Sudan University of Sciences and Technology

College of Graduate Studies

Characterization of Signs for Rejection of Transplanted Kidneys in Sudanese Patients using Ultrasonography

توصيف علامات رفض الكلى المزروعة في المرضى السودانيين باستخدام الموجات فوق الصوتية

A Thesis Submitted in Fulfillment for the Requirement of PhD Degree in Medical Diagnostic Ultrasound

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(إنما يخشى اللهَ من عباده العلماءُ إن الله عزيزٌ غفورٌ)

صدق الله العظيم ،،،

فاطر 28

DEDICATION

I’m dedicating this thesis

To the soul of my father

My mother and my family & to all of whom have given me continuous encouragement and support.

To our teacher Abdalsamad M. Salih who gave me continuous support during the journey of my work in higher education and research.

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Praise is to the Allah almighty who blessed me with knowledge, and spirit to write this thesis. Also deep thanks to my family whom have scarified a lot of their time enabling me to prepare this thesis. I would to thank Dr. Maryam Khojali and Dr.Awadia Gareeballah and Safa Siddeeg for their help in data collection. Great thank to Prof. Bushra Hussein the supervisor of this study and Dr. Mohammed Omer Yousef the co-supervisor for their effective support.

ABSTRACT

A retrospective study was conducted in Khartoum State from July 2015 to April 2017. A total of 115 cases of transplanted kidneys were retrospectively analyzed. There were missing cases. A designed data collection sheet was used to collect the sonographic findings, clinical and demographic data. The renal cortex, corticomedullary differentiation and ratio (CMD & CMR) and graft size were evaluated and analyzed using software statistical program (SPSS).

Assessment of morphology and hemodynamics of transplanted kidneys provides informative data on underlying pathological processes that involve the transplanted kidneys. Identification of these morphological changes is useful to predict the rejection as early as possible. Objective: to predict signs of rejection by evaluating the morphological and hemodynamic changes; Doppler resistive index (RI) corticomedullary differentiation, corticomedullary ratio, cortical thickness and graft size of transplanted kidneys in Sudanese using ultrasonography.

The results of this study the most of the patients were workers (29.6%), employee 27.8% and housewives 20%. Sonographic evaluation of transplanted kidneys showed the CMD was disturbed in 20.9%, lost 4.3%. The CMR was increased by 7.8% and decreased by 13%. The graft cortex was thin in 9.6% of the cases, thick in 0.9% and normal in 87.6%. There was no significant correlation of Doppler resistive index with CMD, CMR, cortical thickness and graft size (p-values = 0.38, 0.11 and 0.37 respectively). The mean RI was 0.67, creatinine was 3.45 mg/dL and blood urea was 76.04mg/dL. The study revealed that rejection was considered to be highly likely when RI ≥.9, Rejection likely when RI = 0.80-0.89, indeterminate when RI= 0.70-0.79 and rejection was unlikely when RI < 0.70. The RI was significantly associated with gender and revealed negative significant correlation with echogenicity of parenchyma of the

graft. However, the RI was not statistically significantly correlated with the graft size, CMD, CMR, cortical thickness, serum creatinine and blood urea (p-values= 0.19, 0.10, 0.50, 0.42, 0.91 and 0.47 respectively). But it elevated in grafts with increased CMR, echogenicity and disturbed CMD. And this is clinically significant since it reflects the intrarenal pathological processes in the grafts.

The present study concluded that in Sudanese patients, there were considerable morphological and hemodynamic changes involving the graft. The Doppler resistive index and duration of transplantation have no statistical correlation with morphological changes in the graft. However, the morphological appearance was attributed to pathological changes which were landmarks to predict the rejection. The RI was significantly different between males and females and it significantly decreased in echogenic grafts. The morphological changes and elevated RI were important signs to predict rejection of the grafts.

مستخلص الدراسة

إن تقييم الكلى المزروعة من حيث التركيب و الدموية يعطي معلومات قيمة عن طبيعة الأمراض التي تعتريها. و معرفة هذه التغيرات المرضية مفيد للتنبؤ برفض الجسم للكلى المزروعة. تهدف هذه الدراسة للتنبؤ برفض الجسم للكلى المزروعة من خلال تقييم التغيرات التركيبية والدموية باستخدام الموجات فوق الصوتية والدوبلر.

هذه الدراسة استرجاعية أجريت في مستشفيات ولاية الخرطوم في الفترة من أغسطس 2015 وحتى أغسطس 2017. تم دراسة تقارير 115 حالة من المرضى السودانيين. تم تصميم استبانة جمع المعلومات التي تختص بمورفولوجيا ودموية الكلى المزروعة من تقارير الموجات فوق الصوتية و معها المعلومات السريرية والديموغرافية. تم تحليل النتائج باستخدام البنامج الأحصائي SPSS .

اوضحت نتائج الدراسة أن معظم مرضى زراعة الكلى من العمال (29.6%) و موظفين 27.8% و ربات منزل 20%

تقييم فحص الموجات للكلى المزروعة أوضح أن التمايز القشري النخاعي معطوب بنسبة 20.9% والتناسب القشري النخاعي مرتفع بنسبة 7.8% و منخفض بنسبة 13%. أما القشرة الكلوية فكانت رقيقة بنسبة 9.6% و سميكة بنسبة 0.9% و صحية بنسبة 87.7%.

لوحظ –إحصائيا-أنه يوجد زيادة ايجابية في مؤشر المقاوم RI والتغيرات المورفولوجية(التمايز القشري النخاعي والنسبي وسمك القشرة و طول الكلية المزروعة ولكن لوحظ زيادة قيم مؤشر المقاوم الدموي في الكلى المزروعة التي بها زيادة و خلل في التمايز القشري النخاعي و ذات انعكاس موجي. وهذا له أهمية اكلنيكية لأنه يعبر عن مدى العمليات المرضية التي تحدث داخل النسيج الكلوي المزروع.

متوسط مؤشر المقاوم الدموي RI في الكلى المزروعة هو 0.68 والكريتينين 3.45ملجم/ديسلتر و اليوريا 76.04ملجم/ديسلتر. لوحظ وجود ارتباط خطي بين مؤشر المقاوم الدموي مع فترة زراعة الكلى و طول الكلى و الكريتينين و اليوريا. و هذا مؤشر مهم على أهمية المقاوم الدموي للتنبؤ بالرفض المبكر للكلى المزروعة.

خلصت الدراسة ان هناك تغيرات مورفولوجية و دموية في الكلى المزرزعة. يرتفع مؤشر المقاوم الدموي مع التغيرات المورفولوجية في الكلى المزروعة. ولكن زيادته في هذه الحالات يعتبر إكلينيكيا مؤشر رئيسي للتنبؤ برفض rejection الجسم للكلى المزروعة. يوجد اختلاف معنوي في قيم RI بين الذكور و الأناث. كما تقل قيم RI معنويا في الكلى ذات الصدى العالي. تعتبر التغيرات المورفولوجية للكلى المزروعة وو ارتفاع قيم المقاوم الدموي RI من العلامات الأساسية للتنبؤ برفض الجسم للكلى rejection

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List of Abbreviations

ATN	Acute tubular necrosis
ARF	Acute renal failuire
AR	Acute rejection
CKD	Chronic kidney disease
CRF	Chronic renal failure
CR	Chronic rejection
CTA	Computerized tomography angiography
EDV	End diastolic velocity
GFR	Glomerular filtration rate
MRA	Magnetic resonance angiography
PI	Pulsatility index
PSV	Peak systolic velocity
RI	Resistive index
RT	Renal transplantation
TA	Time acceleration
US	Ultrasound

Chapter One

1.1: Introduction:

Renal transplantation is the treatment of choice for patients with end-stage renal disease (ESRD). It provides improved quality of life and increased survival rate Post-transplantation monitoring of allograft function is important, as detection of graft dysfunction requires prompt evaluation and management (Khai, Peter and John, 2015). The disadvantage is cost-effective. The first Renal Transplant in Sudan was performed in 1974 [Alsayyari, 2008]. In Sudan, kidney transplant estimated 24% of the whole provided renal replacement therapies [Hisham et al, 2013].

