Sudan University of Science and Technology

College of Graduate Studies

A Study of Normal Renal Blood Perfusion Using Ultrasonography

دراسة نضح الدم الكلوي الطبيعي باستخدام الموجات فوق الصوتية

A Thesis Submitted in Partial Fulfillment for Degree of MSc in Medical Diagnostic Ultrasound

By:

Eman Mohammed Fadl Almoula Gorashi

Supervisor :

Dr. Mohamed Elfadil Mohamed Gar-elnabi

Associate Professor

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بسم الله الرحمن الرحيم

Dedication

To my greatest father and lovely mother….

To My brothers and sisters whom i love….

To my friends , colleagues , and everyone who help me at any time in my life….

Acknowledgements

First of all I thank Allah the almightly for helping me to complete this thesis,

Scensere thanks are to Dr. ***Mohamed Elfadil Mohamed Gar-elnabi*** *whom I was honored by his supervision ,knowledge, advise, assistance, and excellent guidence during the whole process.*

I am also so gratefull to Dr. ***Musab Babatoot*** *who helped me in gathering different information ,collecting data and guiding me all the time in making this work*

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List of abbreviations

AKI	Acute kidney injury
BMI	Body mass index
IAP	Intra abdominal pressure
ICU	Intensive care unit
MAP	Mean arterial pressure
PI	Pulsitility index
PSV	Peak systolic velocity
RVS	Renal vascular resistance
RI	Resistive index

Abstract:

This is a cross sectional descriptive study was done to investigate the utility of Doppler ultrasound in detecting the range of spectrum of the renal arteries of the healthy kidneys. A sample of 50 patients of different gender and age group were selected, Their age range (19-80 years) Male 26 (52%) Females 24 (48%) the study was carried out at Ibn Elhaitham diagnostic centre, during the period of three months. The resistive index (RI), peak systolic velocity (PSV) and pulstality index (PI) of renal arteries (segmental arteries) of the patients were taken to get the range of these values in healthy kidneys of sudanese population. The result was that; maximum number of individuals almost 42% were having the PSV values in the moderate range of 20.6-40.1 cm/s. 52% of individuals were having RI values in the range of 0.56-0.62 .36% of individuals were having the pubtality index(PI) values in the rang of 0.90-1.54 which was the maximum number of individuals. In **conclusion** spectral reassessment of renal arteries is one of the most valuable tool for detecting any renal vascular pathology, even in healthy kidneys, the upper limits of the normal values may be alarming for any hidden problem.

ملخص البحث

هذه دراسة وصفية تهدف إلى التحقق من فائدة الموجات فوق الصوتية (دوبلر) في الكشف عن مجموعة من أطياف الشرايين الكلوية في الكلى السليمة. وقد تم اختيار المرضى عشوائياً، في عينة تتكون من 50 مريضاً من الجنسين 26 من الذكور، و24 من الإناث (52% ذكور، و48% إناث)، وتشتمل العينة على مختلف الفئات العمرية (19 - 80 سنة)، وقد اجريت هذه الدراسة في مركز ابن الهيثم التشخيصي، واستغرقت الدراسة ثلاثة اشهر . وقد استخدمت مؤشر النبض(PI)و مؤشر المقاومة الشريانية(RI). التسارع خلال فترة الذروة الانقباضية و(PSV) للشرايين الكلوية (الشرايين القطعية) لدى العينة المستهدفة، وذلك للحصول على نطاق هذه القيم لدى عينة من السودانيين ذوي الكلى السليمة. وكانت النتيجة أنَّ أكبر عدد من الأفراد (حوالي 42%) قد حصلوا على قيم مؤشر التسارع خلال فترة الذروة الانقباضية (PSV) في نطاق معتدل يتراوح من 20.6 - 40.1 سم / ثانية. بينما حصل 52٪ من الأفراد على قيم مؤشر المقاومة الشريانية (RI) في نطاق يتراوح بين 0.56 – 0.62 . وقد حصل 36% من الأفراد على قيم مؤشر النبض (PI) في نطاق يتراوح بين 0.90 - 1.54. في **الخلاصة:** إنَّ إعادة التقييم الطيفي للشرايين الكلوية تُعْتَبَرُ واحدة أهم الأدوات المستخدمة في الكشف عن أية أمراض ذات صلة بالأوعية الدموية الكلوية. وحتى في الكلى السليمة فإنَّ الحدود العليا من القيم الطبيعية قد تكون إشارة إلى وجود مشكلة خفية

Chapter one

1.1 Introduction:

The renal arteries originate from the abdominal aorta and enter the renal hila to supply the kidneys. Any variant in arterial supply is important to clinicians undertaking surgery or other interventional renal procedures.

The right renal artery courses inferiorly and passes posterior to the IVC and the right renal vein to reach the renal hilum. The left renal artery passes more horizontally, posterior to the left renal vein to enter the renal hilum.

Each renal artery gives off small branches in its proximal course, prior to dividing into dorsal and ventral rami. These branches are very small and often not visualized on imaging studies: inferior adrenal artery, ureteric artery ,and capsular artery

The dorsal and ventral rami divide into segmental branches which then divide into lobar branches. The lobar arteries successively branch into interlobar, arcuate and interlobular arteries. The afferent arterioles, which supply the glomeruli, originate from the interlobular arteries.

1.2 Doppler ultrasound:

Diagnostic ultrasound is recognized as an important adjunct to clinical examination in the care of patients with many common illnesses (P.E.S Palmer, 1995) and it is noninvasive, informative and cost effective tool. It has become one of the most important investigations used in the assessment of vascular disease. This is because it provides accurate information on the flow of blood in the arteries and veins, but it is painless and risk free. Ultrasound has been used safety for years to assess babies in the womb. Colour flow ultrasound provides accurate information on the most arteries. It can assess the flow of blood and weather there is any impairment of flow caused by hardening of the arteriess (WWW,Vascular.co.nz)

Doppler ultrasound is widely utilized as the initial tool in evaluating kidney problems. The goal of the study is to investigate the utility of doppler ultrasound in detecting the range of spectra of the renal arteries of the healthy kidneys

- can be technically difficult and only completed in 60% of patients
- normal peak systolic velocity is 150-180 cm/s and elevation beyond this may indicated a renal artery stenosis of >60% (at the main renal artery).
- normal renal arterial resistive index is ≈ 0.60

1.3 Problem of the Study:

Doppler indices of the renal artery (RI, PI, PSV) are varying from subject to subject, this variation may be due to pathological condition.

1.4 objectives of the study:

1.4.1 General objective:

The general Objective of this study is to study the blood flow indices for the renal artery using Doppler ultrasound in order to find the associated factors.

1.4.2 Specific Objectives:

1. To find the normal renal artery RI, PI,and PSV using Doppler.
2. To find the patient bodies characteristics (age, weight, height and gender).
3. To cross-correlate between body characteristics and renal artery indices.
4. To measure the kidney in coronal section.
5. To correlate the measurements with patients age ,height, and weight.

1.5 Research overview:

The research consists of five chapters. Chapter one is dealing with introduction, problems of the study, importance of the study, objectives and thesis outline. Chapter two shows the literature review and previous studies. Chapter three dealing with subjects and methodology. Chapter four shows the results. Chapter five is dealing with discussion, conclusion and recommendations.

Chapter two

Background and literature review

2.1 Anatomy:

2.2.1 Anatomy of the kidney:

The renal system is comprised of the Kidneys aznd those structures including the ureters, bladder and urethra that form the urinary system. The formation of urine is the function of the kidneys, and the rest of the system is responsible for eliminating the urine. The main functions of the kidney are to regulate extracellular fluid volume (Matthew et al, 2012).

The kidneys are situated in the retroperitoneum located between T12 and L3 on each side of the vertebral column behind the peritoneum (retroperitoneal). The upper portions of the kidneys rest on the lower surface of the diaphragm and are enclosed and protected by the lower rib cage. The kidneys are embedded in adipose tissue that acts as a cushion and is in turn covered by a fibrous connective tissue membrane called the renal fascia, which helps hold the kidneys in place. Each kidney has an indentation called the hilus on its medial side. At the hilus, the renal artery enters the kidney, and the renal vein and ureter emerge. The renal artery is a branch of the abdominal aorta, and the renal vein returns blood to the inferior vena cava. The ureter carries urine from the kidney to the urinary bladder (Valerie et al, 2007).

2.1.2 Anatomy of the renal artery:

There are two blood vessels leading off from the abdominal aorta that go to the kidneys. The renal artery is one of these two blood vessels.

The renal artery enters through the hilum, which is located where the kidney curves inward in a concave shape. Under normal circumstances, once the renal artery enters through the hilum, it splits into two main branches, which each then split into numerous smaller arteries, which deliver blood to different areas of the kidneys, known as nephrons.

