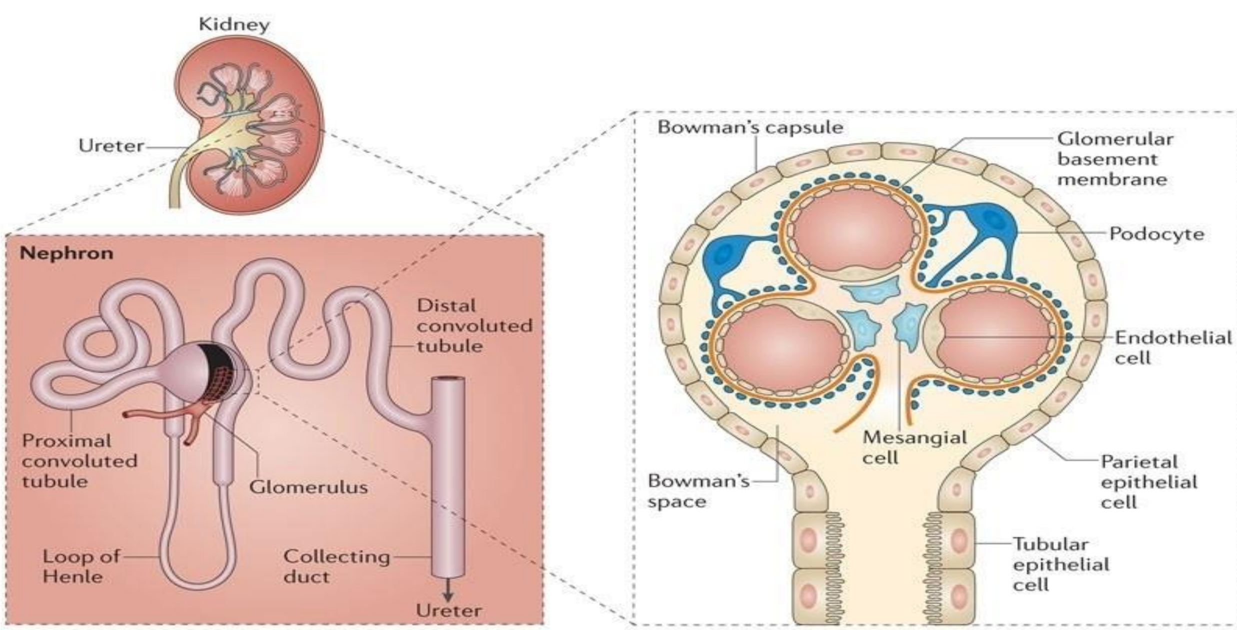
## 2-1 Literature review (Renal Anatomy and Physiology)

### 2-1-1 Renal Anatomy:

The kidneys are pair of bean-shaped retroperitoneal structures that are normally located along the posterior wall of the abdominal cavity between the transverse processes of T12-L3 vertebrae, with the left kidney typically somewhat more superior in position than the right. The upper poles are normally oriented more medially and posteriorly than the lower poles. The kidneys purify toxic metabolic waste products from the blood in several hundred thousand functionally independent units called nephrons. A nephron consists of one glomerulus and one double hairpin-shaped tubule that drains the filtrate into the renal pelvis. The glomeruli located in the kidney cortex are bordered by the Bowman's capsule. They are lined with parietal epithelial cells and contain the mesangium with many capillaries to filter the blood. The glomerular filtration barrier consists of endothelial cells, the glomerular basement membrane and visceral epithelial cells (also known as podocytes). All molecules below the molecular size of albumin pass the filter and enter the tubule, which consists of the proximal convoluted tubule, the loop of Henle and the distal convoluted tubule. An intricate countercurrent system forms a high osmotic gradient in the renal medulla that concentrates the filtrate. The tubular epithelial cells reabsorb water, small proteins, amino acids, carbohydrates and electrolytes, thereby regulating plasma osmolality, extracellular volume, blood pressure and acid–base and electrolyte balance. Non-reabsorbed compounds pass from the tubular system into the collecting ducts to form urine. The space between the tubules is called the interstitium and contains most of the intrarenal immune system, which mainly consists of dendritic cells, but also of macrophages and fibroblasts. .(Thomas R. 2013)



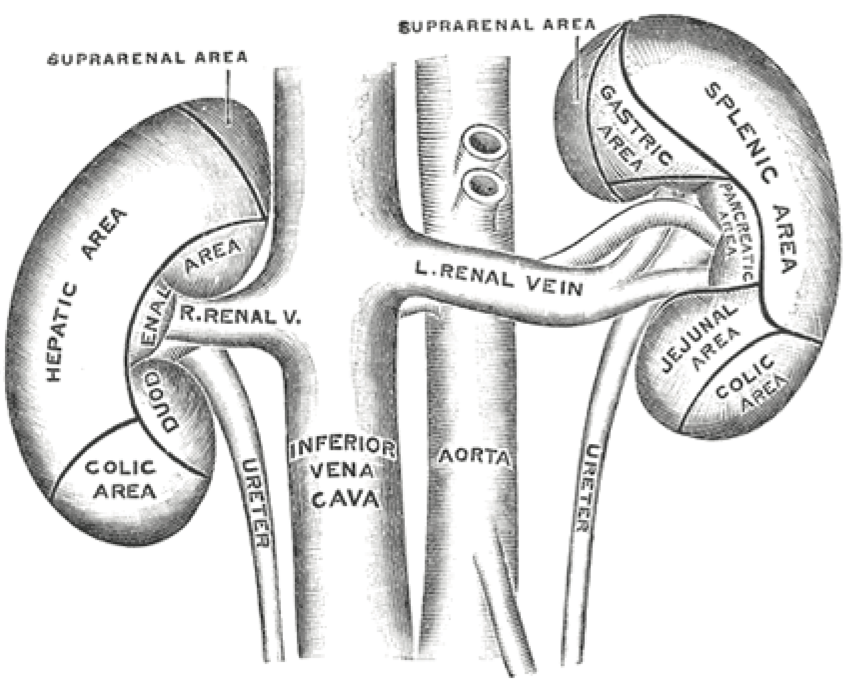

Figer (2-1) A showing renal anatomy




**(B)** **Figer (2-1) B and C showing renal micro anatomy** **(C)**

### 2-1-2 The relationship of neighboring organs to the kidneys is important, as described below:

Superiorly, the suprarenal (adrenal) glands sit adjacent to the upper pole of each kidney. On the right side, the second part of the duodenum (descending portion) abuts the medial aspect of the kidney. On the left side, the greater curvature of the stomach can drape over the superomedial aspect of the kidney, and the tail of the pancreas may extend to overlie the renal hilum. The spleen is located anterior to the upper pole and connected by the splenorenal (lienorenal) ligaments. Inferiorly to these organs, the colon typically rests anteriorly to the kidneys on both sides. Posteriorly, the diaphragm covers the upper third of each kidney, with the 12th rib most commonly crossing the upper pole. The kidneys sit over the psoas (medially) and the quadratus lumborum muscles (laterally) .(Thomas R. 2013)




Figer (2-2) showing the relationship of neighboring organs to the kidneys

### 2-1-3 Vasculature

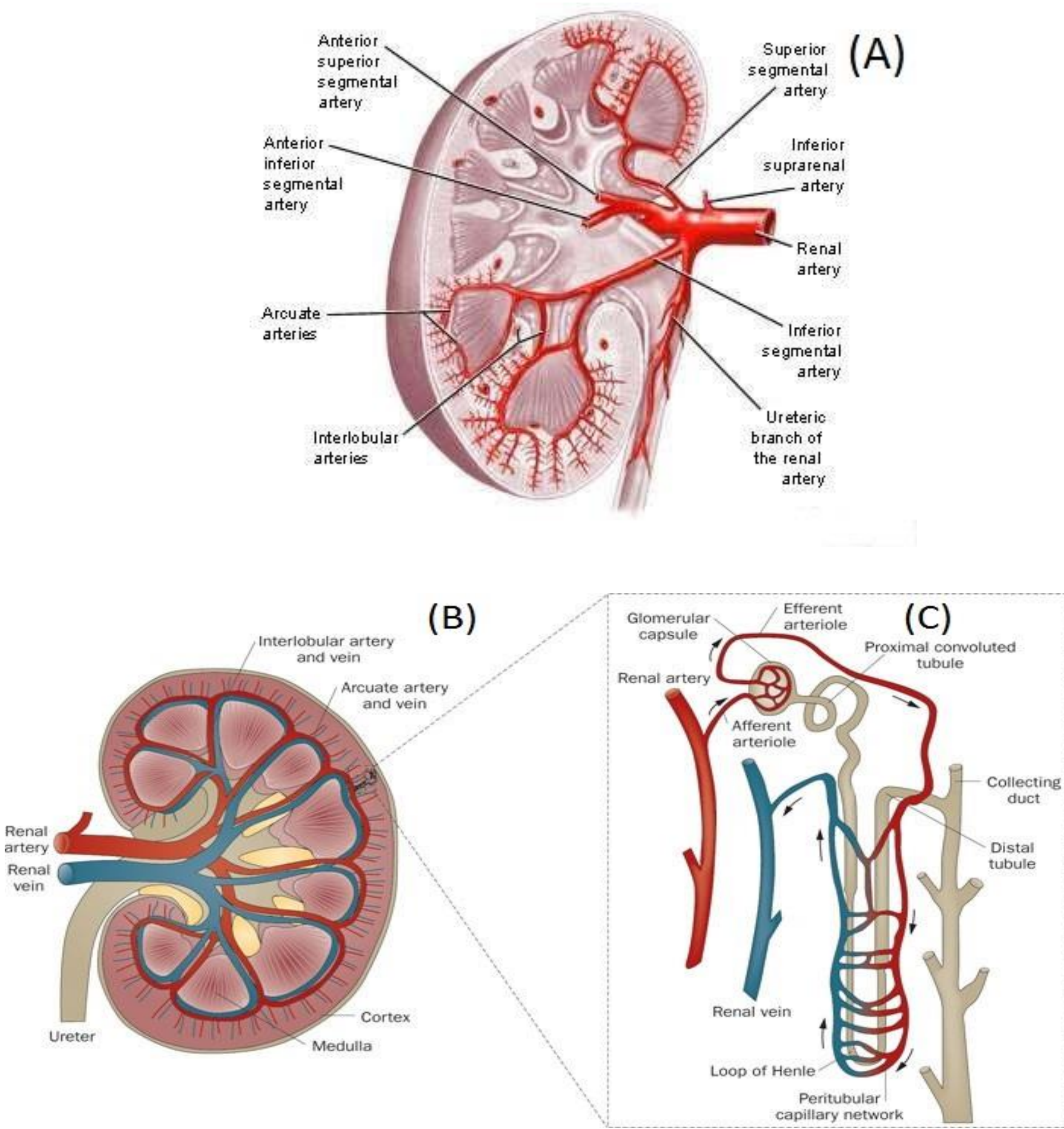
The kidneys receive approximately 20% of the cardiac output. The blood supply to the kidneys arises from the paired renal arteries at the level of L2. They enter into the renal hilum, the passageway into the kidney, with the renal vein anteriorly, the renal artery and the renal pelvis posteriorly.