Transplanted kidneys were at risk of various morphological and physiological abnormalities. The ultrasound plays an effective role to assess these abnormalities. The parenchymal changes that involve the allografts include poor or obscured corticomedullary differentiation (CMD), a defect of the corticomedullary ratio(CMR), decreased or increased echogenicity [Sharfuddin, 2013]. These findings were associated with graft dysfunction and reflect several diseases such as acute tubular necrosis (ATN), hyperacute, acute and chronic rejection, infection and drug nephrotoxicity. However, there is no cure for hyperacute rejection (Flechner, 2013). Chronic kidney rejection's mechanism is not well understood but appears to present itself after 5 years' post-transplant (Gruessner, 2014).

The sonographic assessment of morphological changes provides accurate and early identification of early pathological changes which may develop to rejection. On the other hand, color Doppler ultrasonography provides functional data on assessment of hemodynamic of renal arteries of the grafts. The resistive index (RI) measured in intrarenal arteries is considered a predictor of worse kidney graft function in early posttransplant period (Kolonko et al., 2012)

Previous studies confirmed that the Doppler resistive index(RI) is an important parameter that utilized to assess the function of transplanted kidneys and to predict early pathological changes (Meyer, Paushter and Steinmuller, 1999)

The clinical evaluation of a patient with kidney transplant dysfunction has the choice of a variety of imaging procedures, including ultrasonography, nuclear medicine, computed tomography, magnetic resonance image and urography. Ultrasonography is ideally suited for imaging the kidney, especially allograft, itis easily visualized the cortex, medulla and collecting system have different acoustic properties and are easily discernible. It is a simple, inexpensive, readily available, non-invasive imaging modality, portably, rapidly and accurately depicts many of the common complications after Kidney renal transplantation. It is indicated as the initial investigation in patients presenting with decreased urine output, pain, infection, and hematuria and for doing a percutaneous allograft biopsy. While sonography confirms the diagnosis of obstructive nephropathy and perinephric fluid collections, Doppler imaging is an effective screening modality for the detection of post-transplant vascularity. For these reasons, US is considered to be the first-line diagnostic imaging tool in the postoperative period and in follow-up (Annual Data Report, National Institutes of Health, 1999) (Khalil et al., 2003; Beleva et al., 1982; Dianne et al., 2010; Jane and Bates, 2005).

Based on imaging evaluation, the complications of renal transplantation can be divided into four major categories: peri-renal, renal parenchymal, renal collecting system, and renal vascular complications. Common complications included acute tubular necrosis, graft rejection, drug nephrotoxicity, hematoma, lymphocele, urinoma, hydronephrosis, and vascular complications. Ultrasound has a key role in identification and management of most of these complications. However, some parenchymal complications may only be diagnosed on renal biopsy. Ultrasound is a very powerful screening tool to assess renal transplant dysfunction and has a primary role in early diagnosis and management of structural and vascular complications, which may need surgical intervention to save the graft.

Color Doppler Ultrasonography has been used extensively utilized in the evaluation of kidney function and has the advantage of safety, accuracy and imaging the structure of the graft and its perfusion without need for intravenous insertion. And also it permits rapid assessment of the main renal artery within the graft. In previous studies, RI and PI had significant linear correlation with laboratory findings (creatinine). Therefore, they were regarded as important Doppler indices markers for determining the kidney allograft function and the related vascular complications (Nezami et al., 2007).

Most common complication of Kidney transplantation is allograft dysfunction, which in some cases leads to graft loss. Therefore, prompt diagnosis and management of early post transplantation is important for graft survival. In this case, Doppler imaging has unique contribution to the evaluation of renal transplant dysfunction (Ayşe, 2014)

The aim of this study was to evaluate the morphological changes (CMD, CMR, cortical thickness and graft size) and Doppler parameters of transplanted kidneys in Sudanese recipients using gray scale ultrasonography. And to find whether there was a correlation of RI and duration of transplantation with the morphological abnormalities and Doppler indices. The importance of these abnormalities and RI is to predict early pathological changes that may cause rejection of the graft.

1.2 Statement of the problem:

There are no main reasons to identify the cause of rejection. Many complications can be prevented if they are detected early. The Clinical Practice

Guidelines Committee of the American Society of Transplantation developed the guidelines to help physicians and other health care workers provide optimal care for Kidney transplant recipients. The guidelines are cover the patient screening and prevention of diseases and complications that commonly occur after renal transplantation. They do not cover the diagnosis of diseases and complications after they become manifest. Rejection of Kidney transplant leads to increase of the morbidity and mortality rate in the community. With the increasing number of Kidney transplants we will need fast, reliable diagnosis of the multitude of possible complications that inevitably occur after such complex procedures. So, ultrasound imaging can assess the signs of rejection.

1.3 Objectives of the study: -

1.3.1 General objective:

To assess the morphological changes and Doppler findings of the transplanted kidneys and the expected signs that may develop to rejection and to specify the main systematic findings in Sudanese patients.

1.3.2. Specific objectives:

2. To find sonographic features and signs which predict rejection of the renal grafts.
3. To assess the size, corticomedullary differentiation, corticomedullary ratio and echogenicity (morphological changes) of the transplanted Kidney.
4. To measure the Resistive index (RI) and pulsatality index (PI) in order to assess the vascularity of the transplanted kidneys.
5. To correlate RI with serum creatinine and blood urea levels.
6. To correlate of RI with morphological changes (CMD, CMR and length of the grafts)
7. To identify the systematic findings which associated with the renal allograft.

Chapter two

Literature Review

2.1. Anatomy of The kidney

The kidneys are paired retroperitoneal structures that are normally located 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 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. [1] (national institute of diabetes and digestive and kidney diseases (National Institute of Diabetes and digestive and kidney diseases, 2017)

The kidneys lie in the retroperitoneal cavity near the posterior abdominal wall, just below the diaphragm. The lower ribs protect both kidneys. The right kidney lies slightly lower than the left kidney because the large right lobe of the liver pushes it inferiorly. The kidneys move readily with respiration; on deep inspiration, both kidneys move downward approximately1 inch. The kidneys are dark red, bean-shaped organs that measure 9 to 12 cm long, 5 cm wide, and 2.5 cm thick (Hagen, 2012). The outer cortex of the kidney is darker than the inner medulla because of the increased perfusion of blood. The inner surface of the medulla is folded into projections called *renal pyramids*, which empty into the renal pelvis(Hagen, 2012)

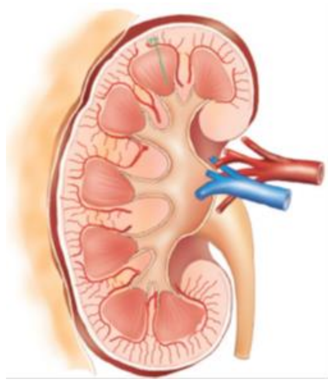

Figure (2.1) The kidney cut longitudinally to show the internal structure (Hagen, 2012)

Each kidney is surrounded by the renal capsule, which is a layer of fibrous tissue. A layer of fatty tissue holds the kidneys in place against the muscle at the back of the abdomen. Outside the layer of fat is Gerota’s fascia, or renal fascia. It is a thin, fibrous tissue.The inside of the kidney is made up of an outer part called the cortex and an inner part called the medulla. The renal pelvis is a hollow, funnel-shaped area in the centre of each kidney where urine collects (John Dick, 2017)

2.2. Renal physiology

The kidneys are critical in regulating the internal environment of the body. In particular, they regulate the total body water, as well as a number of substances which are essential to life (Roger Mark, 2017).