Once the blood has been processed here, it is sent back through the renal vein to the inferior vena cava and to the right side section of the heart.

A normal person's kidneys receive approximately a quarter of the hearts blood output, or 1.2 liters of blood each minute. The body has self-regulating mechanisms in place, which increase or decrease the flow of blood to adapt to stress. Receptors located in the smooth muscle wall of the renal artery allow the arteries to expand or contract to compensate for high or low blood pressure

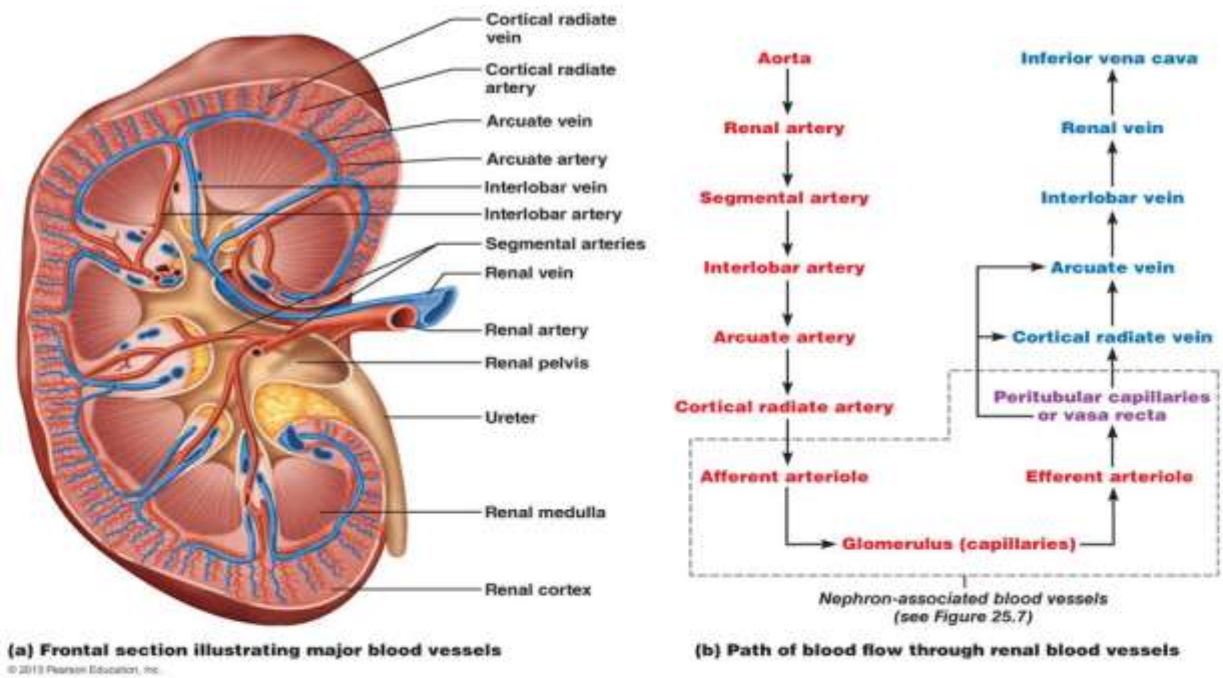
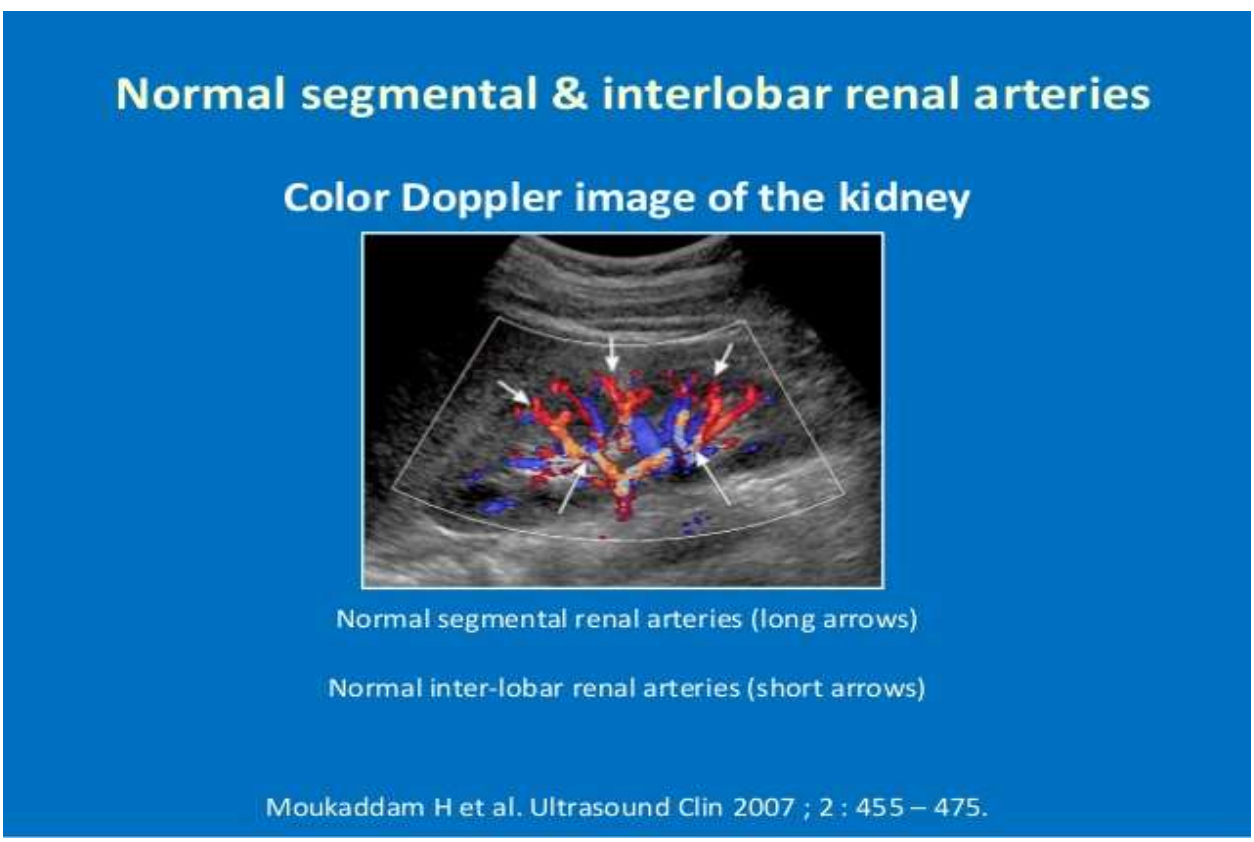


Figure (2-1): Vascular anatomy of the kidney.



Figure(2-2); Sonographic apperance of segmental artery.

2.4 Pathologies of the renal artery:

2.4.1 Renal artery stenosis:

Renal artery stenosis is a narrowing of arteries that carry blood to one or both of the kidneys. Most often seen in older people with atherosclerosis (hardening of the arteries), renal artery stenosis can worsen over time and often leads to hypertension (high blood pressure) and kidney damage. The body senses less blood reaching the kidneys and misinterprets that as the body having low blood pressure. This signals the release of hormones from the kidney that lead to an increase in blood pressure. Over time, renal artery stenosis can lead to kidney failure.