The first branch of the renal artery is the inferior suprarenal artery. The renal artery then branches off into five segmental branches. The posterior segmental artery supplies most of the posterior kidney, with the exception of the lower pole. The anterior branches are the superior segmental artery, anterior superior segmental artery, anterior inferior segmental artery, and inferior segmental artery. These arteries branch into interlobar arteries, which travel in a parallel fashion in between the major calyces and then branch further into arcuate arteries that run within the cortex across the bases of the renal pyramids.

They then radiate into interlobular arteries, which extend into the cortex of the kidney to finally become afferent arterioles, then peritubular capillaries to efferent arterioles. Some of the terminal branches of the interlobular arteries become perforating radiate arteries, which supply the renal capsule. Renal pelvic and superior ureteric branches also originate from the renal artery and supply the upper portion of the collecting system.

The renal veins drain the kidneys in a similar distribution, and the renal vein is generally anterior to the renal artery at the hilum. The left renal vein is longer than the right as it crosses the midline to reach the inferior vena cava (IVC). Generally, the left gonadal vein drains into the left renal vein inferiorly, while the left suprarenal vein drains into the superior aspect of the renal vein at approximately the same level.

Posteriorly, the left second lumbar vein typically drains into the left renal vein as well. The left renal vein then crosses under the origin of the superior mesenteric artery to reach the IVC. On the right side, the renal vein and gonadal vein drain separately and directly into the IVC.(Thomas R. 2013)




Figer (2-3) A, B and C showing the renal vasculature

### 2-1-4 Renal lymphatics

The lymphatic drainage parallels the venous drainage system. After leaving the renal hilum, the left primary lymphatic drainage is into the left lateral aortic lymph nodes, including nodes anterior and posterior to the aorta between the inferior mesenteric artery and the diaphragm. On the right, it drains into the right lateral caval lymph nodes. (Christian Kurts, Ulf Panzer, Hans-Joachim Anders & Andrew J. ReesNature Reviews Immunology13,738–753(2013)doi:10.1038/nri3523)

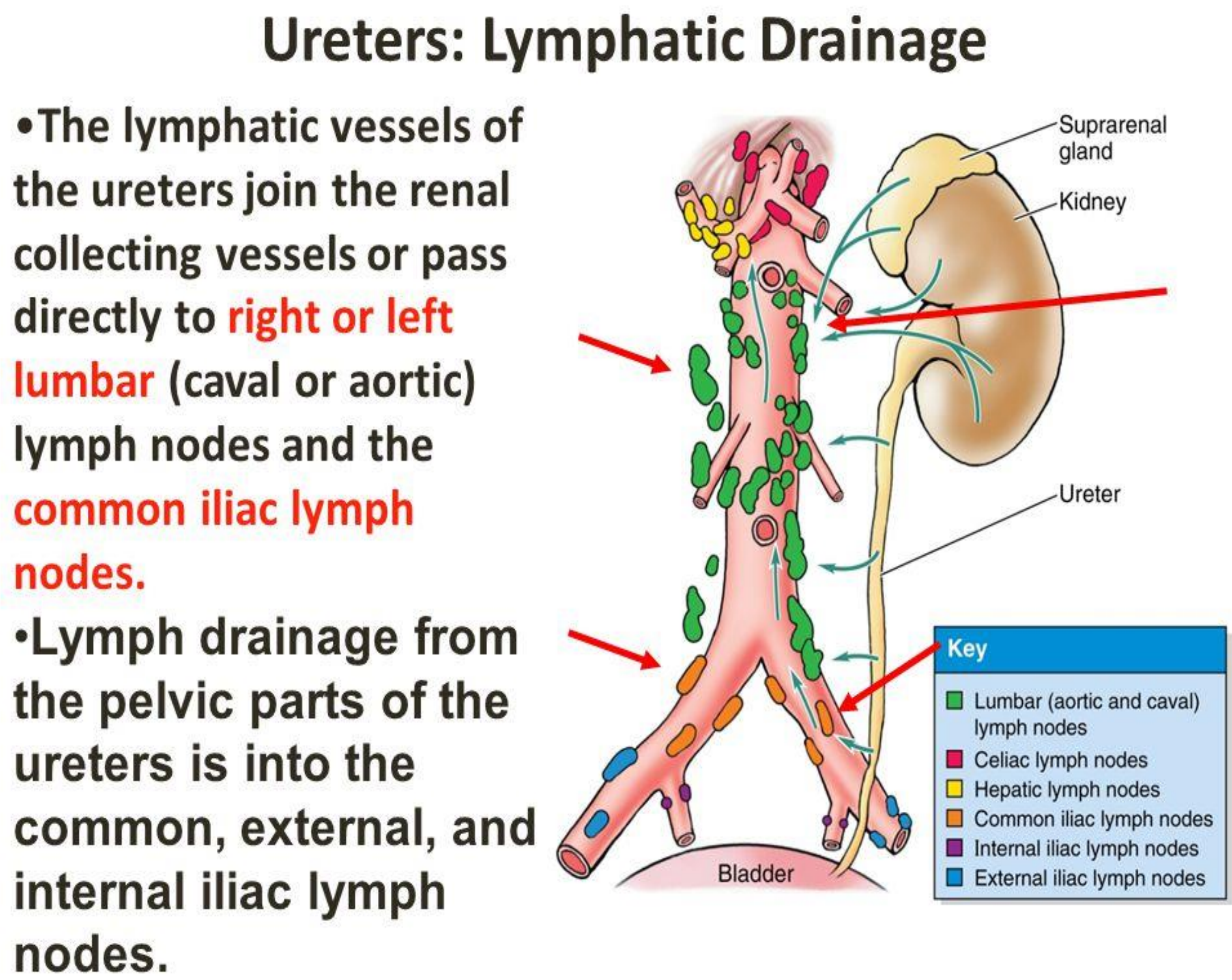



Fig (2-4) showing the renal lymphatic derange.

## 2-1-5 Renal nerve anatomy/autonomic innervation

The kidney receives autonomic supply via both the sympathetic and parasympathetic portions of the nervous system. The preganglionic sympathetic nervous innervation to the kidneys arises from the spinal cord at the level of T8-L1. They synapse onto the celiac and aorticorenal ganglia and follow the plexus of nerves that run with the arteries. Activation of the sympathetic system causes vasoconstriction of the renal vessels. Parasympathetic innervation arises from the 10th cranial nerve (X), the vagus nerve, and causes vasodilation when stimulated.

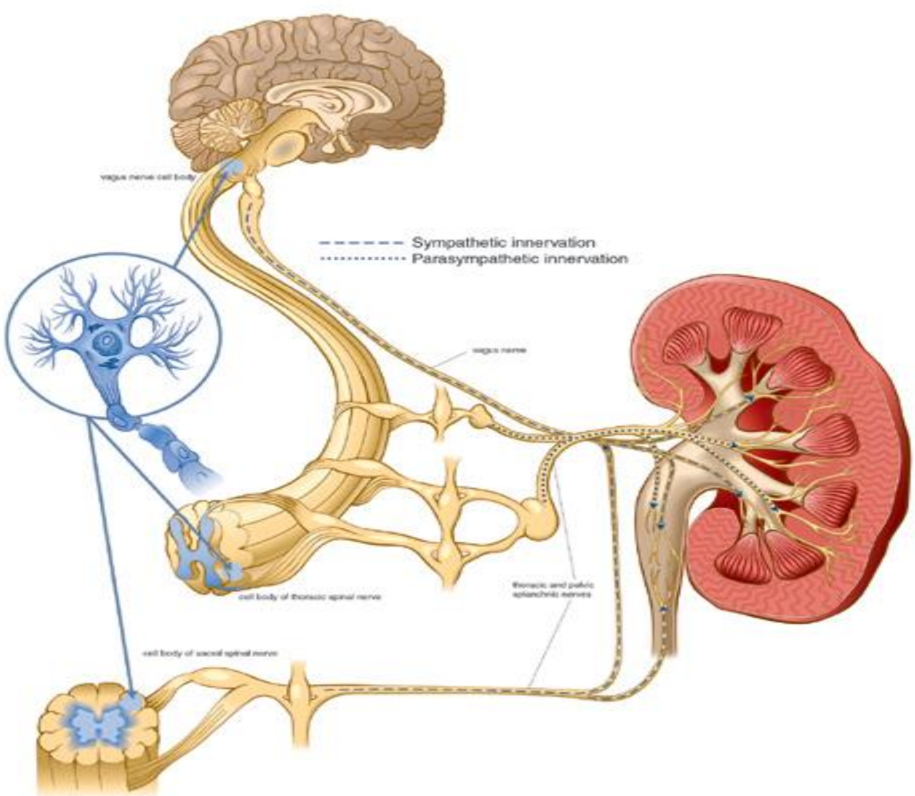



Fig (2-5) showing the renal innervation

### 2-1-6 Natural Variants

Anatomic variations in the renal vasculature occur in approximately 25-40% of patients. Supernumerary, or accessory, renal arteries are the most common arterial variation, with most of these branches supplying the lower pole of the kidney. They may pass anterior to the inferior vena cava (IVC) and over the ureteropelvic junction and be associated with (or cause) obstruction of the ureteropelvic junction (UPJ). Persistence of the right subcardinal vein anterior to the ureter can lead to a retrocaval ureter, which can also cause obstruction. Kidney position in the retroperitoneum is subject to variation as well. A kidney may be in an ectopic location, such as the pelvis, when it does not ascend properly, or it can be malrotated or fused (as in horseshoe kidneys, in which the inferior poles are fused, causing a U-shaped configuration). In some fusion anomalies, such as crossed-fused ectopia, the two kidneys may be located on the same side. Although some of these variations may be associated with pathological conditions, such as hydronephrosis and UPJ obstruction, they can also remain completely asymptomatic and undiscovered until a diagnosis is made by radiographic study. Importantly, in an ectopic kidney, the adrenals should still be in the superior portion of the posterior peritoneum, since their embryologic origin is different from that of the kidneys. Variants may also exist in the collecting system drainage. Duplication anomalies may develop, wherein more than a single collecting system may form and drain separately into the bladder (complete duplication) or join at some point proximally before draining into a single orifice into the urinary bladder (partial duplication). In a complete duplicated system, the upper pole moiety drains inferomedially into the bladder, and the lower pole moiety drains superolaterally, as described by the Weigert-Meyer rule.