2.2.1. Body Fluid Compartments:

Total body water (TBW) is approximately 60% of body weight. It is distributed as intracellular water (ICW) and extracellular water (ECW). Intracellular water is the largest compartment, comprising approximately 40% of body weight. Extracellular water is about 20% of body weight. (Note the 20, 40, 60 rule for ECW, ICW, and TBW respectively.) Figure 1 shows the approximate sizes of the body fluid compartments. Note that ECW is divided into interstitial fluid

(16% of body weight), and blood plasma (4% of body weight). Composition of the body fluid compartments differs markedly. Extracellular fluid contains mostly sodium cations, and chloride anions. Interstitial fluid and plasma are very similar except for the higher concentration of protein in the plasma. On the other hand, intracellular fluid is rich in potassium cations and organic phosphate anions, with very little sodium and chloride.

Why the difference? The intracellular compartment is separated from the extracellular

compartment by cell membranes. This barrier is selectively permeable, and contains active sodium-potassium pumps which maintain the concentration differences. Plasma and interstitial fluid compartments are separated by capillary endothelium, which allows free passage of ions, but is not permeable to large protein molecules.

Water moves freely across all boundaries (Roger Mark, 2017).

2.2.2. Glomerular filtration

The formation of urine begins with a passive ultrafiltration process, in which the movement of water and associated dissolved small molecules is determined by hydrostatic and oncotic pressures. Glomerular capillaries are about 100 times more permeable to water and crystalloids than are muscle capillaries. Note that the plasma oncotic pressure rises as fluid moves along the capillary (due to net loss of water into Bowman's space). Typical glomerular filtration rate (GFR) is ~ 180 liters per day, or 125 ml/min. Of this enormous amount, only 1-2 liters per day are excreted as urine, implying that 99% of the filtered volume is reabsorbed (Roger Mark, 2017)

2.3. Pathologies related to renal grafts

2.3.1. Causes of renal transplantation: Renal failure that lead to end stage kidney disease(ESKD)I is the main cause of renal transplantation. The following are the main causes:

2.3.1.1. **Acute Renal Failure**:

Acute renal failure may occur in pre renal, renal, or post renal failure stages. The pre renal stage is secondary to hypo perfusion of the kidney. The renal stages may be caused by parenchymal diseases (i.e., acute glomerulonephritis, acute interstitial nephritis, or acute tubular necrosis). They may also be caused by renal vein thrombosis or renal artery occlusion (Hagen, 2012)

2.3.1.2. **Acute Tubular Necrosis**

Acute tubular necrosis (ATN) is the most common medical renal disease to produce acute renal failure, although it can be reversible.

2.3.1.3. **Chronic Renal Disease:**

Chronic renal disease is the loss of renal function as a result of disease, most commonly parenchymal disease. Three primary types of chronic renal failure are known: nephron, vascular, and interstitial abnormalities. Glomerulonephritis, chronic pyelonephritis, renal vascular disease, and diabetes are a few of the diseases that lead to renal failure (Hagen, 2012).

People with the following disease are more likely of developing renal failure and ESKD:

1- Diabetes (type 1 or type 2)
2- High blood pressure, especially if severe or uncontrolled
3- Glomerular diseases (These are conditions that damage the glomeruli, such as glomerulonephritis.)
4- Hemolytic uremic syndrome
5- Systemic lupus erythematosus

6- Sickle cell anemia

7- Severe injury or burns

8- Major surgery

9- Heart disease or heart attack

10-Liver disease or liver failure

11- Vascular diseases (These conditions, including progressive 12- systemic sclerosis, renal artery thrombosis [blood clot], and scleroderma, block blood flow to different parts of the body.)

13- Inherited kidney diseases (polycystic kidney disease, congenital obstructive uropathy, cystinosis, prune belly syndrome)

14- Diseases affecting the tubules and other structures in the kidneys (acquired obstructive nephropathy, acute tubular necrosis, acute interstitial nephritis)

15- Taking antibiotics, cyclosporin, heroin, and chemotherapy (These can cause inflammation of kidney structures.)

Gout

16- Certain cancers (incidental carcinoma, lymphoma, multiple myeloma, renal cell carcinoma, Wilms tumor)

17- HIV infection

18- Vesicoureteral reflux (This is a urinary tract problem.)

19- Past kidney transplant (graft failure)

20- Rheumatoid arthritis (emedicine health, 2017)

2.4. Renal Transplantation

Renal transplantation is the treatment of choice for a minority of patients with end-stage renal disease (ESRD). Most adult patients with ESRD are never referred for evaluation for transplantation, and have a 70% 5-year mortality on dialysis. Marked improvements in early graft survival and long-term graft function have made kidney transplantation a more cost-effective alternative to dialysis. In the United States, over 375,000 kidney transplants have been performed, and in 2012, 191,400 patients were alive and with a functioning transplanted kidney; currently, more than 101,000 patients are waiting for kidney transplants (United Network for organ sharing, 2017; Matas et al., 2014)

2.4.1. Surgical Technique of Kidney Transplantation:

The renal allograft is most often placed in the iliac fossas between the peritoneum and the iliacus muscle. Some authors call this a retroperitoneal location1 while others consider it an extraperitoneal location. In a child the allograft may be placed intraperitoneally if it is too big for the usual extraperitoneal location. The renal transplant may also be located intraperitoneal if it is combined with pancreas transplantation (Devin, 2005)

The renal pelvis and ureter are usually positioned anteriorly to permit easier access if later intervention is required. Therefore, a right donor kidney is usually turned over and placed in the recipient's left iliac fossa; similarly, a left donor kidney is usually placed in the recipient's right iliac fossa. "The allograft ureter is passed through an oblique tunnel in the muscular layer of the bladder, forming a nonrefluxing ureterovesical junction (Devin, 2005).

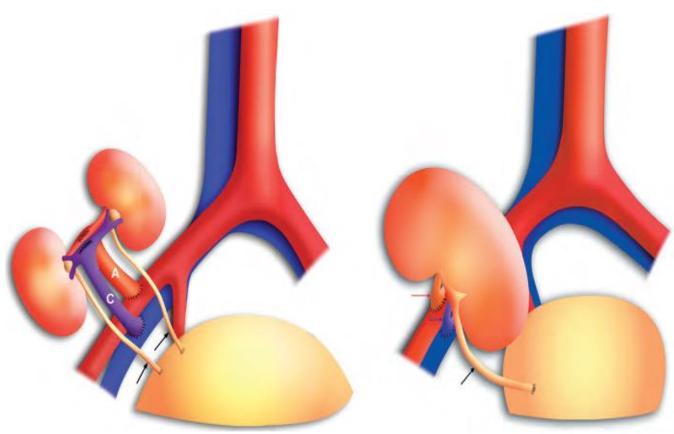

Figure (2.3) Renal transplant surgery: A, Single cadaveric transplant. The main renal artery and main renal vein are anastomosed to the external iliac artery and vein, respectively. The ureter is anastomosed to the superolateral bladder wall. B, Double cadaveric transplant. The aorta (A) and IVC (C) are anastomosed to the external iliac artery and vein, respectively. The ureters are anastomosed to the superolateral bladder wall (Hagen, 2012)

The transplant renal artery may be attached in one of three ways:

1. End-to-side. The end of the allograft artery is attached to the side of the external iliac artery. This is the preferred attachment because of a lower incidence of postoperative stenosis.
2. End-to-end. The end of the allograft artery is attached to the end of the internal iliac artery.
3. Carrell patch. Cadaver kidneys are commonly removed with the renal artery still attached to a portion of the aorta. The aorta is trimmed to an oval or round shape (the Carrell patch) and is sutured end-to-side to the external iliac artery of the recipient.

Multiple renal transplant arteries require additional anastomoses.

The transplant renal vein is usually connected end-to-side to the external iliac vein.