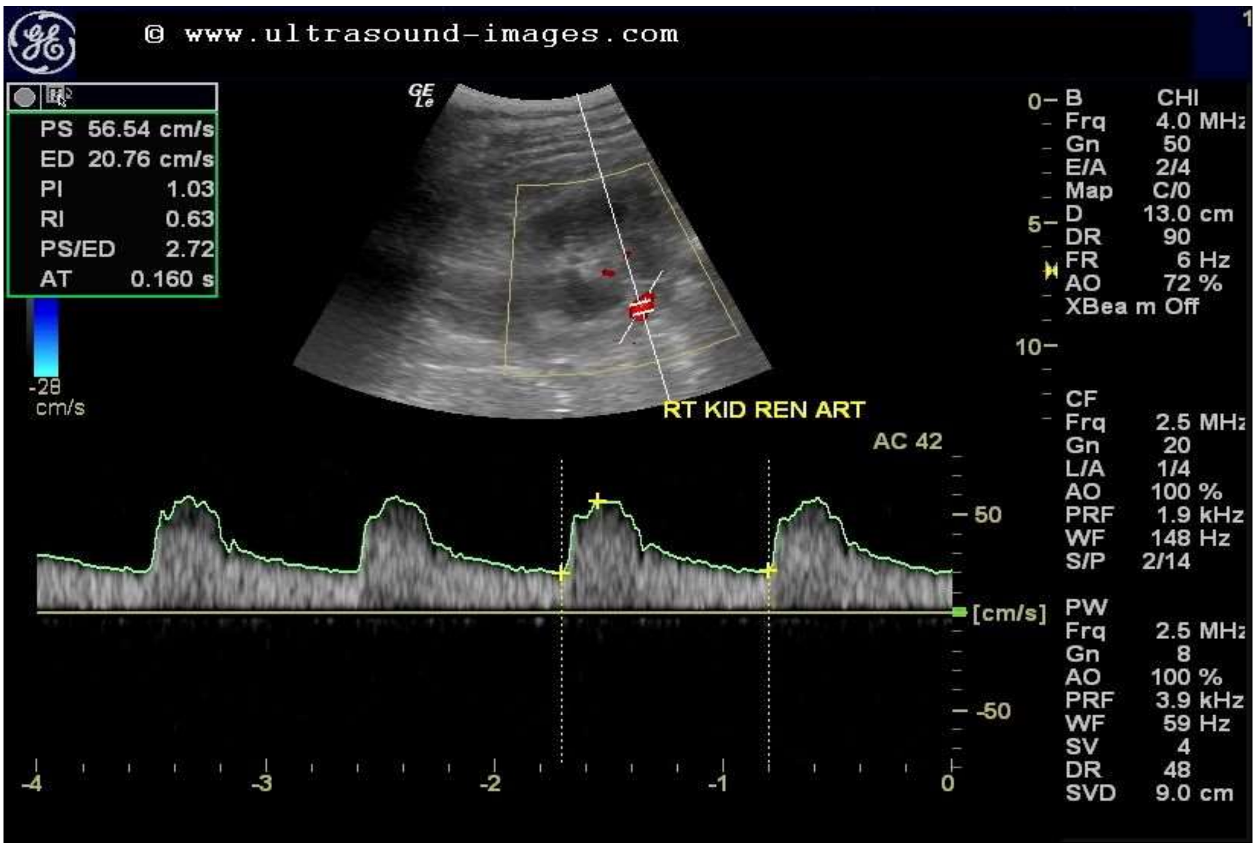
Causes of Renal Artery Stenosis: More than 90% of the time, renal artery stenosis is caused by atherosclerosis, a process in which plaque made up of fats, cholesterol, and other materials builds up on the walls of the blood vessels, including those leading to the kidneys.

More rarely, renal artery stenosis can be caused by a condition called fibromuscular dyplasia, in which the cells in the walls of the arteries undergo abnormal growth. More commonly seen in women and younger people, fibromuscular dyplasia is potentially curable.

Risk Factors for Renal Artery Stenosis: Renal artery stenosis is often found by accident in ‘patients who are undergoing tests for another reason. Risk factors include:

- Older age
- Being female
- Having hypertension

- Having other vascular disease (such as coronary artery disease and peripheral artery disease)
- Having chronic kidney disease
- Having diabetes
- Using tobacco
- Having an abnormal cholesterol level



Figure(2-3): Sonographic appearance of renal artery stenosis:

Symptoms of Renal Artery Stenosis: Renal artery stenosis usually does not cause any specific symptoms. Sometimes, the first sign of renal artery stenosis is high blood pressure that is extremely hard to control, along with worsening of previously well-controlled high blood pressure, or elevated blood pressure that affects other organs in the body.

Diagnosis of Renal Artery Stenosis: If your doctor suspects that you have renal artery stenosis, he or she may order tests to either confirm suspicions or rule it out. These include:

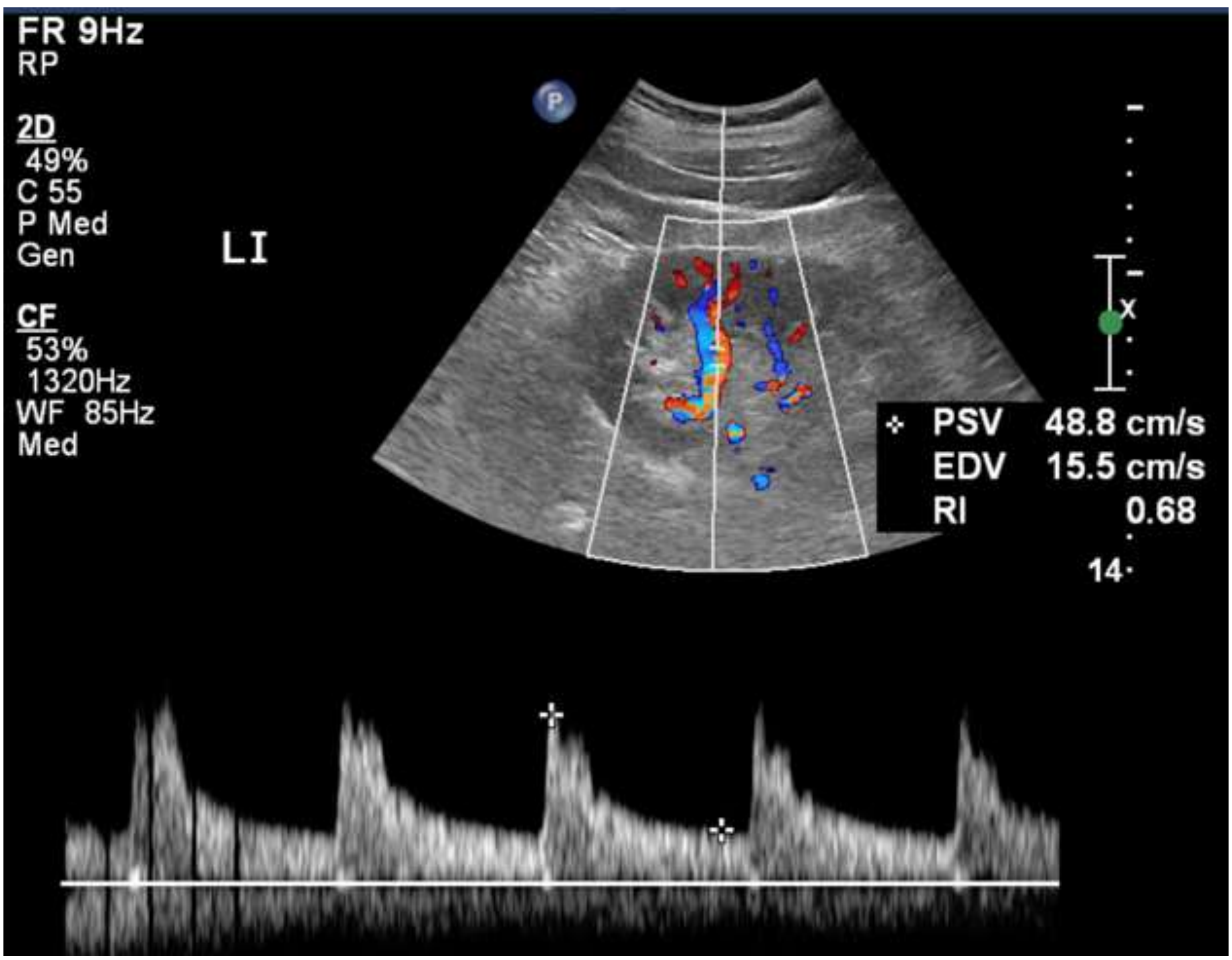
- Blood tests and urine tests to evaluate kidney function
- Kidney ultrasound, which uses sound waves to show the size and structure of the kidney
- Doppler ultrasound, which measures blood-flow speed in arteries to the kidney
- Magnetic resonance arteriogram and computed tomographic angiography, imaging studies that use a special dye (contrast medium) to produce a 3-D image of the kidney and its blood vessels

2.4.2 Atherosclerosis:

Atherosclerosis is a common disorder and a leading cause of morbidity and mortality worldwide. In many cases, individuals are asymptomatic and the disease is therefore not recognized until an acute thrombotic manifestation like myocardial infarction (MI), stroke or sudden death occurs. Moreover, the prevalence of atherosclerotic disease and its related costs are expected to increase not only in the industrialized but also in developing countries. It remains a huge challenge to solve this global clinical problem (Anders et al, 2015)

2.5 Renal Artery Ultrasound:

Renal artery ultrasound is a test that shows the renal arteries, the arteries that carry blood to the kidney. These arteries may narrow or become blocked and this may result in kidney failure or high blood pressure (hypertension). Ultrasound waves—the same ones used in imaging the fetus in a pregnant woman—are used to make an image of the artery. The speed of blood flow through the arteries is measured and determines the degree of narrowing of the artery. Imaging of the renal arteries can be extremely difficult and this test most often is performed in the morning on an empty stomach.