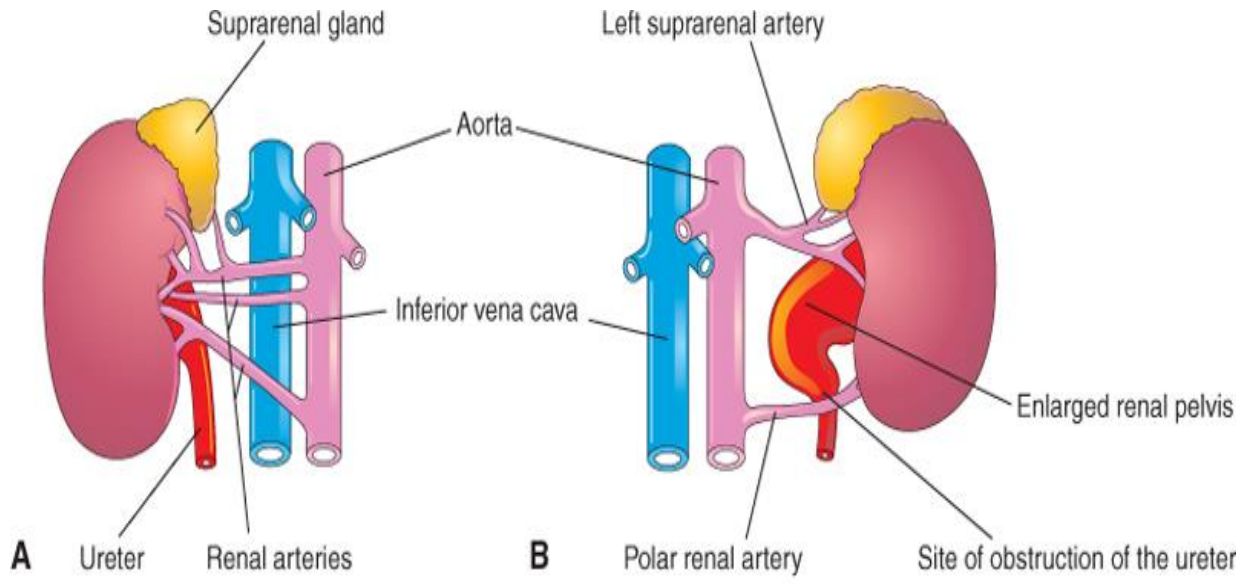



Fig (2-6) A and B showing Supernumerary, or accessory, renal arteries.

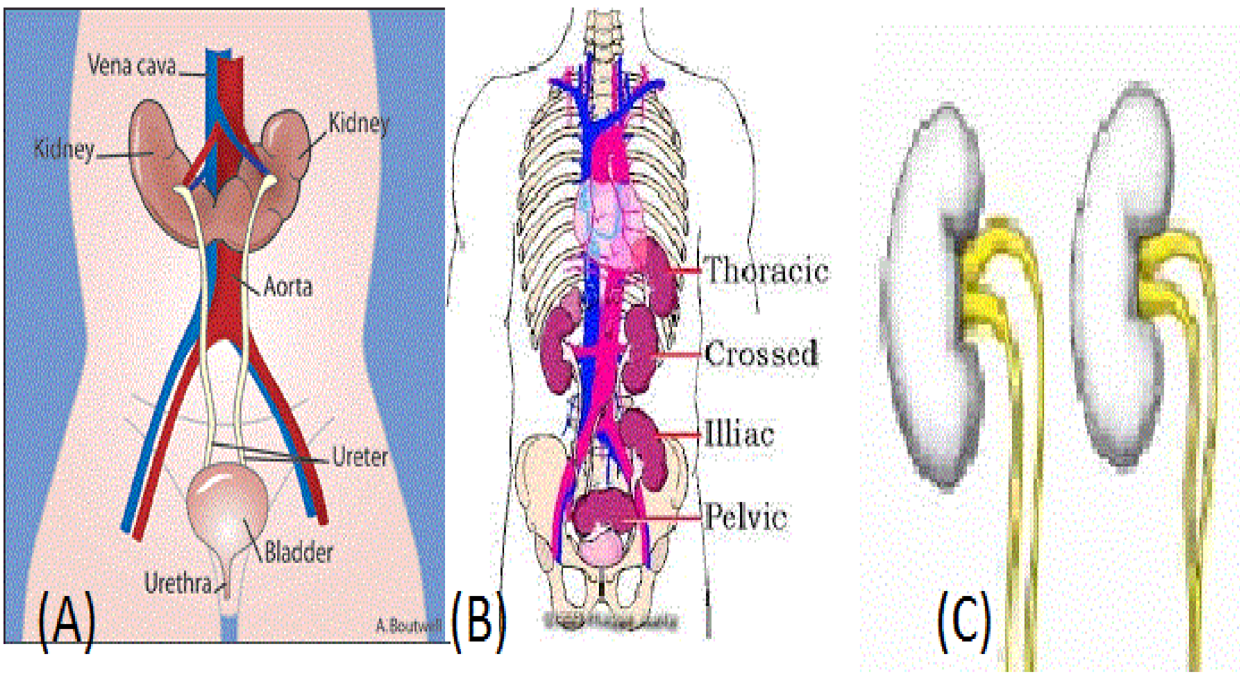



Fig (2-7) A showing fusion anomaly, B ectopic kidneys and C duplication anomalies

## 2-2 Renal physiology:

The kidneys serve important functions, including filtration and excretion of metabolic waste products (urea and ammonium); regulation of necessary electrolytes, fluid, and acid-base balance; and stimulation of red blood cell production. They also serve to regulate blood pressure via the renin-angiotensin-aldosterone system, controlling reabsorption of water and maintaining intravascular volume. The kidneys also reabsorb glucose and amino acids and have hormonal functions via erythropoietin, calcitriol, and vitamin D activation.

### 2-2-1 Maintenance of Homeostasis:

The kidneys maintain the homeostasis of several important internal conditions by controlling the excretion of substances out of the body.

Ions: The kidney can control the excretion of potassium, sodium, calcium, magnesium, phosphate, and chloride ions into urine. In cases where these ions reach a higher than normal concentration, the kidneys can increase their excretion out of the body to return them to a normal level. Conversely, the kidneys can conserve these ions when they are present in lower than normal levels by allowing the ions to be reabsorbed into the blood during filtration. (See more about ions.)

HP: The kidneys monitor and regulate the levels of hydrogen ions (H+) and bicarbonate ions in the blood to control blood pH. H+ ions are produced as a natural byproduct of the metabolism of dietary proteins and accumulate in the blood over time. The kidneys excrete excess H+ ions into urine for elimination from the body. The kidneys also conserve bicarbonate ions, which act as important pH buffers in the blood.

Osmolarity: The cells of the body need to grow in an isotonic environment in order to maintain their fluid and electrolyte balance. The kidneys maintain the body's osmotic balance by controlling the amount of water that is filtered out of the blood and excreted into urine. When a person consumes a large amount of water, the kidneys reduce their reabsorption of water to allow the excess water to be excreted in urine. This results in the production of dilute, watery urine. In the case of the body being dehydrated, the kidneys reabsorb as much water as possible back into the blood to produce highly concentrated urine full of excreted ions and wastes. The changes in excretion of water are controlled by antidiuretic hormone (ADH). ADH is produced in the hypothalamus and released by the posterior pituitary gland to help the body retain water. ( Taylor T.)

Blood Pressure: The kidneys monitor the body's blood pressure to help maintain homeostasis. When blood pressure is elevated, the kidneys can help to reduce blood pressure by reducing the volume of blood in the body. The kidneys are able to reduce blood volume by reducing the reabsorption of water into the blood and producing watery, dilute urine. When blood pressure becomes too low, the kidneys can produce the enzyme renin to constrict blood vessels and produce concentrated urine, which allows more water to remain in the blood.

### 2-2-2 Filtration

Inside each kidney are around a million tiny structures called nephrons. The nephron is the functional unit of the kidney that filters blood to produce urine. Arterioles in the kidneys deliver blood to a bundle of capillaries surrounded by a capsule called a glomerulus. As blood flows through the glomerulus, much of the blood's plasma is pushed out of the capillaries and into the capsule, leaving the blood cells and a small amount of plasma to continue flowing through the capillaries. The liquid filtrate in the capsule flows through a series of tubules lined with filtering cells and surrounded by capillaries. The cells surrounding the tubules selectively absorb water and substances from the filtrate in the tubule and return it to the blood in the capillaries. At the same time, waste products present in the blood are secreted into the filtrate. By the end of this process, the filtrate in the tubule has become urine containing only water, waste products, and excess ions. The blood exiting the capillaries has reabsorbed all of the nutrients along with most of the water and ions that the body needs to function.( Taylor T.)

### 2-2-3 Storage and Excretion of Wastes

After urine has been produced by the kidneys, it is transported through the ureters to the urinary bladder. The urinary bladder fills with urine and stores it until the body is ready for its excretion. When the volume of the urinary bladder reaches anywhere from 150 to 400 milliliters, its walls begin to stretch and stretch receptors in its walls send signals to the brain and spinal cord. These signals result in the relaxation of the involuntary internal urethral sphincter and the sensation of needing to urinate. Urination may be delayed as long as the bladder does not exceed its maximum volume, but increasing nerve signals lead to greater discomfort and desire to urinate.

Urination is the process of releasing urine from the urinary bladder through the urethra and out of the body. The process of urination begins when the muscles of the urethral sphincters relax, allowing urine to pass through the urethra. At the same time that the sphincters relax, the smooth muscle in the walls of the urinary bladder contract to expel urine from the bladder.