The native kidneys of the transplant recipient are left in place unless they are associated with infection. Native kidneys, in dialysis patients, are associated with the development of cysts and neoplasms (Devin, 2005)

2.5. Ultrasonography of renal transplant

US is routinely used to evaluate the transplant within the first 24 hours after transplantation and also serves as the first-line evaluation method following the onset of transplant dysfunction. Grayscale images are obtained to evaluate for transplant size, echotexture, hydronephrosis, peri-transplant fluid collections, and masses and to measure renal cortical thickness. Color Doppler images evaluate the patency and direction of flow in transplant arteries and veins. Spectral analysis of vascular waveforms and velocities can provide information about a range of pathologies, including RAS and RVT. Advantages of US over CT include portability, no radiation exposure, and the lack of need for potentially nephrotoxic iodinated contrast agents. US is fast and real time, particularly when compared to MRI. Vascular evaluation with US instead of MRI can avoid the risk of nephrogenic systemic fibrosis (NSF) from gadolinium-based contrast agents. Are lative limitation of US in comparison to CT or MRI is its operator dependence.

The renal allograft is usually located superficially, therefore a 5 to 7 MHz linear or curved array transducer may be used. This transducer provides a good near field image quality and a broad field of view (Devin, 2005) .

Grayscale US abnormalities in dysfunctional renal transplants include a reduction in corticomedullary differentiation, reduction in renal sinus echogenicity, increased and reduced renal parenchymal echoes, and increased cortical echogenicity. Unfortunately, these findings are of limited value as the features are nonspecific and generally occur well after the onset of transplant dysfunction (Myles et al, 2016)

2.5.1. Ultrasonography protocol of the renal graft: A baseline scan of the transplant kidney is usually performed within the first 24 to 48 hours following surgery. This provides a frame of reference against which all future scans will be compared. "Typically, a second scan is performed 1 to 2 weeks Post transplant, and a third scan is obtained at about 3 months (Devin, 2005)

The kidney is scanned longitudinally and transversely: Maximum length, width and anteroposterior (AP) measurements are taken and renal volume is calculated using the standard formula (volume = length x width x AP dimension x 0.523). An increase in the size of the allograft is an important feature of graft pathology and is best appreciated through volume measurements. 1,2 The echogenicity of the renal cortex, medulla and renal sinus is evaluated and, if it is a follow-up scan, compared to the baseline and previous scans (Devin, 2005)

The perirenal areas are scanned for possible fluid collections, masses, hematoma and lymphadenopathy. Scans of transplant kidneys are usually performed with a full bladder. The bladder displaces the overlying bowel away from the transplant (Devin, 2005)

Slight dilatation of the renal pelvis (pelviectasis) is a common and usually normal finding, particularly in the postoperative period. However, dilatation of the renal calyces (calyectasis) is a relatively reliable sign of obstruction.1 Therefore, if hydronephrosis is present (or suspected), the bladder should be emptied to see if the dilatation is caused by bladder distention, a dilated ureter should be searched for (Devin, 2005)

Doppler evaluation for patency of the arteries and vein is an essential part of the renal allograft US evaluation. Spectral waveforms of upper, mid and lower pole intrarenal arteries are obtained and RI calculated from the waveforms. Color Doppler is often used to identify the intrarenal artery locations for spectral tracings. Power Doppler provides evaluation of vascular perfusion of the renal allograft and is used to detect focal flow defects (Devin, 2005)**.**

The central approach of renal transplant ultrasound is to evaluate for possibly treatable surgical or medical complications arising in the transplanted kidney (Tim and Zishan, 2017)

2.5.2. Structural assessment:

Gross structural assessment is as for a native kidney and includes:

- renal echogenicity
    - corticomedullary differentiation should be preserved
- renal size

- enlargement may indicate oedema, which is non-specific, but a change in size between studies is an indication of underlying disease (Tim and Zishan, 2017)

2.5.3. Assessment of Surgical complications using ultrasound:

Ultrasound can detect:

1- Obstructive uropathy
2- hydronephrosis
3- proximal hydroureter
4- Fluid collections

The nature of post-transplant fluid collections cannot be reliably determined on ultrasound appearances alone as most are anechoic with variable internal acoustic characteristics. This is best done based on the time scale as different fluid collections tend to present at different times in the postoperative period:

2.5.4. Immediate post-operative: Haematoma is the most common finding and appears in1-2 weeks' post-operative. Urinoma appears 3-4 weeks' post-operative and perinephric abscess in 2nd month and beyond is lymphocoele (Tim and Zishan, 2017)

2.5.6. Doppler assessment of renal allograft

Renal segmental or intralobar artery resistive indices (RI), measured by duplex Doppler US, are often used as a useful parameter for allograft dysfunction. Using RI >0.90 is a significant indicator of chronic pathologies in the grafts. Antonio et al92015) reported that " Doppler indexes display high diagnostic accuracy and in particular cases are more useful during the post-transplantation follow-up period". Previous studies have shown that renal arterial RI is useful in predicting graft survival (Radermacher et al, 2003), especially when using a lower RI cutoff of 0.8. Radermacher et al (2003), used a cutoff of 0.80 at 3 months after transplantation, found that 47% of patients with RI >0.80

developed chronic allograft nephropathy (CAN), compared to 9% of patients with RI <0.80. McArthur et al (2011) found that both RI and pulsatility index measured between week 1 and 3 months significantly correlated with the 1-year estimated glomerular filtration.

Doppler US is a first-line noninvasive tool in the evaluation of suspected RAS and uses a combination of direct insonation of the anastomosis and main renal artery in addition to indirect intrarenal waveform morphology. Peak systolic velocity (PSV) in the renal artery is commonly used as the parameter to assess for the presence of RAS on US. Cutoff values of 200 to 300 cm/s have been proposed in various studies (Baxter et al, 1995; Krumme et al, 1997), but the lower limit suffers from low specificity, leading to unnecessary angiography procedures [Patel et al, 2003). As in native kidneys, a tardus parvus waveform (small peak amplitude with delayed upstroke) can be seen within the transplanted kidney downstream to the stenosis. This morphologic waveform change is reflected quantitatively by the acceleration time (AT). De Morais et al (2003) reported a sensitivity of 90% to 96.8% and a specificity of 87.5% to 70% using various PSV

thresholds in the main renal artery and a sensitivity of 100% and specificity of 96.7% using an AT of 0.09 or less as normal. Another parameter that can be used is the renal artery to iliac artery ratio, which has been shown to have a sensitivity of 90% and specificity of 96.7% using a cutoff value of 1.8. Alternatively, AbuRahma et al (2012)

found that a PSV of 285 cm/s or renal-aortic ratio of 3.7 alone was better than any combination of PSVs, end-diastolic velocities, or renal-aortic ratios in detecting ≥60% stenosis. As evaluation for RAS with US is operator dependent, MR angiography (MRA) or CT angiography (CTA) may be more reliable in centers with little experience in evaluating for RAS with US (Myles et al, 2016).

In general, sonographic Assessment of vascular assessment assesses:

1- renal vein thrombosis or stenosis
2- reversal of diastolic flow in the renal artery
3- renal artery thrombosis or stenosis
4- high flow velocities at the stenosis site (Brown et al., 2000)
5- peak systolic velocity ≥2 m/, velocity difference between pre- and post-stenotic segments of 2:1
6- raised resistive index (RI) > 0.8 (25) (Brown et al., 2000)
7- focal or diffuse parenchymal oedema (complication)
8- post stenotic spectral widening
9- pseudoaneurysm: usually following biopsy or other renal puncture
10- intrarenal arteriovenous fistula (Tim and Zishan, 2017)

Ultimately, patients with suspected medical causes of transplant dysfunction undergo biopsy for definitive diagnosis.

2.5.7. Sonographic features of transplanted kidneys:

Doppler studies can often differentiate rejecting transplants from those that normally function. While very high Doppler indices are specific for rejection, waveforms in acute tubular necrosis may be abnormal (Laurence and Alfred, 1987).