Figure(2-4):Renal artery Doppler.

What patients require renal artery ultrasound: Doctors will request an renal artery ultrasound on patients who have early signs of kidney failure or blood pressure is difficult to control despite multiple medications.

What happens during renal artery ultrasound: You will be asked to lie down on an examination table. The technician (or physician) will place a clear gel on your abdomen. The gel is simply a lubricant that allows the transducer (a device that both puts out and detects ultrasound signals) to slide around easily on your skin. When the transducer is placed against the skin, an image of the artery is shown on a video screen. The renal arteries are identified and a measurement will be made of the speed of blood flow through the artery. This test is typically not performed during the screening program, but patients who may require the study are identified and are set up for the study at a later date.

The risks of renal artery ultrasound: Since the procedure is done without entering the body and does not use dyes or x-rays, there is no risk or pain involved in having a renal artery ultrasound.

How does renal artery ultrasound work: The transducer emits high-frequency, ultrasound waves that pass into the body and bounce off the abdominal aorta. The sound waves are reflected differently by different parts of the body. The transducer detects the different reflections of the sound waves, which are then measured and converted by a computer into live pictures of the artery.

2.10 previous study:

Granata et al. (2009) found that renovascular disease is a complex disorder, most commonly caused by fibromuscular dysplasia and atherosclerotic diseases. It can be found in one of three forms: asymptomatic renal artery stenosis (RAS), renovascular hypertension, and ischemic nephropathy. Particularly, the atherosclerotic form is a progressive disease that may lead to gradual and silent loss of renal function. Thus, early diagnosis of RAS is an important clinical objective since interventional therapy may improve or cure hypertension and preserve renal function. Screening for RAS is indicated in suspected renovascular hypertension or ischemic nephropathy, in order to identify patients in whom an endoluminal or surgical revascularization is advisable. Screening tests for RAS have improved considerably over the last decade. While captopril renography was widely used in the past, Doppler ultrasound (US) of the renal arteries (RAs), angio-CT, or magnetic resonance angiography (MRA) have replaced other modalities and they are now considered the screening tests of choice. An arteriogram is rarely needed for diagnostic purposes only. Color-Doppler US (CDUS) is a noninvasive, repeatable, relatively inexpensive diagnostic procedure which can accurately screen for renovascular diseases if performed by an expert. Moreover, the evaluation of the resistive index (RI) at Doppler US may be very useful in RAS affected patients for predicting the response to revascularization. However, when a discrepancy exists between clinical data and the results of Doppler US

Schnell et al. (2015) found that there are three Doppler-derived techniques have been proposed to assess renal perfusion at bedside: Doppler-based renal resistive index (RI) which has been extensively but imperfectly studied in assessing renal allograft status and changes in renal perfusion in critically ill patients and for predicting the reversibility of an acute kidney injury (AKI), semi-quantitative evaluation of renal perfusion using colour-Doppler which may be easier to perform and may give similar information than RI and contrast-enhanced sonography that may allow more precise renal and cortical perfusion assessment. These promising tools have several obvious advantages including their feasibility, non-invasiveness, repeatability and potential interest in assessing renal function or perfusion. However, several limits need to be taken into account with these techniques, and promising results remain associated with large areas of uncertainty. This editorial will describe more carefully advantages and limits of these techniques and will discuss their potential interest in assessing renal perfusion.

House et al. (1999) determined the accuracy of direct and indirect parameters for the diagnosis of renal artery stenosis and to determine the most useful thresholds for these parameters. One hundred twenty-five arteries in 63 patients were examined with renal Doppler sonography and angiography for the presence or absence of renal artery stenosis. Arteries were considered stenosed on angiography if there was a diameter reduction of greater than 60%. Renal Doppler sonographic measures of peak systolic velocity, renal aortic ratio, acceleration time, and acceleration were recorded and compared with the angiographically determined presence or absence of disease. Doppler examination was technically successful in 87% of kidneys and 76% of patients. Receiver operating characteristic analysis showed the optimal peak systolic velocity threshold to be 180 cm/sec and the optimal renal aortic ratio threshold to be 3.0. An acceleration time greater than 70 msec and an acceleration less than 300 cm/sec2 yielded sensitivities of 41% and 56%, respectively, and specificities of 85% and 62%, respectively. Combining a renal aortic ratio of greater than 3.0 or peak systolic velocity greater than 180 cm/sec provided the best combination of parameters with a sensitivity and sensitivity at 85% and 76%, respectively.

The most accurate use of parameters was found to be a combination of either peak systolic velocity greater than 180 cm/sec or renal aortic ratio greater than 3.0. Indirect parameters were not found to be useful in predicting the presence or absence of renal artery stenosis.

Kumileo et al. (2008) used Doppler ultrasonography to assess renal perfusion is increasing in many kidney diseases and in the ICU. The Doppler-based renal resistive index, which is a simple, rapid, noninvasive, and repeatable marker, could be a promising tool to prematurely detect the patients most at risk of developing AKI in the ICU and to distinguish transient from persistent AKI. Moreover, the resistive index could also be useful to adjust preventive or therapeutic modalities for the kidney perfusion at the bedside. The recent progress in ultrasound with contrast-enhanced ultrasound gives the opportunity to assess not only the kidney

Mostbeck et al. (2012) evaluated the histopathologic changes influencing Doppler measurements of the resistive index (RI) in renal arteries in renal parenchymal diseases, 68 kidneys in 34 consecutive patients with various forms of renal parenchymal diseases were studied by duplex Doppler ultrasound (duplex US) immediately before percutaneous renal biopsy. The RI, renal length, and renal cortical echogenicity were correlated with the amount of glomerular, interstitial, and vascular changes graded on a scale from 0 to 100. The renal vascular resistance and therefore the RI are significantly correlated with the prevalence of arteriolosclerosis, glomerular sclerosis, arteriosclerosis, edema, and focal interstitial fibrosis. There was no significant difference of the RI in five groups of different renal parenchymal diseases. Of 34 patients, 24 presented with an RI less than 0.7, which was thought to be within the normal range so far. Additionally, the RI increases as the patient's age increases, due to higher incidence of arteriosclerosis. Of our patients, 44% presented with normal cortical echogenicity.

Quantitative duplex US using the RI does not reliably distinguish different types of renal medical disorders.

Jörg et al. (2002) Stated that renovascular disease is a complex disorder, most commonly caused by fibromuscular dysplasia and atherosclerotic diseases. It can be found in one of three forms: asymptomatic renal artery stenosis (RAS), renovascular hypertension, and ischemic nephropathy. Particularly, the atherosclerotic form is a progressive disease that may lead to gradual and silent loss of renal function. Thus, early diagnosis of RAS is an important clinical objective since interventional therapy may improve or cure hypertension and preserve renal function. Screening for RAS is indicated in suspected renovascular hypertension or ischemic nephropathy, in order to identify patients in whom an endoluminal or surgical revascularization is advisable. Screening tests for RAS have improved considerably over the last decade. While captopril renography was widely used in the past, Doppler ultrasound (US) of the renal arteries (RAs), angio-CT, or magnetic resonance angiography (MRA) have replaced other modalities and they are now considered the screening tests of choice. An arteriogram is rarely needed for diagnostic purposes only. Color-Doppler US (CDUS) is a noninvasive, repeatable, relatively inexpensive diagnostic procedure which can accurately screen for renovascular diseases if performed by an expert. Moreover, the evaluation of the resistive index (RI) at Doppler US may be very useful in RAS affected patients for predicting the response to revascularization. However, when a discrepancy exists between clinical data and the results of Doppler US, additional tests are mandatory.

Chapter Three

Materials and Methods

3.1 Material:

Toshiba machine ,with curve linear probe (3.5-5Mhz) Ultrasound transducer. The applied Ultrasound transducer was a convex probe with a frequency of 3 .5 MHz

3.2 Population :

The population of this study include Males and females aged between (19-80) with normal status, and patients with abnormalities (Diabetes or Hypertension), the data of this study collected from Ibn Elhaitham medical diagnostic centre in three months.

3-4 Sample size and type:

The sample of this study was selected conviently which consist of 50 patients.

3-5 patient preparation:

The patients were examined early in the morning if at all possible after overnight fast to diminish the amount of bowel gas.

3-6 examination technique:

All patients underwent duplex ultrasonography for estimation of renal size, cortical echogenicity and intrarenal arterial resistance index, pulsitility index ,and peak systolic velocity. The patients were examined in supine, right decubitus and left decubitus positions. A low-frequency (3.5 MHz) was used. Kidney length and width were evaluated by using brightness mode (B-mode). Then, colour Doppler followed by pulse wave Doppler. (PW) modes were applied for the spectral analysis and determination of intrarenal arterial (RI) value which obtained from kidneys.