### 2-2-4 Production of Hormones:

The kidneys produce and interact with several hormones that are involved in the control of systems outside of the urinary system. Calcitriol: Calcitriol is the active form of vitamin D in the human body. It is produced by the kidneys from precursor molecules produced by UV radiation striking the skin. Calcitriol works together with parathyroid hormone (PTH) to raise the level of calcium ions in the bloodstream. When the level of calcium ions in the blood drops below a threshold level, the parathyroid glands release PTH, which in turn stimulates the kidneys to release calcitriol. Calcitriol promotes the small intestine to absorb calcium from food and deposit it into the bloodstream. It also stimulates the osteoclasts of the skeletal system to break down bone matrix to release calcium ions into the blood (Tim Taylor, Anatomy and Physiology Instructor http://www.innerbody.com) .Erythropoietin: Also known as EPO, is a hormone that is produced by the kidneys to stimulate the production of red blood cells. The kidneys monitor the condition of the blood that passes through their capillaries, including the oxygen-carrying capacity of the blood. When the blood becomes hypoxic, meaning that it is carrying deficient levels of oxygen, cells lining the capillaries begin producing EPO and release it into the bloodstream. EPO travels through the blood to the red bone marrow, where it stimulates hematopoietic cells to increase their rate of red blood cell production. Red blood cells contain hemoglobin, which greatly increases the blood's oxygen-carrying capacity and effectively ends the hypoxic conditions.

Renin: Renin is not a hormone itself, but an enzyme that the kidneys produce to start the renin-angiotensin system (RAS). The RAS increases blood volume and blood pressure in response to low blood pressure, blood loss, or dehydration. Renin is released into the blood where it catalyzes angiotensinogen from the liver into angiotensin I. Angiotensin I is further catalyzed by another enzyme into Angiotensin II. Angiotensin II stimulates several processes, including stimulating the adrenal cortex to produce the hormone aldosterone. Aldosterone then changes the function of the kidneys to increase the reabsorption of water and sodium ions into the blood, increasing blood volume and raising blood pressure. Negative feedback from increased blood pressure finally turns off the RAS to maintain healthy blood pressure levels. ( Taylor T.)

## 2-3 Technique:

No patient preparation needed.

Patient lies supine the coupling agent placed on the both sides right and left. Then the ultrasound transducer placed on the right side at (ten o'clock) at the mid axillary line of the right side of the patient to scan the longitudinal axis of the right kidney to measure the length and width of the right kidney. Then the ultrasound prop rotated (90 degrees) to obtain the short axis of the right kidney and measure the antroposterior diameter of the right kidney.

Then the ultrasound transducer placed on the left side at (one o'clock) at the mid axillary line of the left side of the patient to scan the longitudinal axis of the left kidney to measure the length and width of the left kidney. Then the ultrasound prop rotated (90 degrees) to obtain the short axis of the left kidney and measure the antroposterior diameter of the left kidney.

## 2-4 Previous Studies:

Kim J. H. et. al. (2013) studied Length and Volume of Morphologically Normal Kidneys in Korean Children: Ultrasound Measurement and Estimation Using Body Size, they examined 794 Korean children under 18 years of age including a total of 394 boys and 400 girls without renal problems. The maximum renal length (L) (cm), orthogonal anterior-posterior diameter (D)ss (cm) and width (W) (cm) of each kidney were measured on ultrasound. Kidney volume was calculated as 0.523 × L × D × W (cm3). Anthropometric indices including height (cm), weight (kg) and body mass index (m2/kg) were collected through a medical record review. they used linear regression analysis to create simple equations to estimate the renal length and the volume with those anthropometric indices that were mostly correlated with the US-measured renal sizes. In result Renal length showed the strongest significant correlation with patient height ($R^2$, 0.874 and 0.875 for the right and left kidneys, respectively, $p < 0.001$). Renal volume showed the strongest significant correlation with patient weight ($R^2$, 0.842 and 0.854 for the right and left kidneys, respectively, $p < 0.001$). The following equations were developed to describe these relationships with an estimated 95% range of renal length and volume ($R^2$, 0.826-0.884, $p < 0.001$): renal length = 2.383 + 0.045 × Height (± 1.135) and = 2.374 + 0.047 × Height (± 1.173) for the right and left kidneys, respectively; and renal volume = 7.941 + 1.246 × Weight (± 15.920) and = 7.303 + 1.532 × Weight (± 18.704) for the right and left kidneys, respectively.

Konu S . L. et, al (1998) evaluated Dimensions kidney, liver and spleen In Neonates, Infants, And Children With ultrasonography, The Objective of their study was to determine the normal range of dimensions for the liver, spleen, and kidney in healthy neonates, infants, and children. This Prospective studyed involved 307 Pediatric subjects (169 Girls and 138 boys) with normal physical or sonographic findings who were examined because of problems unrelated to the measured organs. The Subjects were 5 Days to 16 Years old. All Measured organs were sonographically normal. At Least two dimensions were obtained for each liver, spleen, and kidney. Relationships Of the dimensions of these organs with sex, age, body weight, height, and body surface area were investigated. Suggested Limits of normal dimensions were defined. In results: Dimensions Of the measured organs were not statistically different in boys and girls. Longitudinal Dimensions of all three organs showed the best correlation with age, body weight, height, and body surface area. Height Showed the strongest correlation of all. This Correlation was a polynomial correlation

TIV A. O. et, al. (2012) studied Sonographic Measurement of Renal Size in Normal Indian Children, the study made at Pediatric teaching hospital, Mumbai, India, 1000 normal Indian children aged 1 month – 12 years were scanned, sonographic assessment of renal size (length, width and thickness) was performed using Philips real time mechanical sector scanner of 3.5-5 MHz frequency with electronic caliper. The mean renal dimensions and volume were calculated for each age group with ± 2SD. The renal length and calculated renal volume were correlated with somatic parameters like age, weight, height and body surface area. Regression equations were derived for each pair of dependent and independent variables. In results: No statistical difference found in renal size between sexes and between right and left kidney. A strong correlation was seen between renal size with various somatic parameters, the best correlation was between renal size length and body height (coefficient of correlation=0.9).

Agwu K.K. et. al. 2014 study determined sonographically the normal limits and percentile curves of the kidney dimensions according to age, gender and somatometric parameters among school-age children. A prospective cross-sectional research design and convenience sampling method utilized. Participants included 947 normal subjects (496 boys and 451 girls) aged 6–17 years old. The sonographic examination performed on a Shenzhen DP-1100 machine with 3.5 MHz convex transducer. Longitudinal and transverse dimensions of the kidneys obtained in coronal plane with the subject in the supine or left lateral decubitus position. In RESULTS: The means of right and left kidney lengths in mm were 79.6 ± 8.1 and 81.6 ± 8.3, respectively while those of the right and left kidney widths in mm were 35.03 ± 3.6 and 35.09 ± 3.6, respectively. Dimensions of the kidneys were not statistically different in boys and girls ($p > 0.05$). There was a statistically significant difference between right and left kidney length ($p < 0.05$). Height correlated best with both kidney lengths. Thus the normal limits, prediction models and percentile curves of kidney lengths were established with respect to height.

Haugstvedt S. et. al. (2010) studied Kidney length and depth, the study measured kidney by sonography in 46 normal children from 0 to 16 years of age. Sonography was used to obtain kidney measurements without the known magnification caused by factors of chemical and photographic nature seen by urography. The results of this study were used to control the age-adapted equipment for renography in children. There was a good correlation between kidney length and depth and variables like age, weight, height and body surface area. The best values found in the correlations to body surface area. The study confirmed the previous findings by other methods of kidney size measurements in children that there is no significant difference in kidney length between boys and girls. The left kidney is slightly longer than the right one and the kidney centre distance is slightly but significantly larger on the left side. No such difference was present in the distance skin to kidney surface.

Anita S. et. al. (2016) study obtained To determine the renal size in normal children by ultrasonography and Correlation of renal size with somatic parameters like age, weight, height and body surface area. It was a prospective observational study, was done in Niloufer hospital for womenand child between 2012 march to 2013 march. Normal children aged 1 month to 12 yrs were included in the study. These children were either healthy siblings of patients attending the out patient clinics or those visiting well –baby clinics. A Philips real –time mechanical sector scanner of 3.5 – 5 MHZ frequency with electronic calipers was used to measure the length, width and thickness of each kidney with the child placed in a supine oblique position. Child somatic parameters were compared to kidney size. In Results: There were 250 children in 16 age groups from 1 month to 12 years of age. The mean renal length increased steadily with age from 4.4 cm at 1 month to 8.7 cm at 12yrs of age with a standard deviation of 0.5 at 1 month to 0.9 at 12 years of age. The mean renal volume increased from 9.9 ml at 1 month of age to 62.8 ml at 12 yrs of age with a standard deviation of 5.0 at 1 month to 13.9 at 12 years of age. The best correlation was of length with body height and the best correlation was of renal volume with BSA.

# Chapter Three

# Methodology

## 3-1 Design of the study:

This is a descriptive study designed to measure kidneys length and volume in Sudanese children using B-mode ultrasonography.

## 3-2 Population of the Study:

The study included volunteers in ages of 6-13 years of both genders with no morphological abnormalities, while children with ectopic kidney, cyst, stones or other pathological conditions were excluded.

## 3-3 Sample size and type:

The sample of this study consist of 104 volunteers, 49 volunteer from Khartoum state (24 male and 25 female), and 55 volunteers from western Kurdufan state (25 male and 30 female).

## 3-4 Study area and Duration:

This study have carried out in Khartoum state and western Kurdufan state, In Khartoum state the data collected at Alzaeem Alazhary private primary school, in western Kurdufan, the data collected In Babanusa city at Alhamya primary school. The data collected during period from September to October 2016.

### 3-5 Material:

The data collected by Fukuda Denshi Ultrasound machine, using curve linear transducers, frequencies of 2.5 - 5 MHz have carried out.

### 3-6 Method of data collection:

Each volunteer scanned twice, in an international scanning guidelines and protocols, firstly by the researcher and then by a qualified sinologist to confirm the findings. Ultrasound technique was performed with patient lying in supine position, were an adequate amount of ultrasound coupling gel had been placed on the patient's abdomen,

### 3-7 Study Variables:

The variables of the study consist of the following: age, gender, height and weight to calculate BMI, and right and left kidneys length and volume.