Hollenbeck et al. (1994) studied the sensitivity and specificity of Doppler sonographic detection of renal transplant rejection with serial investigation technique. Their findings revealed that " in 41 cases primary rejections were better recognized by an increase in PI compared to the preceding value than by the absolute PI value (with a sensitivity of 90%; specificity was 76% and 42% respectively). The RI was less specific (with a sensitivity of 90%; specificity was

47% for the relative RI increase and 30% for the absolute RI value). The continuous PI increase started an average of 3.3 days (95% CI −15.25 to + 1.55) before rejection was diagnosed. Vascular rejection episodes showed higher PI values than interstitial rejections (3.86 ± 2.14 vs. 2.19 ± 0.87; P < 0.01)". They concluded that Doppler sonography recognizes rejection at an early stage (Hollenbeck et al., 1994)

2.5.8. The importance of renal morphological parameters in evaluation of Kidney diseases:

2.5.8.1. Cortical thickness: The morphological changes of the healthy kidneys had been reported in several studies. Al-rashad and Abdul-Fattah H. (2014) studied sonographic assessment of renal size in healthy adults. They assessed the normal sonographic values of renal length and cortical thickness in healthy adults and establish reference ranges in our population for comparison when examining renal disease. They reported that "the mean renal lengths for the right and left kidney were 10.68 ± 1.4 and 10.71 ± 1.0 cm, respectively (p = 0.56) without a significant change with age. The minimum cortical thickness was 0.6 cm. The renal length correlated with the weight of the patients (p < 0.01) and their BMI (p < 0.01) but not with their height".

The renal cortical thickness is a predictor of kidney dysfunction in CKD. Samia et al (2015) reported that "the correlation between GFR and measurements of renal cortical thickness, bipolar length, and parenchymal thickness was, respectively, moderate (r = 0.478; p < 0.001), poor (r = 0.380; p = 0.004), and poor (r = 0.277; p = 0.116)".

2.5.8.2. Estimation of Renal size: Measurement of kidney size by ultrasound is essential for evaluating possible renal diseses that affect the kidney. Renal length was extensively studied. Estimation of normal renal size

Chronic renal disease frequently leads to renal shrinking. Reliable criteria depicting a shrunken or enlarged kidney have not been published for adults. A renal length of 9-12 cm is considered normal, renal length correlating to body length. The correlation is poor however. Frequently the right kidney is shorter than the left kidney whereas renal function estimated by szintigraphy and renal volume estimated by CT are equal. A better correlation can be found between renal volume and body weight or body surface area. Renal volume is frequently estimated as length x depth x width (cm) / 2. In children with healthy kidneys normal renal volume (ml) could be estimated as body weight (kg) x 2. The few available data in adult populations – which were not evaluated for normal renal function - do not contradict these findings. A normal renal volume can therefore be defined as body weight (kg) x 2 ±20%. (Jörg Radermache, 2017)

Aylin et al (2014) evaluated the relationship between kidney volume and body indexes in the Turkish population determined using ultrasonography. They reported that "kidney lengths were 10.3±7.8 cm for the right and 10.4±9 cm for the left. Volumes were 158±39 cm3 for the right and 168±40 cm3 for the left. Volumes in women were 151.8±39 cm3 for the right and 159.8±37 cm3 for the left, and 164.3±38 cm3 for the right and 175.8±41 cm3 for the left in men. Kidney measurements correlated with body height and weight".

2.5.8.3. The renal parenchyma: assessment of renal parenchyma is a key role to identify and diagnose the pathological processes that involve the kidney. The normal renal parenchyma in children age 6 and older and in adults should be slightly less echogenic than that of liver and spleen. Normal renal parenchyma from birth until 6 months of age is slightly brighter than that of the liver. Increased echogenicity compared to liver and spleen in adults is a sensitive but unspecific sign of renal disease. The normal parenchymal width of 15-25 mm can be measured most reliably from the basis of a medullary pyramid to the kidneys surface. The renal hilum should be visible when measuring parenchymal width to avoid underestimation. If such a depiction is not technically possible a normal parenchymal width can be assumed if the parenchyma-pelvis relation is normal. The relation of ventral and dorsal parenchymal width to pelvic width should be 2: 1. Medullary pyramids are usually less echogenic than the surrounding parenchyma. Columns of Bertini (columnae renales) are extensions of the renal parenchyma in the renal pelvis and hypertrophied columns of Bertini should not be confused with pelvic tumors. The left kidney sometimes has a very wide parenchyma in the medial portion, a so called splenic notch or dromedary hump. This also is a normal finding and should not be confused with renal masses. The echogenicity in the area of the hump will be the same as in the surrounding parenchyma and the medullary pyramids will still be present and the vessel architecture will be unaffected (Jörg Radermache, 2017). In literature,the normal length of the kidney was ranged between 10-12 cm and the cortical thickness is generally 7-10 mm (Kristoffer et al, 2016).

2.5.8.4. The renal echogenicity: the echogenicity of the kidney is useful to diagnose several pathological diseases that involve the kidneys. Increased echogenicity of the kidney parenchyma results from the increased presence of material that can reflect sound waves back, thus increasing its brightness on the ultrasonography image. Because fibrous tissue (e.g., glomerulosclerosis, interstitial fibrosis) increases echogenicity, CKD is typically associated with increased echogenicity. Inflammatory infiltrates may explain the increased echogenicity that occurs with acute interstitial nephritis and glomerular nephritis (GN) (Page t al, 1994). For instance, cortical necrosis is a rare cause of AKI that is classically characterized by a dark, hypoechogenic renal cortex on ultrasonography. Renal cortical necrosis is characterized by diffuse or patchy ischemic destruction of all elements of renal cortex as a result of renal diminished perfusion due to vascular injury. Progression to ESKD is a rule in diffuse cortical necrosis. It is a rare cause of AKI in developed countries accounts 1.9%-2% of all patients with AKI (Jai and Vijay, 2015)

2.5.8.5. Summary of abnormal renal transplant ultrasound findings (Matthew, 2017**).**

1- Increasing size of renal transplant: the differential diagnosis was rejection, infection, venous thrombosis
2- Decreasing size of renal transplant: the differential diagnosis was chronic ischemia, chronic rejection
3- High resistive index: the differential diagnosis was acute tubular necrosis, obstruction, infection, severe rejection, extrinsic compression.
4- Low resistive index: the differential diagnosis was arterial stenosis, advanced aortic or iliac atherosclerosis, arteriovenous fistula
5- Hydronephrosis: the differential diagnosis was obstruction (stone, clot), anastomotic stenosis/edema, neurogenic bladder, bladder outlet obstruction

2.6. Renal Transplant Complications

2.6.1. Renal transplant complications

These can be broadly categorised as perirenal, renal parenchymal, renal collecting system, and/or renal vascular complications (Irshad et al., 2007; Sebastià et al., 2001):

- renal transplant rejection
    - acute renal transplant rejection
    - chronic renal transplant rejection
- renal arterial stenosis in the transplant renal artery (Akbar et al., 2005):
    - peak systolic velocity (PSV) >200 cm/s
    - 2:1 PSV ratio between stenotic and prestenotic artery
    - spectral broadening distally (i.e. turbulent flow)

    - +/- renal parenchymal tardus-parvus waveform
- renal vein thrombosis
- arteriovenous fistula
- perinephric fluid collection
    - urinoma
    - lymphocoele
    - haematoma
    - abscess
- renal artery pseudoaneurysm

 urinary obstruction: distal-third ureter stenosis (50%) with other causes including pelvic fibrosis, calculi, papillary necrosis, external compression (Akbar et al., 2005)

 graft pyelonephritis (Rice and Safdar, 2005)

2.6.1.1 Extra-renal transplant complications

- avascular necrosis
- amyloidosis
- metastatic joint calcification
- increased incidence of malignancy: e.g. lymphoma
- pseudoaneurysm

2.6.1.2 Medical complications

There are a number of medical causes of renal transplant dysfunction or failure (Brown et al., 2000)