3.7 Method of data collected and analysis:

Researcher uses excell and SPSS to analyse the data to find the significant difference between the patients (normal, diabetic,and hypertensive), and variables , in addition to linear relationship between body characteristics and blood flow indicces.

Variables used for data collection are age, gender, RI, PI, PSV, weight, height, kidney length & width, BMI, and the patient status.

3.8 Ethical approval:

The researcher got an ethical approval from the hospital and the department to collect the data from the patient for the research and verbal consent from the patient.

Chapter Four
Results

Table (4-1): The mean, maximum, minimum and standard deviation of the variables that collected from 50 patients.

	Mean±SD	***Minimum***	***Maximum***
Resistive Index	0.58±0.05	.49	.68
Pulsitility Index	0.97±0.53	.06	2.54
Peak systolic velosity	26.9±14.6	10.3	66.
Age	39.3±15.1	19	80
Height	165.8±9.04	145	182
Weight	68.9±12.8	40	115
Kidney length	10.03±0.71	8.7	11.9
Kidney width	4.2±0.6	3.2	6.10
BMI	25.05±4.06	18.6	37.26

Table (4-2) significant test for age gropus using ANOVA

		Sum of Squares	*Mean Square*	*F*	*Sig.*
Ri	***Between Groups***	0.007	0.002	0.844	0.477
	Within Groups	0.119	0.003		
	Total	0.126			
PI	***Between Groups***	0.435	0.145	0.495	0.687
	Within Groups	13.474	0.293		
	Total	13.909			
PSV	***Between Groups***	464.673	154.891	0.712	0.550
	Within Groups	10007.306	217.550		
	Total	10471.979			

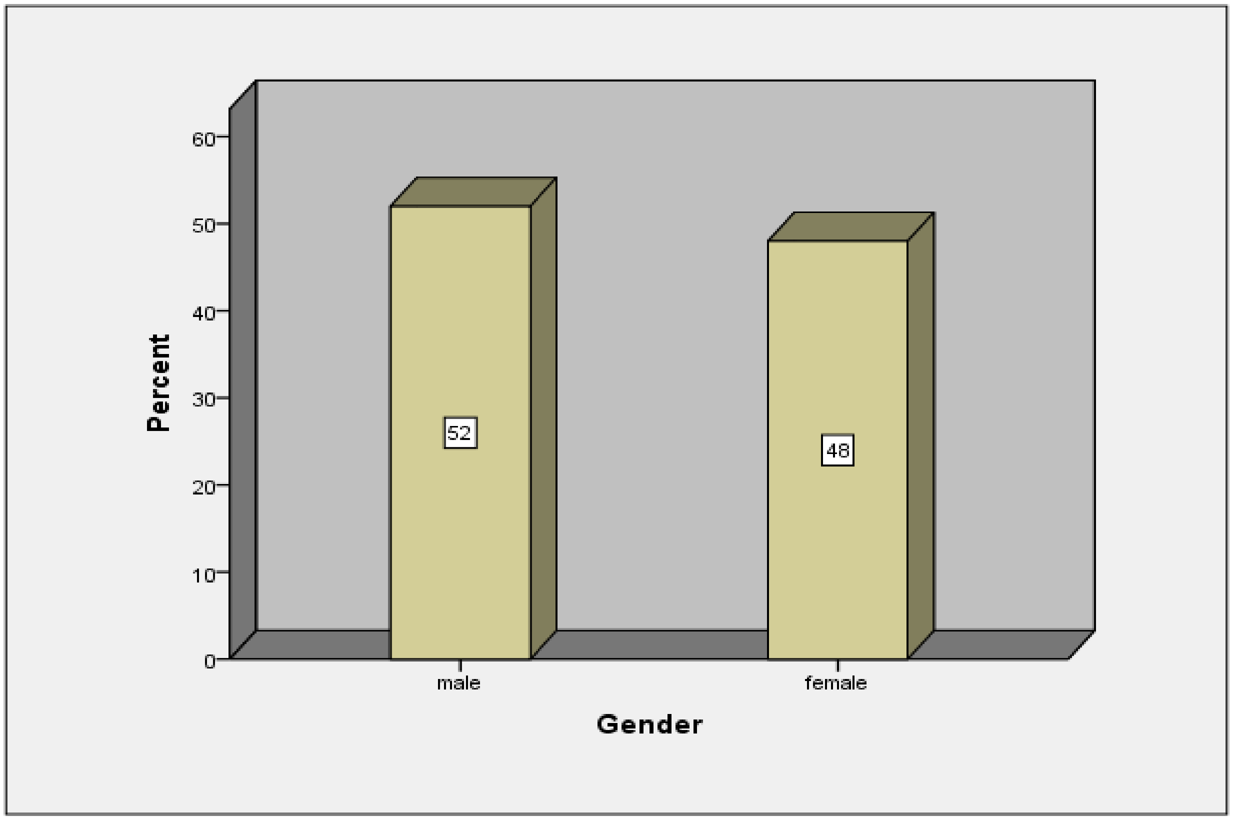


Figure (4-1): Male to female ratio

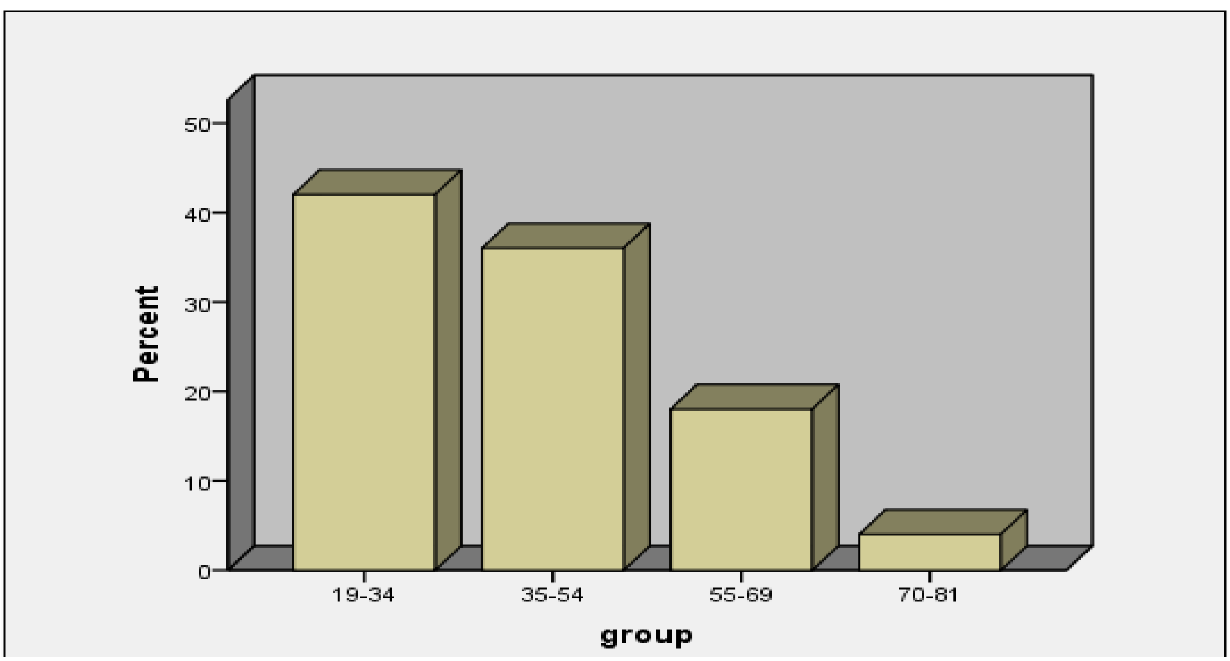


Figure (4-2): The persent of age groups

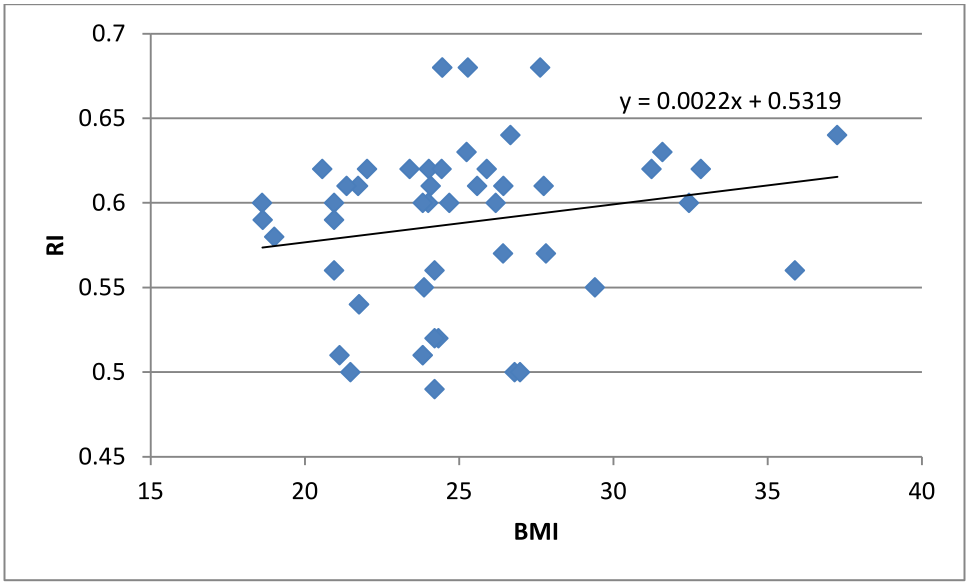


Figure (4-3): The relation between BMI and renal RI.