### 3-8 Method of data analysis:

The data analyzed using SPSS and EXIL under windows, by finding the correlation, liner association and significant differences between kidneys length and volume and age, gender, height, weight, BMI and geographic area.

### 3-9 Ethical Clearance:

Permission of departments and at the area of the study granted as well as volunteers parents' permission to use the collected data for scientific purposes; volunteers' details will not be disclosed.

# Chapter Four

# Results

## 4-1 Results:

The result of this study obtained from following figures and tables presenting the data obtained from 104 subjects 49 volunteer from Khartoum state (24 male and 25 female), and 55 volunteers from western Kurdufan state (25 male and 30 female) scanned by B-mode ultrasound machine with 2.5 - 5 MHZ linear transducer and the relation between different variables presented by using t.test and scatter plot.

**Table 4-1: Mean and standard deviation of Right and Left kidney measurements**

| Kidney measurements | Mean | Std. Deviation |
|---|---|---|
| Length (Rt) | 8.034 | .8241 |
| Length (Lt) | 8.212 | .8863 |
| Width (Rt) | 3.496 | .5297 |
| Width (Lt) | 3.818 | .5420 |
| AP (Rt) | 3.684 | .5303 |
| AP (Lt) | 3.834 | .5276 |
| Volume (Rt) | 55.9348 | 19.96373 |
| Volume (Lt) | 64.9968 | 21.67046 |

**Table 4-2: T-test shows significant difference in means between Right and Left kidney measurements**

| Kidneys measurements | T | Sig. (2-tailed) |
|---|---|---|
| Length Rt & Length Lt | 3.513 | .001 |
| Width Rt & Width Lt | 6.755 | .000 |
| AP Rt & AP Lt | 3.665 | .000 |
| Volume Rt & Volume Lt | 6.600 | .000 |

**Table 4-3: Mean and standard deviation of Right and Left kidney measurements in respect to area**

| Study variables | Area | Mean | Std. Deviation |
|---|---|---|---|
| Length Rt | Kurdufan | 7.949 | .8641 |
| | Khartoum | 8.109 | .7870 |
| Width Rt | Kurdufan | 3.267 | .4038 |
| | Khartoum | 3.700 | .5481 |
| AP Rt | Kurdufan | 3.373 | .4182 |
| | Khartoum | 3.960 | .4645 |
| Volu1e Rt | Kurdufan | 46.8590 | 13.77971 |
| | Khartoum | 64.0205 | 21.21514 |
| Length Lt | Kurdufan | 8.169 | .9689 |
| | Khartoum | 8.249 | .8128 |
| Width Lt | Kurdufan | 3.637 | .5503 |
| | Khartoum | 3.980 | .4843 |
| AP Lt | Kurdufan | 3.553 | .4678 |
| | Khartoum | 4.084 | .4488 |
| Volume Lt | Kurdufan | 57.3773 | 20.36816 |
| | Khartoum | 71.7851 | 20.67255 |

**Table 4-4: T-test shows significant difference in means between Right and Left kidney measurements in respect to area**

| Independent Samples Test | | |
|---|---|---|
| | t-test for Equality of Means | |
| | t | Sig. (2-tailed) |
| Length Rt | -.989 | .325 |
| Width Rt | -4.536 | .000 |
| AP Rt | -6.735 | .000 |
| Volu1e Rt | -4.826 | .000 |
| Length Lt | -.456 | .649 |
| Width Lt | -3.384 | .001 |
| AP Lt | -5.900 | .000 |
| Volu1e Lt | -3.573 | .001 |

**Table 4-5: Mean and standard deviation of study variables in respect to gender**

| Study variables | Gender | Mean | Std. Deviation |
|---|---|---|---|
| Height | Male | 131.980 | 12.3819 |
| | Female | 130.236 | 12.4573 |
| Weight | Male | 26.796 | 7.5801 |
| | Female | 26.473 | 7.3355 |
| BMI | Male | 15.059 | 2.0963 |
| | Female | 15.424 | 2.4893 |
| Length Rt | Male | 8.159 | .7646 |
| | Female | 7.922 | .8653 |
| Width Rt | Male | 3.537 | .5510 |
| | Female | 3.460 | .5123 |
| AP Rt | Male | 3.749 | .5378 |
| | Female | 3.625 | .5215 |
| Volume Rt | Male | 58.1235 | 20.59422 |
| | Female | 53.9849 | 19.36445 |
| Length Lt | Male | 8.292 | .8777 |
| | Female | 8.140 | .8958 |
| Width Lt | Male | 3.931 | .4993 |
| | Female | 3.718 | .5631 |
| AP Lt | Male | 3.863 | .5053 |
| | Female | 3.807 | .5500 |
| Volume Lt | Male | 67.7545 | 20.98717 |
| | Female | 62.5400 | 22.16226 |

**Table 4-6: Significant T.test of study variables in respect to gender**

| Independent Samples Test | | |
|---|---|---|
| | t-test for Equality of Means | |
| | t | Sig. (2-tailed) |
| Height | .714 | .477 |
| Weight | .221 | .826 |
| BMI | .802 | .424 |
| Length Rt | 1.475 | .143 |
| Width Rt | .736 | .464 |
| AP Rt | 1.188 | .238 |
| Volume Rt | 1.056 | .294 |
| Length Lt | .871 | .386 |
| Width Lt | 2.025 | .045 |
| AP Lt | .538 | .591 |
| Volume Lt | 1.228 | .222 |

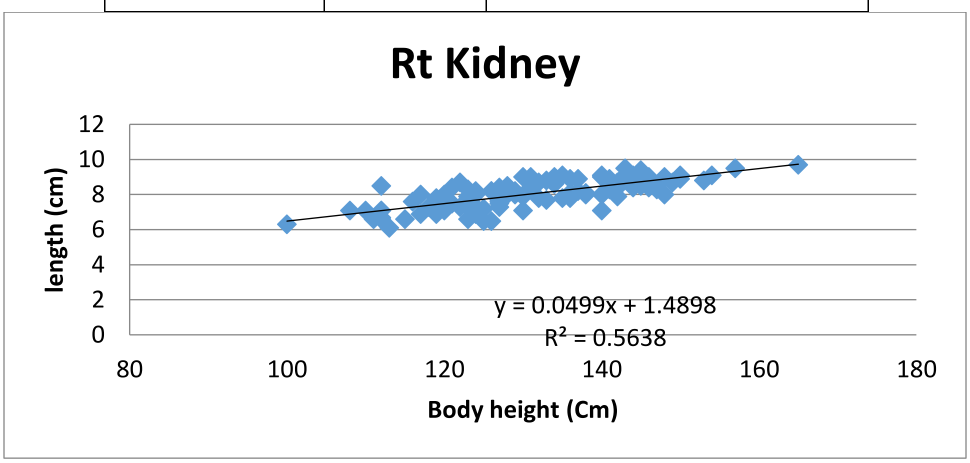



**Diagram (4-1): scatter plot diagram for length of right kidney (cm) and Body height (Cm).**

Diagram (4-1) is a scatter plot use to show linear relationship between body height (cm) and length of Right kidney (cm). A regression equation and correlation squared were calculated, the regression equation was as following: **Length of Right kidney = 0.0499 * Body height + 1.4898.** The correlation was **$R^2$ = 0.5638**

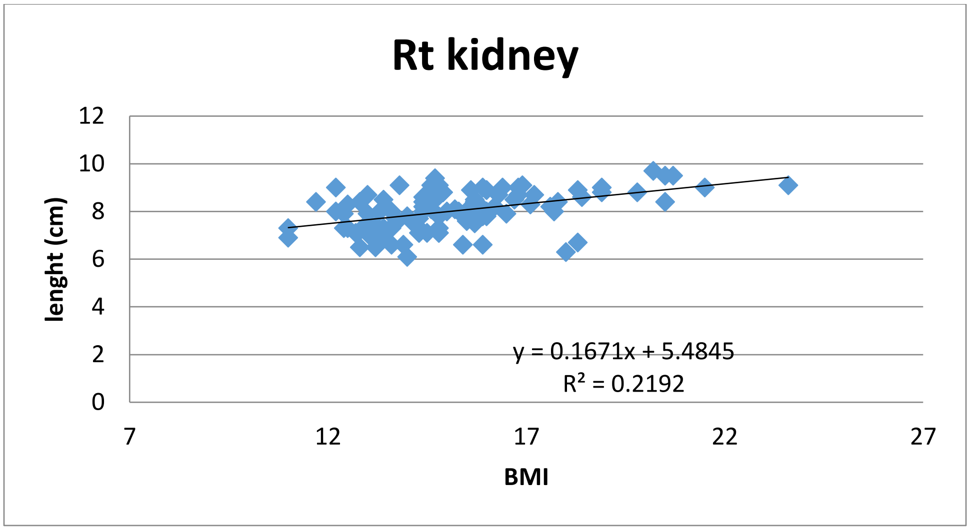



**Diagram (4-2): scatter plot diagram for length of right kidney (cm) and BMI**

Diagram (4-2) is a scatter plot use to show linear relationship between BMI and length of Right kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: **Length of Right kidney = 0.1671* BMI + 5.4845. The correlation was $R^2$ = 0.2192. {Rt kidney length = (0.045×body height) + (0.111×BMI) + 0.435}**

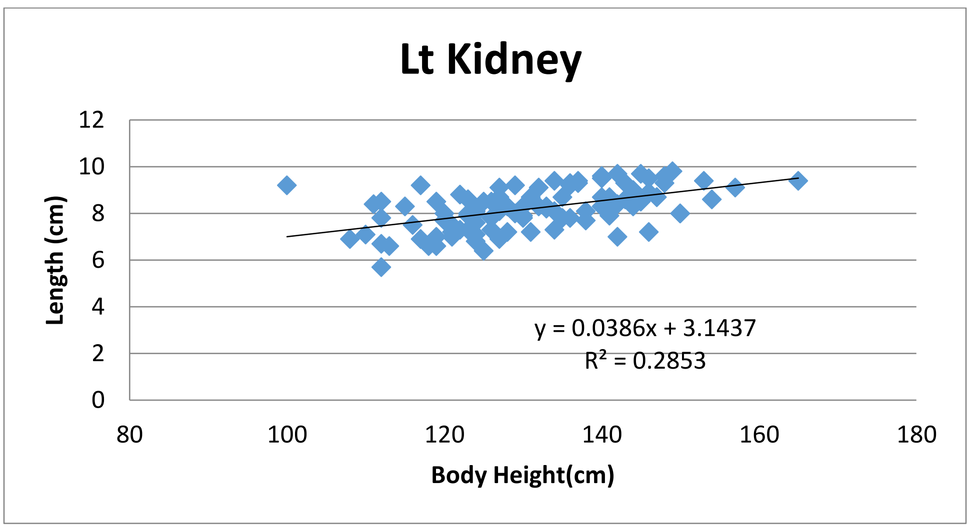



**Diagram (4-3): scatter plot diagram for length of left kidney (cm) and Body height(Cm).**

Diagram (4-3) is a scatter plot use to show linear relationship between body height (cm) and length of left kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: Length of left kidney = 0.0386 * Body height + 3.1437. The correlation was $R^2$ = 0.2853.