2.6.1.3. Acute tubular necrosis

1- Rejection
2- Hyperacute: immediately post-operative
    - acute: 1-3 weeks post-transplant
    - chronic: >3 months post-transplant

3- drug nephrotoxicity
4- recurrent disease, e.g. recurrent IgA nephropathy
5- pyelonephritis
6- occurs in 80% of recipients in the first year

2.6.2. Renal Transplant Rejection

Rejection can be classified according to the period of appearance as hyperacute (occurring within minutes), acute (occurring within days to weeks), late acute (occurring after 3 months), or chronic (occurring months to years after transplantation) (Nankivell and Alexender, 2010). When hyperacute rejection happens, graft dysfunction is usually irreversible. The humoral reaction of the patient leads to a severe vascular lesion and to cortical necrosis. Imaging does not play any role. Absence of perfusion will be seen in Doppler, angiography or scintigrams (Rajiah, 2006). Accelerated acute rejection occurs within the first week. The imaging features are the same as of acute rejection (AR). Cortical nephrocalcinosis may be seen in rejected transplants left in situ (Rajiah, 2006; Elsayed et al, 2011)

Currently, the overall risk of acute rejection within 1 year after transplantation is less than 15% (Nankivell and Alexender, 2010). AR can be divided in acute-antibody mediated rejection and T-cell-mediated rejection. Acute-antibody mediated rejection is characterized by a rapid graft dysfunction due to inflammation. T-cell-mediated rejection can also present as an increasing creatinine level and diminished urinary output. Fever and graft tenderness now rarely occur. As mentioned before, imaging in AR is non-specific. Imaging findings superpose with other conditions such as ATN, drug nephrotoxicity, UC, and VC. The sonographic features are similar to those described for ATN (Rajiah, 2006; Irshad et al, 2008). They include renal enlargement, heterogeneity of renal cortex, loss, increase or decrease of CMD, hypoechogenicity of renal pyramids, cortex and sinus, thickening of renal cortex and thickening of the walls of collecting system. Although both ATN and AR cause PI and RI rise on Doppler US, the likelihood of AR is greater with high values [Park et al. 2007]. An elevated RI (>0,9) is highly suggestive of AR, but is not specific (O Neill and Baumgarten, 2002; Grant and perella, 1990; Schwenger et al, 2006; DuPont et al, 2003; Baxter, 2001). A PI of more than 1.5 is used in some centers for helping diagnosing rejection. Radionuclide studies show decreased renal perfusion and function (Dubovsky et al, 1995; Brown et al, 2000)

Chronic rejection (CR) occurs after at least 3 months to years after transplantation. It happens due to an insufficient immunosuppression to control residual antigrowth lymphocytes and antibodies. It presents as a progressive decline in renal function (Nankivell and Alexender, 2010) and may be difficult to diagnose by a non-invasive technique. Initially, the graft is enlarged and shows increased cortical thickness, which later changes to a thin cortex and mild hydronephrosis on both US, CT, and MRI (Sebastia et al, 2001; Brown et al, 2000; Sebastia et al, 2001; Irshad et al, 2008; Kalb et al, 2008; Irshad et al, 2008)

However, renal transplant rejection can be broadly classified into two group:

1- acute renal transplant rejection
2- chronic renal transplant rejection: usually after one-year post transplantation (at least after 3 months)

2.6.2.1. Clinical signs of rejection: these include: (Vanderbilt transplant, 2017)**:**

- Increase in temperature
- Increase in blood pressure
- Sudden increase in weight or ankle swelling
- Decrease in urine output
- Pain, tenderness or swelling of the new kidney
- Elevated creatinine

2.7. Previous studies

In Sudan, the previous studies regarding the renal transplantation and the ultrasound assessment were not enough. Sudan was a leading country in Africa and Arab World. The first kidney transplantation in Sudan was in 1973.

2.7.1. Study 1: Hanan and Elsid (2005) studied the ultrasonographic Findings in transplanted Kidneys. They reported that "Based on resistive index, 85.5% of cases were diagnosed as normal kidney graft, when the resistive index was in normal range (0.5 – 0.7) increased reistive index (> 0.7 – 1.0) noticed in acute iii rejection 33.3%, chronic rejection 100%, acute tubular necrosis 30.8% and cyclosporine toxicity in 100%. From the study we found that, when resistive index was normal (0.5- 0.7), blood urea was also normal (0-50 mg/dl) in 93.5 %, and when resistive index was high (0.7-1.0), blood urea was also high (100-150mg/dl) in 83.3%. When serum creatinine with normal range (0.5-1.0 mg/dl), resistive index was normal (0.5-0.7) in 80 % and when serum creatinine was high (2.5-3.0 mg/dl) resistive index was also high in 100% When the symptoms of patients compared with U/S diagnosis we found that patients with no complain, U/S reveal normal renal allograft in 75.9%, while patients with nausea, vomiting, abdominal pain, lower limb oedma had abnormal U/S findings". They concluded that "Doppler ultrasound was found to be useful and is complementary to laboratory investigation in the assessment of kidney graft".

2.7.3. Study 2: Matthew et al., (1987) reported that " Doppler examinations May be insensitive for detecting purely cellular rejection [6], and this may account for the cases of Rejection in our study that had normal values. The differentiation of any form of rejection from other causes of severe transplant dysfunction is more fundamental than actually diagnosing the type of rejection. To institute Appropriate therapy, the clinician must distinguish rejection from other causes of renal dysfunction. Eleven patients with acute tubular necrosis and two with normal kidney function had resistive indexes in the rejection range" (36). They demonstrated the criteria for diagnosis of transplant rejection. RI of ≥ 0.9, ejection highly likely; RI of 0.8-0.89, rejection likely; RI of 0.70-0.79, indeterminate and RI values < 0.70 rejection is unlikely.

2.7.3. Study 3: Al-Khulaifat (2017) evaluated transplanted kidney by Doppler ultrasound. He reported the signs of acute and chronic rejection. The sonographic appearance of acute rejection (AR) includes: Graft enlargement due to edema, 2- decreased cortical echogenicity and swelling of the medullary pyramids resulting in loss of cortico-medullary differentiation. 3- Edema within the renal sinus fat, which may obliterate the sinus echo complex. However, Ultrasound findings chronic rejection (CR) were small graft with thinned echogenic cortex and the RI is normal to slightly elevated. Biopsy is often required to exclude superimposed and potentially treatable AR.

2.7.4. Study 4: Angelo et al studied "Early assessment of renal resistance index after kidney transplant can help predict long-term renal function". They reported that the mean RI in early transplantation was 0.63 ± 0.07. They concluded that " early determination of RI can help predict long-term graft function in kidney transplant recipients". They stated that the assessment of RI, early after the transplant, was a good predictor of short-term allograft function.

2.7.5. Study 5: Grzegorz et al (2016) studied "The value of Doppler ultrasound in predicting delayed graft function occurrence after kidney transplantation". They assessed "the predictive value of blood flow velocity and vascular resistance measured by Doppler ultrasound in terms of pulsatility index (PI) and resistive index (RI) respectively, in the occurrence of delayed graft function (DGF) after kidney transplantation". Their results revealed that " The highest sensitivity of RI to predict DGF occurrence was observed intraoperatively and on the first postoperative day, with values of 77.8% and

72.2%, respectively. The study concluded that ' the utilization of Doppler ultrasound with measurement of hemodynamic parameters (PI, RI), play a crucial role in predicting the outcomes of kidney transplantation'.

2.7.6. Study 6: Stenberg et al (2016) studied "The prevalence and significance of renal perfusion defects in early kidney transplants quantified using 3D contrast enhanced ultrasound (CEUS)". They found that "Perfusion defects in kidney transplants were more common than expected and were highly likely to reduce renal function at 1-3 months, and the size of the defect affected the degree of functional change at 3 months".