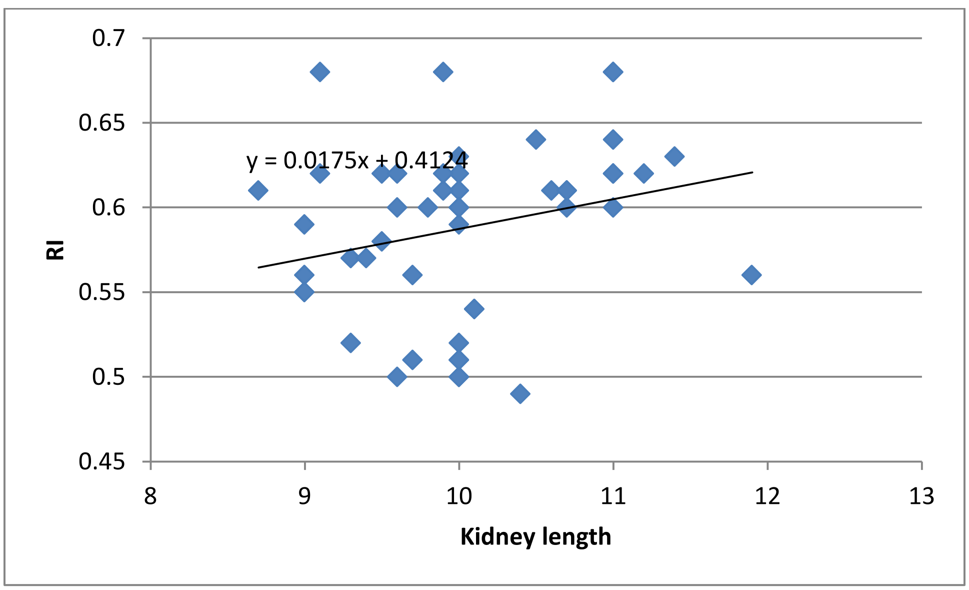


Figure (4-4): The relation between renal length and RI.

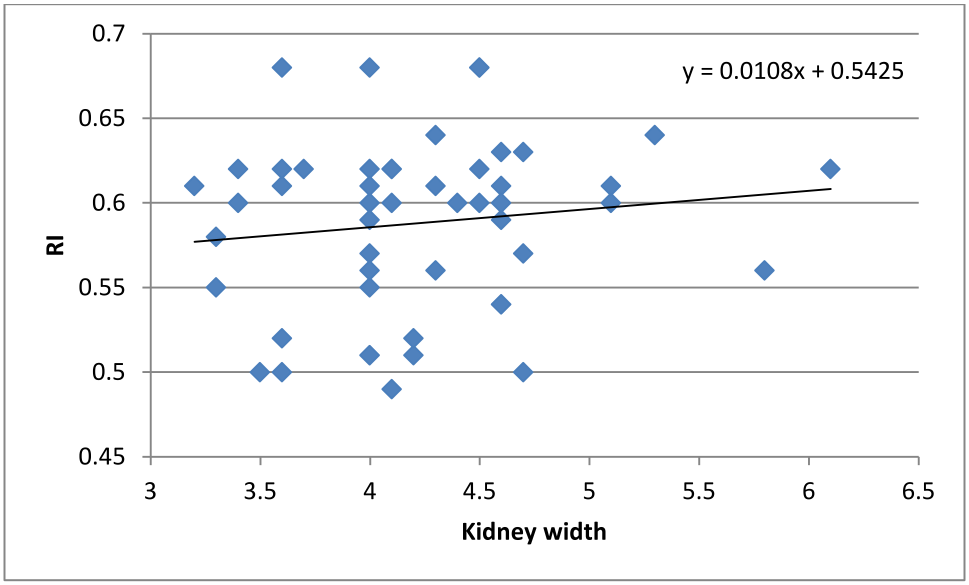


Figure (4-5): The relation between renal width and RI.

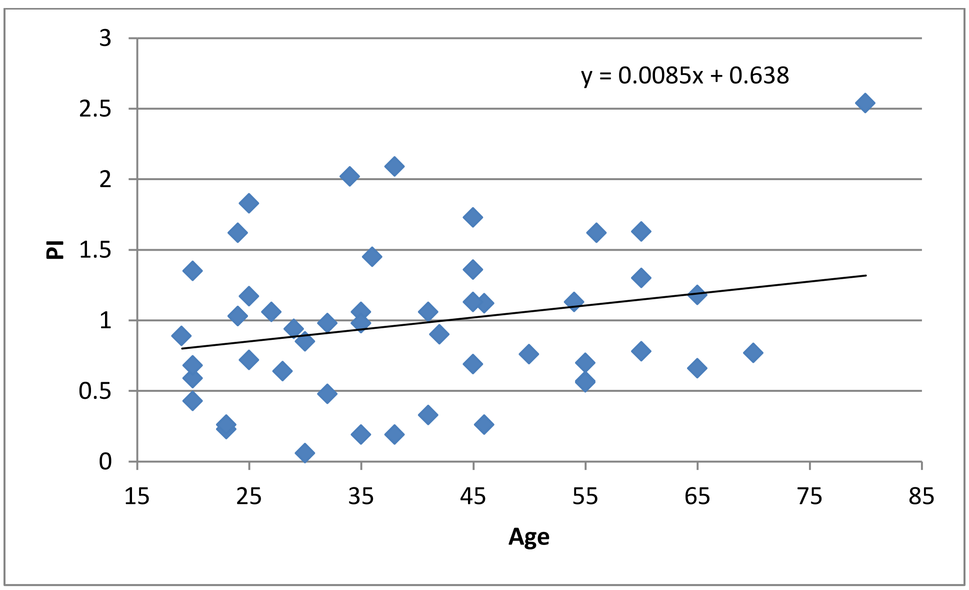


Figure (4-6): The relation between age and PI.

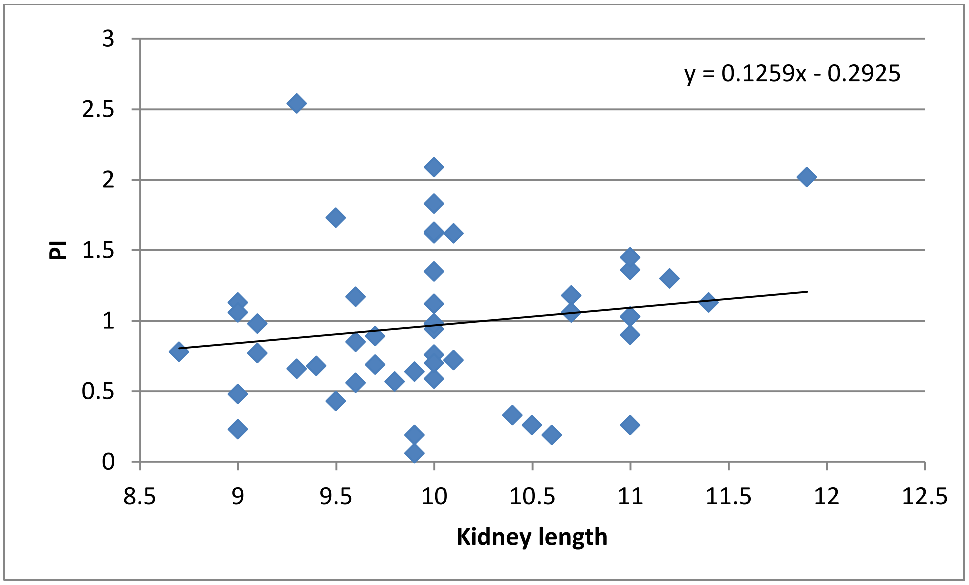


Figure (4-7): The relation between renal length and PI.