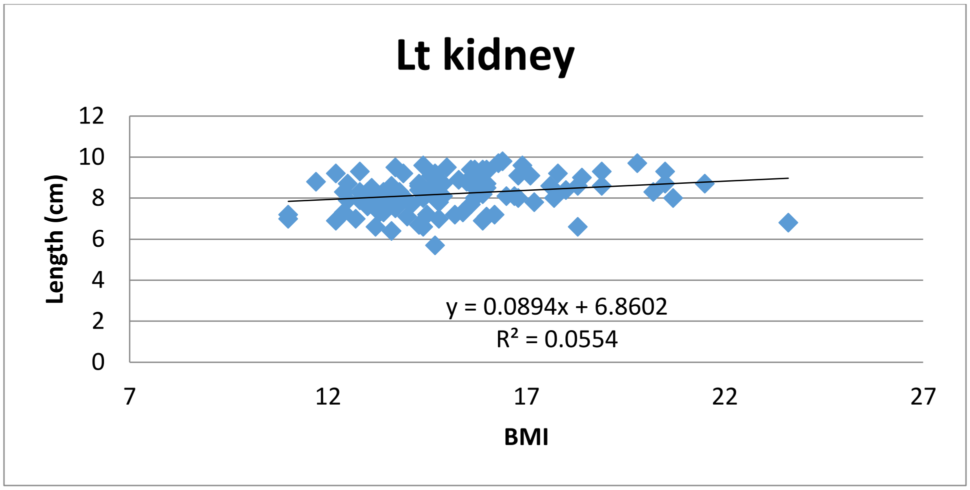



**Diagram (4-4): scatter plot diagram for length of left kidney (cm) and BMI**

Diagram (4-4) is a scatter plot use to show linear relationship between BMI and length of left kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: Length of left kidney = 0.0894* BMI + 6.8602. The correlation was $R^2$ = 0.0554. **{Lt Kidney length = (0.046 * body height) + (0.104 * BMI) + 0.653}**

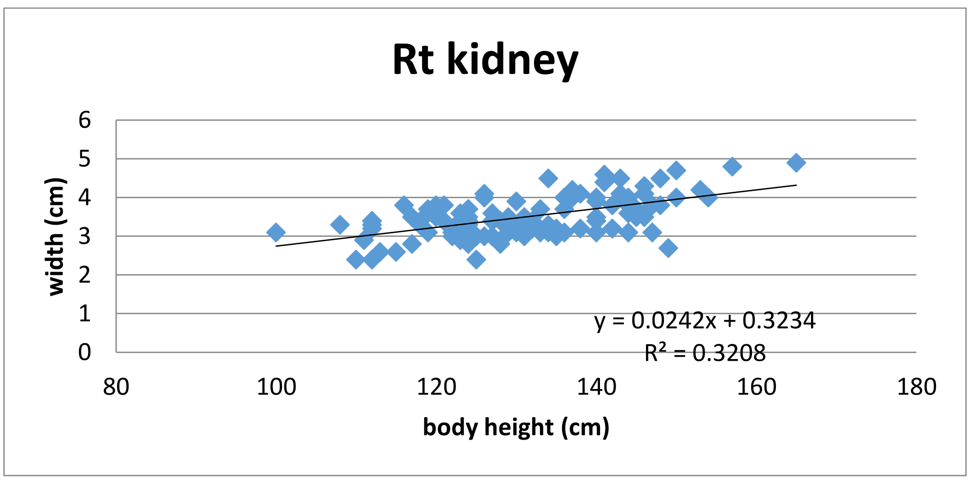



**Diagram 4-5: scatter plot diagram for width of right kidney (cm) and Body height (Cm).**

Diagram 4-5 is a scatter plot use to show linear relationship between body height (cm) and width of Right kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: width of Right kidney = 0.0242* Body height + 0.3234. The correlation was $R^2$ = 0.3208.

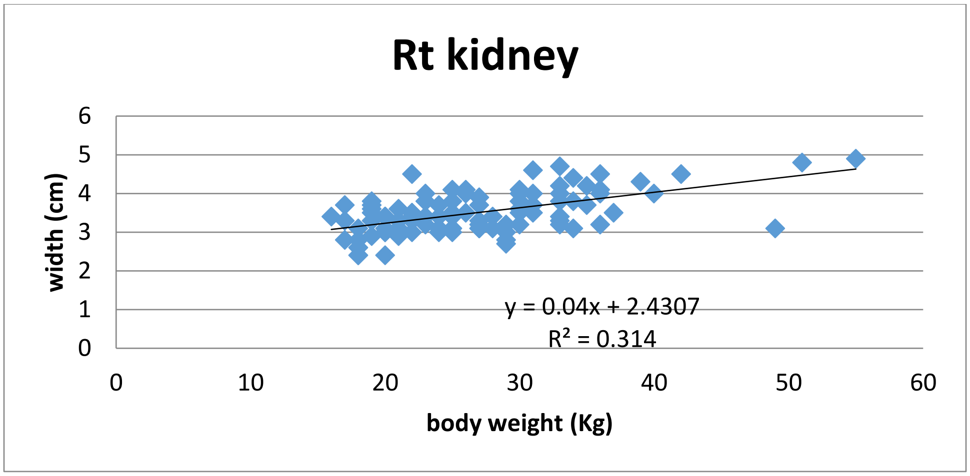



**Diagram 4-6: scatter plot diagram for width of right kidney (cm) and Body weight (kg).**

Diagram 4-6 is a scatter plot use to show linear relationship between body weight (kg) and width of Right kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: width of Right kidney = 0.04* Body weight + 2.4307. The correlation was $R^2 = 0.314$

**{Rt kidney width=(0.014*Body height)+( 0.021 * Body weight)+ 1.112}**

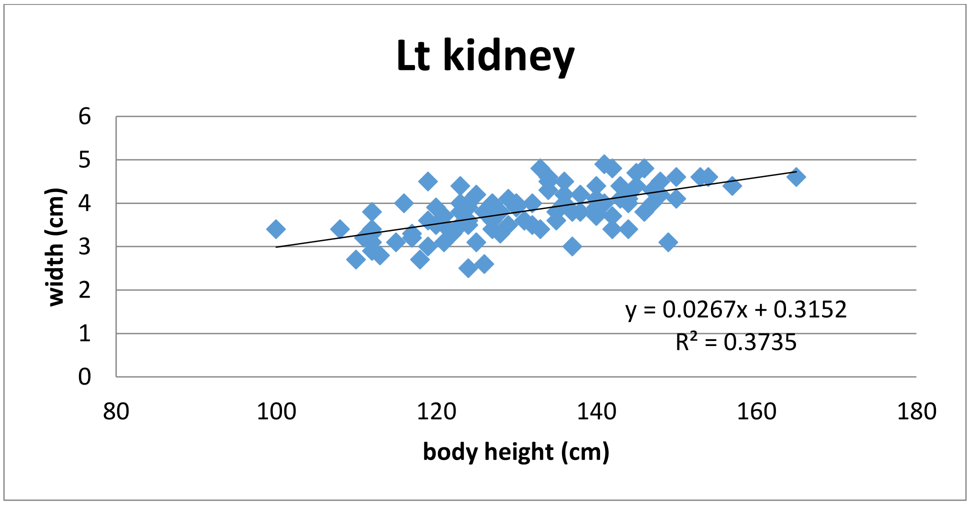



**Diagram 4-7: scatter plot diagram for width of left kidney (cm) and Body height (Cm).**

Diagram 4-7 is a scatter plot use to show linear relationship between body height (cm) and width of left kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: width of left kidney 0.0267* Body height + 0.3152. The correlation was $R^2 = 0.3735$. **{Lt kidney width = (0.0267 * Body height + 0.3152)}**

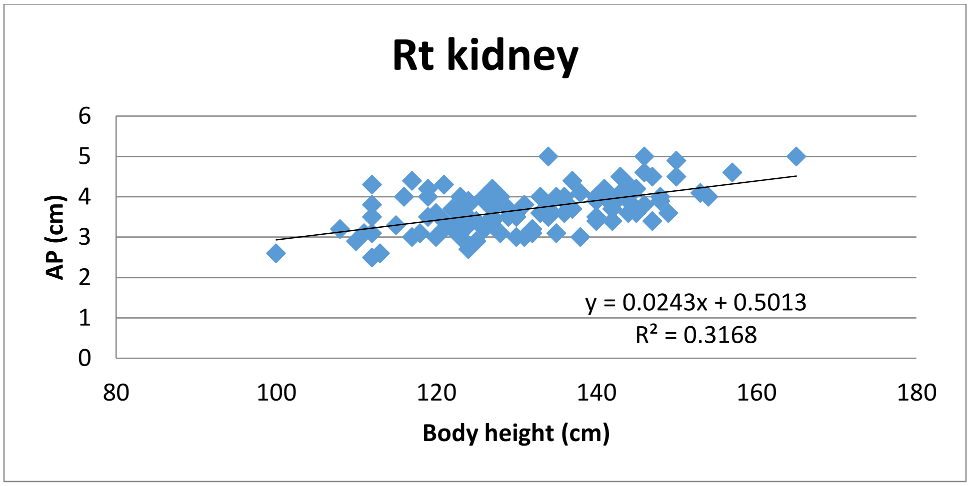



**Diagram 4-8: scatter plot diagram for AP of right kidney (cm) and Body height (Cm).**

Diagram 4-8 is a scatter plot use to show linear relationship between body height (cm) and AP of right kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: AP of right kidney = 0.0243* Body height + 0.5013 The correlation was $R^2 = 0.3168$. **{Rt kidney AP = (0.0243* body height) + (0.5013), $R^2 = 0.3168$}**