2.7.7. Study 7: Schwarz et al (2017) studied the "Impact of ultrasound examination shortly after kidney transplantation". The study revealed that " Delayed graft function was more common in subjects with a high RI ($\geq$0.7) than in patients with an RI < 0.7 (47.2 vs. 28.2%; $p = 0.032$)." they concluded that " ultrasound evaluation of the transplanted kidney shortly after transplantation is a valuable tool not only for detecting vascular complications but also as a predictor of graft outcome regarding delayed graft function."

2.7.8. Study 8: Granata et al (2015) evaluated the role of Doppler ultrasound in assessment of vascular complication of transplanted kidneys. The study concluded that "Doppler ultrasound is highly specific in cases of transplanted renal artery stenosis, pseudoaneurysms, arteriovenous fistulas, and thrombosis with complete or partial artery or vein occlusion. A single measurements of color Doppler indexes display high diagnostic accuracy and in particular cases are more useful during the post-transplantation follow-up period".

2.7.9. Study 9: Spatola and Andrulli (2016) studied the role of Doppler ultrasound in kidney diseases as a parameter in clinical long-term follow-up. The study stated that " Renal Resistive Index is a useful marker in allograft diseases because it has been widely showed a correlation with histological lesions during worsening of renal function, both in acute rejection and in chronic allograft nephropathy. Recent studies suggest its role in the risk of new onset diabetes after transplantation and it could be one of the parameters to evaluate to shift or withdrawal immunological and/or hypertensive therapy".

Chapter 3

Materials and Methods

3.1 Type of the study:

The study is a retrospective cross-sectional type, dealed with evaluation of transplanted kidney by gray scale sonography and Doppler ultrasound.

3.2 Study area:

The study was conducted in Khartoum State at the following hospitals and clinics

1. Ibn Sina Hospital.
2. Diagnostic Advance Center

3.Sharg El nile hospital.

4.Ahmed Gasim hospital.

3.3 Duration of the study:

The study conducted from August 2015 to August 2017.

3.4 Study Population:

The study composed of patients with transplanted kidney referred to these centers for evaluation. The US reports and records were reviewed.

3.5 Sampling and sample size:

A total of 115 records of patients with transplanted kidney were reviewed. The demographic data such as: clinical history, age, region were collected records. The Doppler and sonographic findings were collected from the ultrasound reports that existed in records of patients. Creatinine and urea values were also collected from the records and we approved the recent laboratory examinations. Previous results were excluded. The inclusion criteria included patients who underwent renal transplantation and their data (demographic and sonographic) were existed in the records. Patients with systematic diseases such as cardiac disorders were excluded from the study.

3.6 Study variables:

Study concerned with abdominal ultrasound findings in renal transplanted patients and these include:

1-Renal size

2-Renal echogenecity

3-Cortical thickness

4-Corticomedullary differentiation

5- Doppler parameters, mainly the RI indices.

3.8 data collection: the data was collected using a designed data collection sheet.

3.8.1. Equipment used for examination the patients:

An U/S machine used by researcher then by consultant radiologists include:-

a- Mindary

b- Sonoscape

3.8.2 Tool of Data Collection:

3.9.1 Data collection sheet

3.9.2 Reports from records

3.8.3. The sonographic procedure:

3.8.1: B-mode imaging

It was stablished that US is the most suitable imaging method since it is effective, accurate, available and safe. In this study, the Sonologists and Sonographers used a high-frequency 5.0-7.0-MHz curved array transducer since the renal transplant is usually superficial. For larger patients with deeper transplant kidneys, a 3.5-4.0-MHz sector transducer may be used. The kidney is scanned in its long and transverse axes. Measurements are made of its greatest length, width, and anteroposterior (AP) dimensions. Renal volume is calculated by the standard formula (volume = length × width × AP dimension × 0.523). The echogenicity of the cortex, medulla, and renal sinus is carefully evaluated and compared to images from previous US examinations. The perirenal areas are scanned for fluid collections, hematomas, solid masses, and adenopathy. A full bladder is preferred to displace overlying bowel out of the pelvis and away from the transplant. If hydronephrosis is present, the bladder should be emptied to see whether the dilatation is caused by bladder distention. Ureters were evaluated. Patency of the transplant arteries and vein should be confirmed with color and spectral Doppler.

3.5.3.2. Doppler ultrasound Imaging:

The Resistive Index (RI) calculated from the arterial waveform (Fig.1). Spectral waveforms of renal and intrarenal arteries at the upper pole, mid-kidney, and lower pole are obtained. Use of the RI eliminates the need for accurate angle-corrected measurements of blood flow in assessment of vascular resistance. Values of RI were calculated from the waveforms and categorized into four groups. An RI of less than 0.7 is considered normal and rejection is unlikely whereas an RI in excess of 0.9 is a strong indicator ad predictor of transplant rejection (dysfunction) (O’Neill, 2000) (O’Neill and Baumgarten, 2002). Values of RI between 0.80-0.89 rejection was likely whereas 0.70-0.79 rejection was indeterminate.

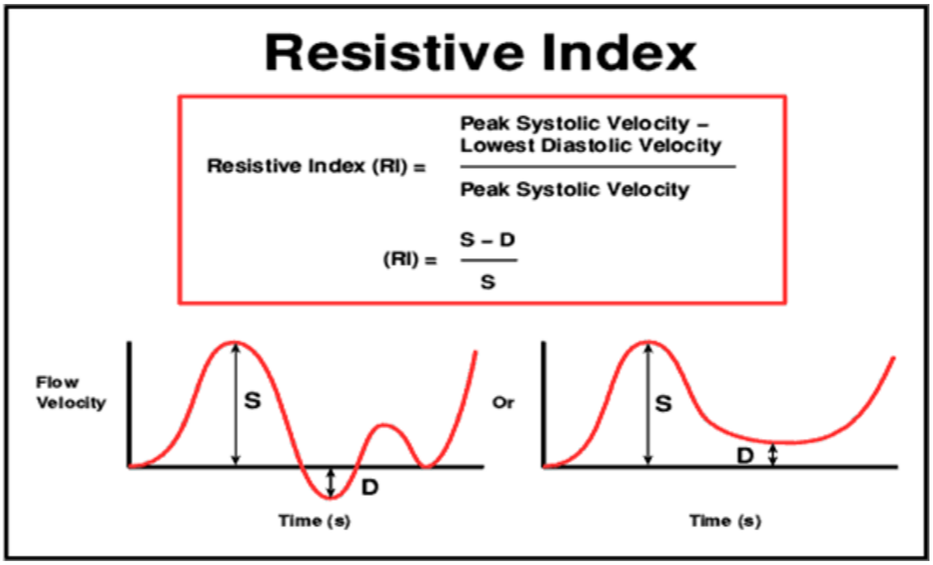

Fig (1) The diagram illustrated how to measure the Resistive Index

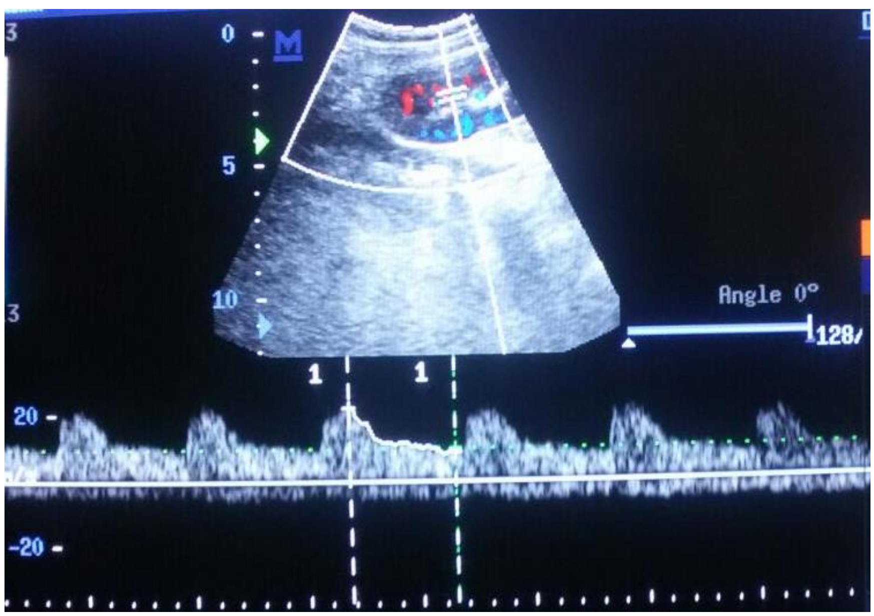

Figure. 2: Normal resistive index. A sonogram of a 17-year-old male shows the normal RI for renal transplant. Color Doppler sonogram is used to identify inter-lobar artery (arrow); waveform is maximized using lowest pulse repetition frequency possible.