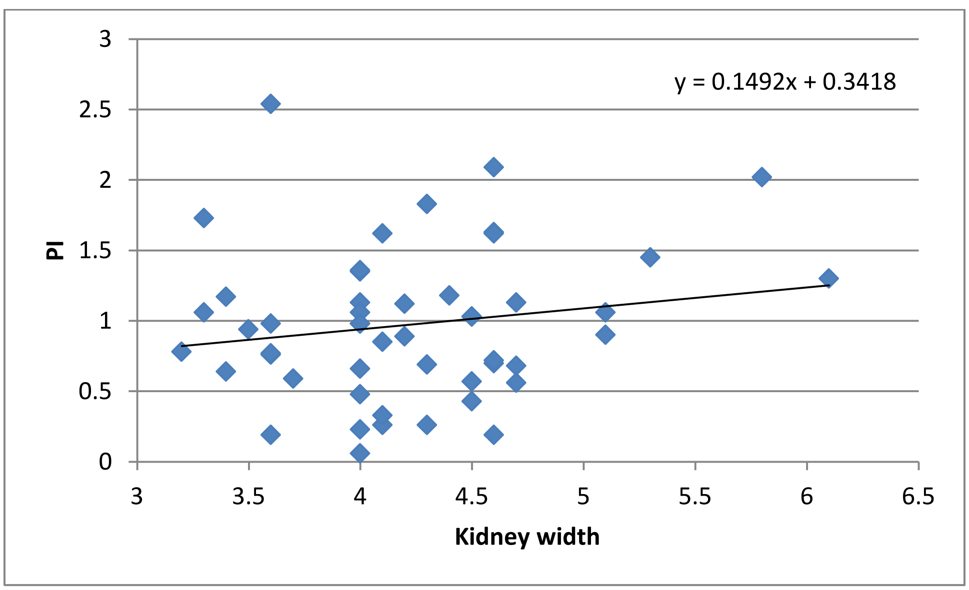


Figure (4-8): The relation between kidney width and PI.

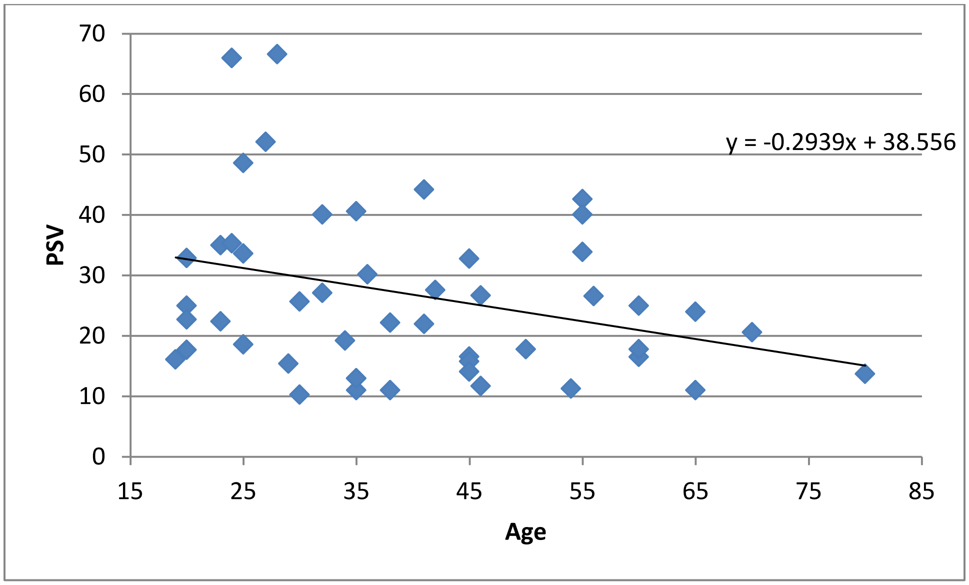


Figure (4-9): The relation between age and PSV.

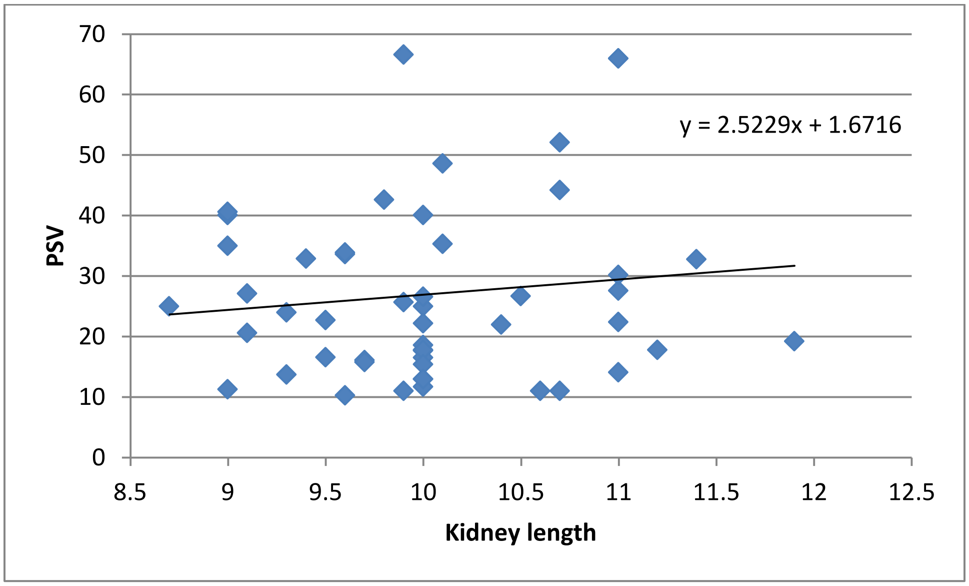


Figure (4-10): The relation between kidney length and PSV.

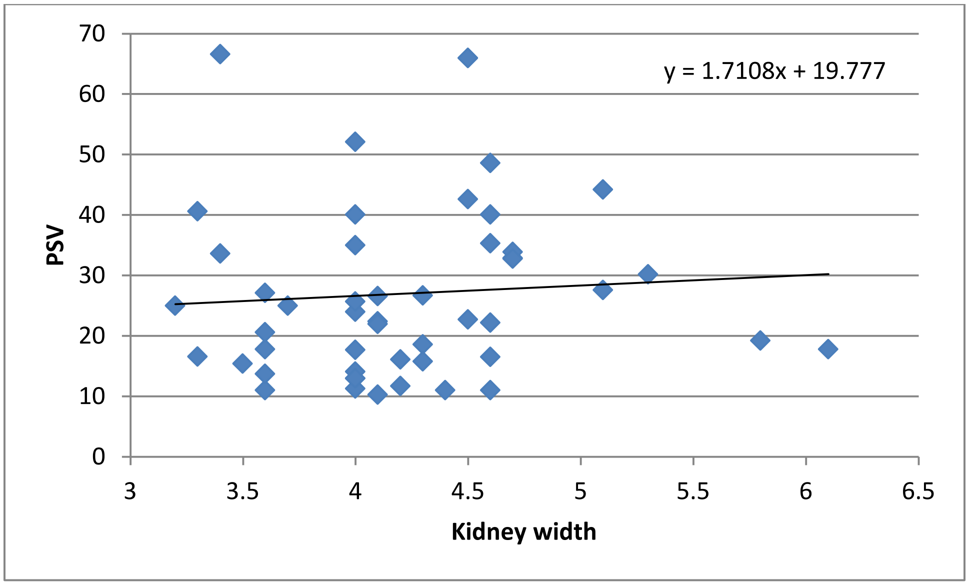


Figure (4-11): The relation between kidney width and PSV.