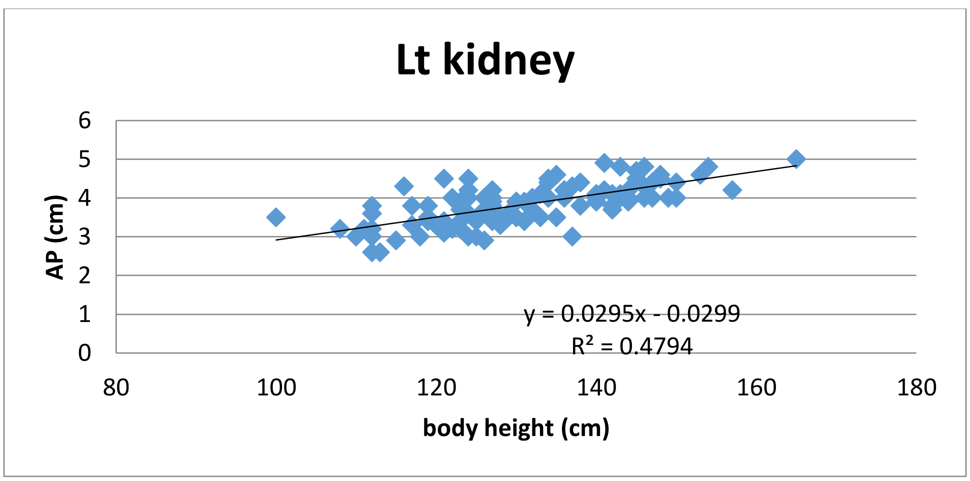



**Diagram 4-9: scatter plot diagram for AP of left kidney (cm) and Body height (Cm).**

Diagram 4-9 is a scatter plot use to show linear relationship between body height (cm) and AP of left kidney(cm). A regression equation and correlation squared were calculated, the regression equation was as following: AP of left kidney = 0.0295* Body height - 0.0299. The correlation was $R^2 = 0.4794$. **{Lt Kidney AP = (0.0295* body height) - (0.0299), $R^2 = 0.4794$}**

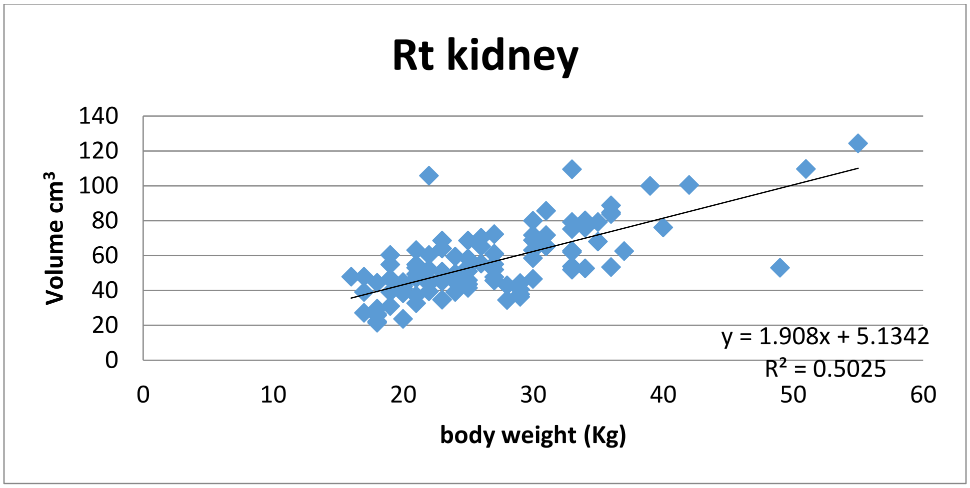



**Diagram 4-10: scatter plot diagram for right kidney volume (cm³) and Body weight (kg).**

Diagram 4-10 is a scatter plot use to show linear relationship between body weight (kg) and right kidney volume (cm3). A regression equation and correlation squared were calculated, the regression equation was as following: right kidney volume = 1.908* Body weight + 5.1342 The correlation was $R^2 = 0.5025$.

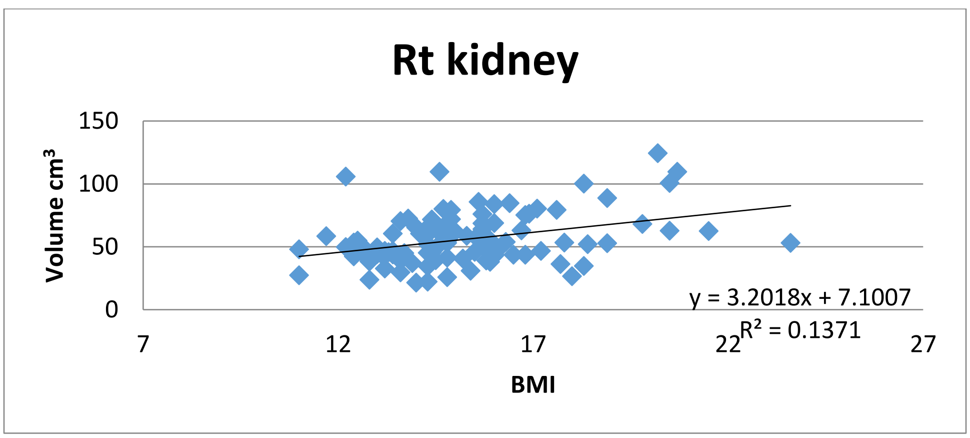



**Diagram 4-11: scatter plot diagram for right kidney volume (cm³) and BMI.**

Diagram 4-11 is a scatter plot use to show linear relationship between BMI and right kidney volume (cm3). A regression equation and correlation squared were calculated, the regression equation was as following: right kidney volume = 3.2018 * BMI + 7.1007. The correlation was $R^2 = 0.1371$. **{Rt kidney volume = (2.540*body weight) – (2.772*BMI) + 30.592}**

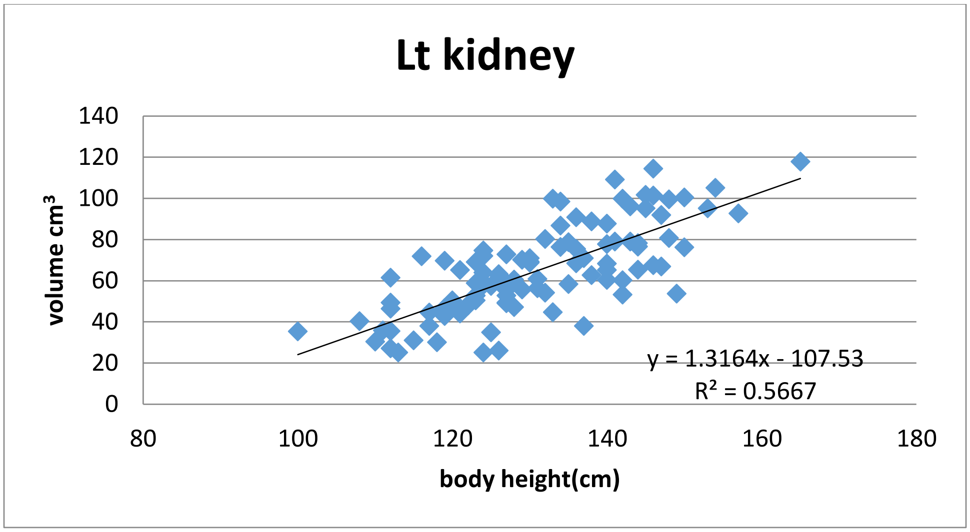



**Diagram 4-12: scatter plot diagram for left kidney volume (cm$^3$) and Body height (cm).**

Diagram 4-12 is a scatter plot use to show linear relationship between body height (cm) and left kidney volume (cm3). A regression equation and correlation squared were calculated, the regression equation was as following: left kidney volume = 1.3164* Body height - 107.53 The correlation was $R^2 = 0.5667$.

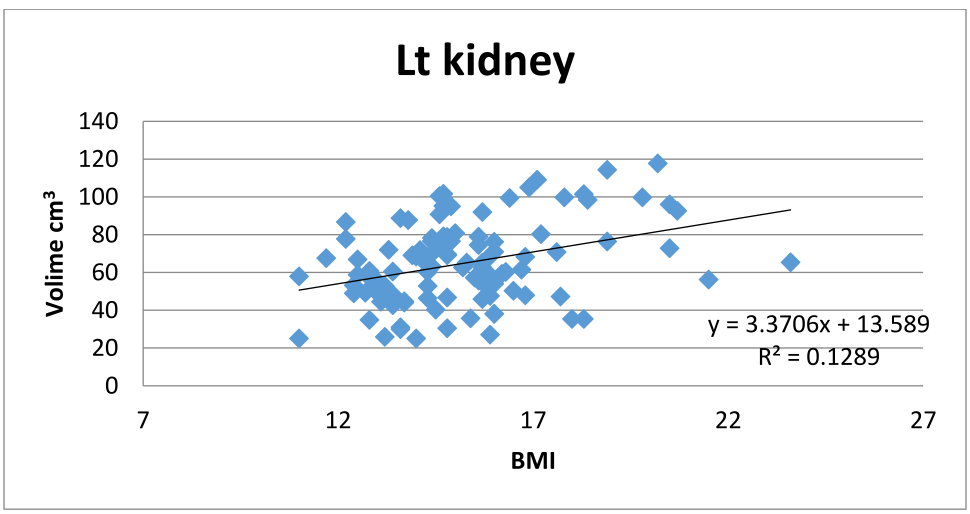



**Diagram 4-13: scatter plot diagram for left kidney volume (cm$^3$) and BMI.**

Diagram 4-13 is a scatter plot use to show linear relationship between BMI and left kidney volume (cm3). A regression equation and correlation squared were calculated, the regression equation was as following: left kidney volume = 3.3706x * BMI + 13.589 . The correlation was $R^2 = 0.1289$ **{Lt kidney volume = (1.237*body height)+(1.818*BMI) ) – 124.8}**

# Chapter Five

# Discussion, conclusion and recommendation

## 5-1 Discussion:

The main objective of this study was to measure the kidneys length and volume in Sudanese children who have no morphological abnormalities and no renal system complains in Khartoum state and Western Kurdufan state. The study included volunteers in ages of 6-13 years of both genders with no morphological abnormalities, while children with ectopic kidney, cyst, stones or other pathological conditions excluded. The sample of this study consist of 104 volunteers, 49 volunteer from Khartoum state (24 male and 25 female), and 55 volunteers from western Kurdufan state (25 male and 30 female). This study have carried out in Khartoum state and western Kurdufan state, In Khartoum state the data collected at Alzaeem Alazhary private primary school, in western Kurdufan, the data collected In Babanusa city at Alhamya primary school. The data collected during period from September to October 2016.

In results, the main objective fulfilled, right and left kidney measurements were calculated, the mean of right kidney length, width, AP and volume were 8.034, 3.496, 3.684 and 55.9348 respectively while the mean of left kidney length, width, AP and volume were 8.212, 3.818, 3.834 and 64.9968 this agreed with Haugstvedt et.al. (2010) study, which stated that the left kidney is longer than the right kidney. Agwu et.al (2014) measured the right and left kidney length, which equaled 7.9 ± 0.8 cm and 8.2 ± 0.8 cm respectively ad right and left width both equaled 3.5±0.3. The difference in length between right and left kidney is due to anatomical position and the relation of the kidney with the neighboring organs especially liver.

The result showed significant difference between the right and left kidneys measurements (mean of length, width, AP and volume) using T.test with p value = 0.05 (Table 4-2), this result agreed with Agwu et.al. (2014) which stated that there is significant difference between the right and left kidney length, but disagreed with TIV A. O. et. al. (2012) who stated that there is no significant difference between the right and left kidneys size.

The data of this study was collected from two different geographic areas in Sudan (Khartoum state and Western Kurdufan state), the results shows significant difference between the right and left kidneys AP diameter, this difference influence the value of volume in respect to geographic area (Table 4-4) illustrated. The difference in body characteristics was the main reason of difference.

Mean of male height and weight were higher than those of female, while mean of female BMI was higher than male BMI, right and left kidney measurement (length, width, AP and volume) in male were slightly higher than those of female.

T.test of study variables in respect to gender (Table 4-6) showed no significant difference between male and female in both right and left kidneys measurements, as previous studies of Konu S. L. et. al. (1998), Haugstvedt S. et.al. (2010), TIV A. O. et, al. (2012), Agwu K.K. et.al. (2014) stated that there is no significant difference between male and female kidneys length and volume.

The mean of right and left kidney length measurements was 8.034 cm 8.4 cm respectively; they have direct linear relationship with body height and BMI (diagrams 4-1 & 4-2 revealed the relation to the body height and diagrams 4-3&4-4 revealed the relation to BMI). This linear relationship translated to two equations showed the effect of these dependent variables (Body height and BMI) over the kidneys length. The equations was **{Rt Kidney length = (0.045*Body height) +**

**(0.111*BMI) + 0.435} and {Lt Kidney length = (0.046*Body height) + (0.104*BMI) + 0.653}** all previous studies found a strong and direct correlation between kidney length and body height. Kim J. H. et. al. (2013) stated that kidney length correlated with body height with $R^2$ for right kidney = 0.874 and $R^2$ for left kidney = 0.874 and Real length = 2.384+0.045*height ( ± 1.135), while in this study $R^2$ for right kidney in correlation with height = 0.564 and $R^2$ for left kidney = 0.219.

Width of kidneys were measured and the mean of right and left kidneys width calculated I results, left kidneys were wider than right kidneys (mean of right kidney width = 3.49 cm, mean of left kidney width = 3.818 cm). Direct correlation was found between right kidney width and body height and weight as shown in (diagram 4-5, 4-6), this correlation was translated to an equation to measure the width of right kidney in Sudanese pediatrics with different height and weight **{Rt Kidney width = (0.014*Body height) + (0.021*Body weight) + 1.112},** but only body height has linear relationship with left kidney width ( diagram 4-7) and regression equation was **{ left kidney width= 0.0267* Body height) + 0.3152 }, $R^2$ = 0.3735.**

Mean of AP diameter of right and left kidneys measured 3.684 cm and 3.834 cm respectively, the left kidneys were slightly higher in AP diameter value than right kidneys. The AP diameter of right and left kidneys was correlated with body height, {**Right Kidney AP = 0.0243 * body height + 0.0513} $R^2$ = 0.3168** as scatter plot diagram (4-8) showed. and {**left Kidney AP = 0.0295 * body height - 0.0299} $R^2$ = 0.4794** as scatter plot diagram (4-9) showed.

Right and left kidneys volume were calculated by the equation (Length*Width*AP* 0.523). The mean of Right and left kidneys volume were 55.9348 $cm^3$ and 64.9968 $cm^3$, the mean of left kidney volume were higher than the mean of right kidney volume. The right kidney volume were highly correlated with the body weight and BMI( Diagram 4-10 and 4-11) the correlation was translated to the equation **{ Right**

**kidney volume = (2.540*Body weight)+(2.772*BMI)+30.592}.** While the left kidney volume correlated with body height _in state of body weight_ and BMI, the equation to calculate left kidney volume was **{ left kidney volume = (1.237*Body height)+(1.818*BMI) - 142.8 },** this result disagreed with Kim J. H. et. al. (2013) who stated that only the weight that affect right and left kidneys volume with $R^2$ for right kidney = 0.842 and $R^2$ for left kidney = 0.854, and his study also stated that renal volume equal {7.941+1.246*weight (±15.920)} and {7.303+1.532* weight(± 18.704)} for right and left kidneys respectively.

## 5-2 Conclusion:

Kidneys are vital organs that need accurate measurements of length and volume specially in pediatric, these values are changing with different body characteristics, so to know these values will increase diagnosing accuracy and decrease time consumption. This study made among 104 healthy volunteers in ages ranged from 6-13 years old in two different states in Sudan. The data collected in master data sheet.

The result of this study showed that the mean of the length of right and left kidneys measured 8.034 cm and 8.212 cm respectively, and the mean of the volume of right and left kidneys was also calculated and measured 55.935 $cm^3$ and 64.497$cm^3$ respectively. Left kidney was larger than right kidney in all measurements (Length, Width, AP diameter and volume) and the significant difference between the right and left kidneys was found. Significant difference between right and left kidney measurements in different geographic areas ( Khartoum and Western Kurdufan) was also found.

Gender is one of the main variables, so male and female measurements were studied and no significant difference was reported.

equations for measuring kidney length were created as a result of correlation between kidney length and body height and BMI and they were **{Rt Kidney length = (0.045*Body height) + (0.111*BMI) + 0.435} and {Lt Kidney length = (0.046*Body height) + (0.104*BMI) + 0.653}.** Right kidney width was correlated with body height and body weight **{Rt Kidney width = (0.014*Body height) + (0.021*Body weight) + 1.112}.** While left kidney width was only correlated with body height **{Left kidney width= 0.0267* Body height) + 0.3152 }.** AP diameter for right and left kidney was correlated with body height {**Right Kidney AP =**

**0.0243 * body height + 0.0513}** and {**left Kidney AP = 0.0295 * body height - 0.0299}.** The right kidney volume correlated with body weight and BMI **{ Right kidney volume = (2.540*Body weight)+(2.772*BMI)+30.592}** while left kidney volume correlated with body height and BMI **{ left kidney volume = (1.237*Body height)+(1.818*BMI) - 142.8 }.**

## 5-3 Limitations:

The main limitation of this study is that the kidney length and volume were not plotted in a table or a graph to show the changes in these measurements with different ages. Also the limited range of ages of volunteers which can be wider.

## 5-4 Recommendations:

- This study highly recommended further studies to overcome the study limitations specially that related to age.
- This study also recommended further studies with increase in variables like body surface area.
- Other geographic areas in Sudan should be studied and compared with this study.

## References:


1. CU EzeI; KK AgwuI; DN EzeasorII; KK AgwunaIII; AE AronuIV; EI MbaV, Sonographic biometry of normal kidney dimensions among school-age children in Nsukka, Southeast Nigeria, West Indian med. j. vol.63 no.1 Mona Jan. 2014.
2. Christian Kurts, Ulf Panzer, Hans-Joachim Anders & Andrew J. Rees Nature Reviews Immunology13,738–753(2013)doi:10.1038/nri3523 https://en.wikipedia.org/wiki/Kidney.
3. David M., Sonographic Assessment Of Renal Length in Normal Children, ajronline, 105.239.186.54, 11/26/16.
4. Kliegman R. F., Behrman R. E., Jenson H. B., Stanton B.F., Nelson Textbook of Pediatrics. 18th edition. Philadelphia:Saunders; 2007.
5. Konuş O. L., Ozdemi A., Akkaya A., Erbaş G., Celik H. and Işik S., Normal liver, spleen, and kidney dimensions in neonates, infants, and children: evaluation with sonography, 1998, American Journal of Roentgenology ,Volume 171, Issue 6.
6. . Kim J.H., Kim M.J., , Lim S.H., Kim J.,2 and Lee M., Length and Volume of Morphologically Normal Kidneys in Korean Children: Ultrasound Measurement and Estimation Using Body Size, 2013, Korean J Radiol, 2013Jul-Aug; 14(4): 677–682.
7. Lanna Cheuck, DO David M Hoenig, MD David M Hoenig, MD Eric M Ghiraldi Thomas R Gest, PhD ,kidney anatomy,14 oct 2013, Medscape

8. Ravikumar N., Anita S, Venkateshwara C., Determine the Renal Size in Normal Children by Ultrasonography, iosrjournals, Volume 15, Issue 4, Apr. 2016.

9. TIV A. O., EHTA K. M., ALI U. AND ADKARNIM. N., Sonographic Measurement of Renal Size in Normal Indian Children, 2001, Mumbai, India, Anjali, May 02, 2011.
10. Tim Taylor, Anatomy and Physiology Instructor, www.nature.com/nri/journal/v13/n10/box/nri3523_BX1.html
11. www.innerbody.com
12. WWW.google. Com .
13. wikipedia.org/wiki/Kidney.

# *Chapter One*

# Chapter Two

# Chapter Three

# Chapter Four

# *Chapter Five*

# *Appendix*

# Master data sheet

| No | Age | Gender | Height CM | Weight KG | BMI KG/M² | Right kidney | | | | Left kidney | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Length CM | Width CM | AP CM | Volume CM³ | Length CM | Width CM | AP CM | Volume CM³ |
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