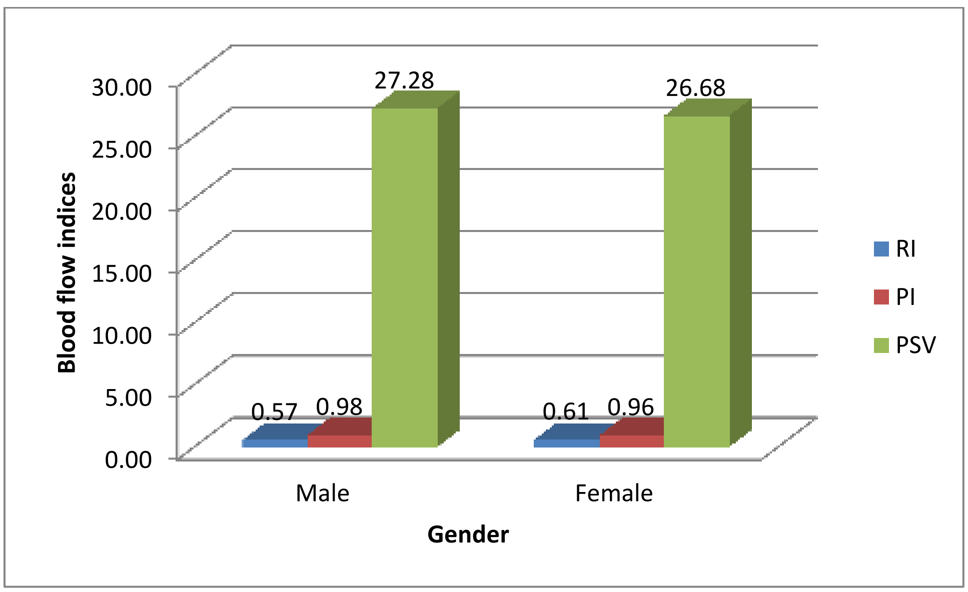


Figure (4-12): The relation between age group and mean RI according to gender

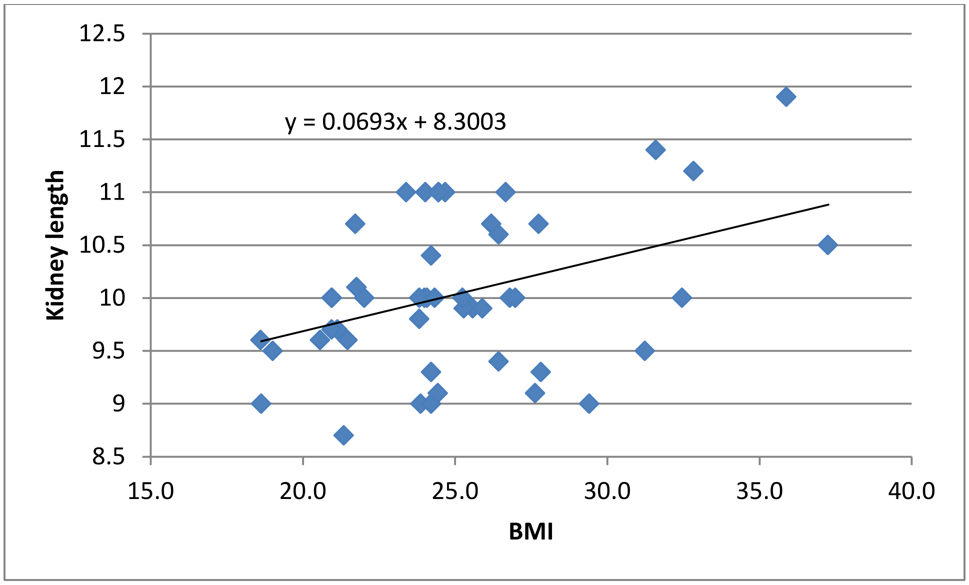


Figure (4-13): The relation between kidney length and BMI.

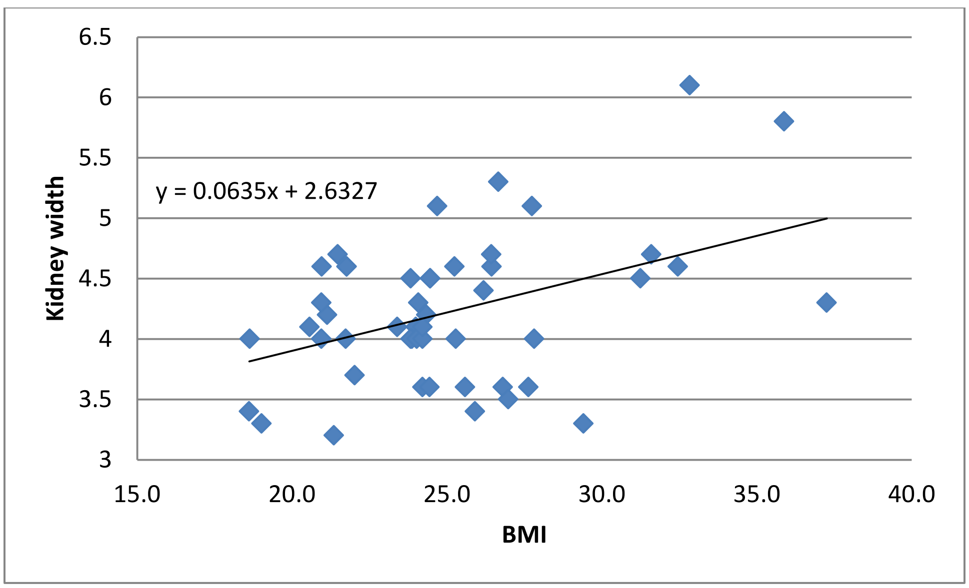


Figure (4-14): The relation between kidney width and BMI.

Chapter five

Discussion, Conclusion and Recommendation

5.1 Discussion:

This study includes 50 patients, the data were collected by selected 9 variables (The RI, PI, PSV, age, gender, height, weight, renal length & width and patient status) using Doppler ultrasonography. The results include the mean, maximum, minimum and standard deviation of the variables as well as relationship between body characteristics and blood flow indicces. The pecentage of males was 52%, while the percetage of females was 48%, (Figure 4-1).

The mean age of patients included in this study was 39.3±15.1, with their mean BMI 25.05±4.06. Their average measurement of their kidney length and width was 10.03±0.71 & 4.2±0.6 respectively. The blood flow indices of these patients in average was 0.58±0.05, 0.97±0.53, and 26.9±14.6 for RI, PI, and PSV respectievly. (Table 4-1).

There is no significant difference in blood flow indices in respect to age groups which is range from (19-34) up to (70-81) years. (Table4-2).

The result of this study showed that there is a direct linear relationship between RI and BMI ; it was found that RI increased by 0.002/ kg/m^2 , (Figure 4-3),this means the BMI affected the kidneys ,and hence the blood flow by tightening the vesseles. Similarly the kidney length has direct relationship with RI, where RI is increased by 0.017/each cm of kidney length, (Figure 4-4) as well as the kidney width which increased by 0.01/ for each cm of kidney width (Figure (4-5).This means kidney dimentions affect blood flow indices for perfect blood perfusion.

This study showed that there is a direct linear relationship between PI and age ; it was found that PI increased by 0.0085/year , (Figure 4-6), this means that age affected the myocardium hence the blood perfusion for the kidneys. Similarly the kidney length has direct relationship with PI, where PI is increased by 0.125/each cm of kidney length (Figure (4-7), as well as the kidney width which increased by 0.149/ for each cm of kidney width (Figure (4-8).This means kidney dimentions affect PI as a compensetory mechanism.

The relation between PSV and age showed that the PSV values decreased by 0.29/year, (Figure 4-9). This means the age affect the cardiac muscle ,so the velocity decreased .

Also the kidney length has direct relationship with PSV, where PSV was increased by 2.52 cm/sec/cm of the kidney length, (Figure 4-10) as well as the kidney width which increased by 1.71 cm/sec/cm of the kidney width (Figure 4-11).This means kidney dimensions affect blood flow velocity to accommodate blood perfusion.

The result of this study showed that the mean RI, PI, and PSV for males was 0.57, 0.98 and 27.28 respectively. While the mean RI, PI, and PSV for females was 0.61 , 0.96 and 26.68 respectively (Figure 4-12). Although there is slight change in average between male and female, but this different was insignificant using T test at P =0.05

The length of the kidney is found to be increased by 0.06 cm/ kg/m^2 in relation to BMI , (Figure 4-15). The relation between kidney width and BMI was evaluated; it was found that the kidney width increased by 2.63 cm/ kg/m^2 , (Figure 4-16).

5.2 Conclusion:

Doppler ultrasound is widely utilized as the initial tool in evaluating kidney problems. The goal of the study is to investigate the utility of Doppler ultrasound in detecting the range of spectrum of the renal arteries of the healthy kidneys.

The resistive index (RI), peak systolic velocity (PSV) and pulsitility index (PI) of renal arteries (segmental arteries) of the patients were taken to get the range of these values in healthy kidneys of Sudanese population.

There is a linear relationship between patient's age and PSV of the renal artery. The PSV of the renal artery decreased by increasing patient's age.

There is a linear relationship between the kidney length and RI of the renal artery. The RI of the renal artery increased by increasing the kidney length.

Spectral reassessment of renal arteries is one of the most valuable tool for detecting any renal vascular pathology, even in healthy kidneys, the upper limits of the normal values may be alarming for any hidden problem.

5.3 Recommendations:

- Further studies shouid be done with larger sample volume to assess the normal range of Doppler indices of renal arteries for Sudanese population..
- Study can also be done in depth for other types of medical images like CT and MRI .
- Initiation of Ultrasound units with Doppler facilities can help a lot in detecting renal problems.

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