The highest frequency probe that gives measurable waveforms should be used, supplemented by color or power Doppler sonography as necessary for vessel localization. Waveforms should be optimized for measurement by using the lowest pulse repetition frequency without aliasing, the highest gain without obscuring background noise, and the lowest wall filter (Fig.2).

Patients are placed in a supine or decubitus position to make the angle of the ultrasound beam and the flow direction of the examined vessels of the transplant kidney less than 30°. A curved linear transducer of 3.5- 5MHz Proper settings for color flow and pulsed Doppler imaging play a key role in acquiring satisfactory images and spectrums (O'Neill and Baumgarten, 2002).

Doppler imaging usually starts with a low wall filter for slow flow in the intrarenal vessels and then make adjustments accordingly the location of the transplanted kidney (retroperitoneal or intraperitoneal), Routine Doppler of Kidney transplants includes observing morphologic characteristics on gray scale imaging, assessing vascularity with color flow imaging, and quantitatively evaluating hemodynamics of the transplanted kidney by pulsed Doppler imaging. Use of a narrowed color Doppler box to concentrate Doppler energy on the magnified region improves visualization of small intrarenalarteriovenous fistulas and pseudoaneurysms. A widened view on color imaging is mainly used when observing global abnormalities of the transplanted kidney Post processing of color Doppler images is an effective tool for picking up high-velocity and turbulent flow (O'Neill, 2000) (O'Neill and Baumgarten, 2002).

3.9 Data Analysis and presentation:

The data was analyzed using statistical software program (SPSS). We used descriptive statistics to describe the data as frequency and mean with standard deviation (SD). Chi-square test and correlations were used for continuous and qualitative variables respectively. Data was presented in dummy tables and figures and stored on personal computer and compact disk.

3.10. Ethical Consideration:

The study was approved from the institutional ethical committee. Permission was taken the hospital to review the patients' records. Patient identification and individual details were not published.

Chapter four

Results

The demographic data:

A total of 115 cases of transplanted kidneys were retrospectively reviewed and there were missed and unknown cases. The study composed of 89 males (77.4%), 26 females (26%), 74 married and 41 unmarried as shown in table 1, figure 1 and figure 2. It was observed that most of the patients were workers (29.6%), employee (27.8 %) and housewives (20%). Students were less frequent (7.8%) as shown in table 2 and figure 3. It was noted that most of the patients were from the middle of Sudan especially Gezira State (63.48%). Then west of Sudan were 16.52%, east 7% and south 4.3% as shown in table 3 and figure 4. The age groups were shown in table 5 and it was noted that most of the patients lie at the age groups of 41-50 and 20-30 years old and represent 29.56% and 23.48% respectively. Renal transplantation was less frequent at the age group of 61-70 years. The clinical history was revealed in table 5 and figure 6 and it was observed that hypertension was the most common previous clinical history in the study population (59.1%), then diabetes mellitus is the second (6.2%). Recurrent UTI and glomerulonephritis were less frequent, 3.5% and 0.9% respectively.

The Doppler and sonographic findings:

The mean RI of transplanted kidneys in this study was 0.67 while the PI was 0.79. The mean value of PSV was 58.7 cm/s. The measurement of the graft length was characterized into small, normal and enlarged (table 6). A 4.35% of the grafts were small in size, 10.43% enlarged and 85.22% were normal. The laboratory findings revealed that the mean values of serum creatinine and urea were 3.4 mg/dl and 76.04 mg/dl respectively (table 7). The mean duration of the transplantation was 11.06 months. The sonographic assessment of cortico-medullary ratio(CMR) revealed that the CMR was normal in 74.8 % of the cases, 14.78% decreased and 10.43 % increased (table8 and figure 7). It was observed the mean RI increased in grafts with increased CMR (68±0.11).

The cortico-medullary differentiation was preserved in 83 cases (72.2%), disturbed in 24 cases (20.9%) and lost in 5 cases (4.3%) as shown in table 9 and figure 8). It was observed the mean RI increased in grafts with increased CMD (68±0.10). Although the elevation of RI was not significant in grafts with changes in CMR and CMD (p-values = 0.33 and 0.6 respectively), but clinically this elevation is important.

The sonographic assessment of pelvocalyceal system of the transplanted kidneys was normal without effect in 82.6 % of the cases, dilated in 11.3 %, thickened in 1.74% and dilated and thickened in 4.35 % of the cases (table 10 and figure 9). It was observed that the renal cortex was normal in 87.8 of the cases, 2.6% thick and thin in 9.6 % (table 11 and figure 10). It was noted the mean RI increased in grafts with thick and thin cortexes (RI=75±0.11 and 0.68±0.12 respectively). Although it was statistically in significant, but it was of clinical importance.

The echogenicity of renal cortex of the allografts was increased in 17.8% of the cases, decreased in 2.6 % and normal in 79.6% of the cases (table 12 and figure 11). On the other hand, the echogenicity of the parenchyma was increased in11.3%, decreased in 7% and normal in 81.7% (table 13 and figure 12). It was observed the mean RI increased in grafts with increased and decreased echogenicity.

The RI values were categorized into four groups as shown in table 14. The signs of rejection were dependent on the interpretation of these values. Value of RI ≥ 0.9 was interpreted rejection highly likely and value of RI = 0.80-0.89 interpreted rejection was likely to occur. If RI<0.7, rejection was unlikely. In our study, rejection in the majority of allografts was unlikely (59.2%), 31.48 % rejection was indeterminate, 5.56% rejection was highly likely and 3.70%

rejection likely. It was observed that gender had significant association with RI (P-value = 0.02). It was significantly higher in male than female as revealed in table 15.

It was observed that echogenicity of the kidney parenchyma was significantly correlated with RI (r = −0.18, P-value = 0.02). This indicated that the RI values were significantly decreased in echogenic allografts. There was no statistical significant correlation of RI with thickness of renal cortex, CMD and CMR (P-values = 0.42, 0.10 and 0.50 respectively) as shown in table 17. But the elevation of RI values in the grafts with morphological changes is clinically important and reflect the pathological processed. It was noted that the RI had no significant association with duration of the transplantation (P-value = 0.65), shown in table 18. Most of the cases were transplanted in duration between 7-12 months (figure 16).

There was linear correlation of RI with age of transplantation (figure 13). It was observed the cubic relationship was more accurate than linear one of RI with the length of the grafts and serum creatinine which was demonstrated in figure 14 and figure 15. Regression models were obtained to demonstrate these correlations. The regression model: $RI=0.665 -7.263D$ demonstrates the linear correlation of RI with the duration (D). It indicated that the RI values decreased by -7.263 in month (figure 13). The second model was $RI=1.258 -1.06L +0.005L2$ which showed the relation of RI with the length (L) of the grafts. The third model was a cubic relationship of RI with serum creatinine (Sr) (figure 15). These results indicate that RI can predict the status of the graft.

Table 4-1: gender distribution of the study population

Gender	frequency	Percent %
male	89	77.4
female	26	22.6
Total	115	100.0

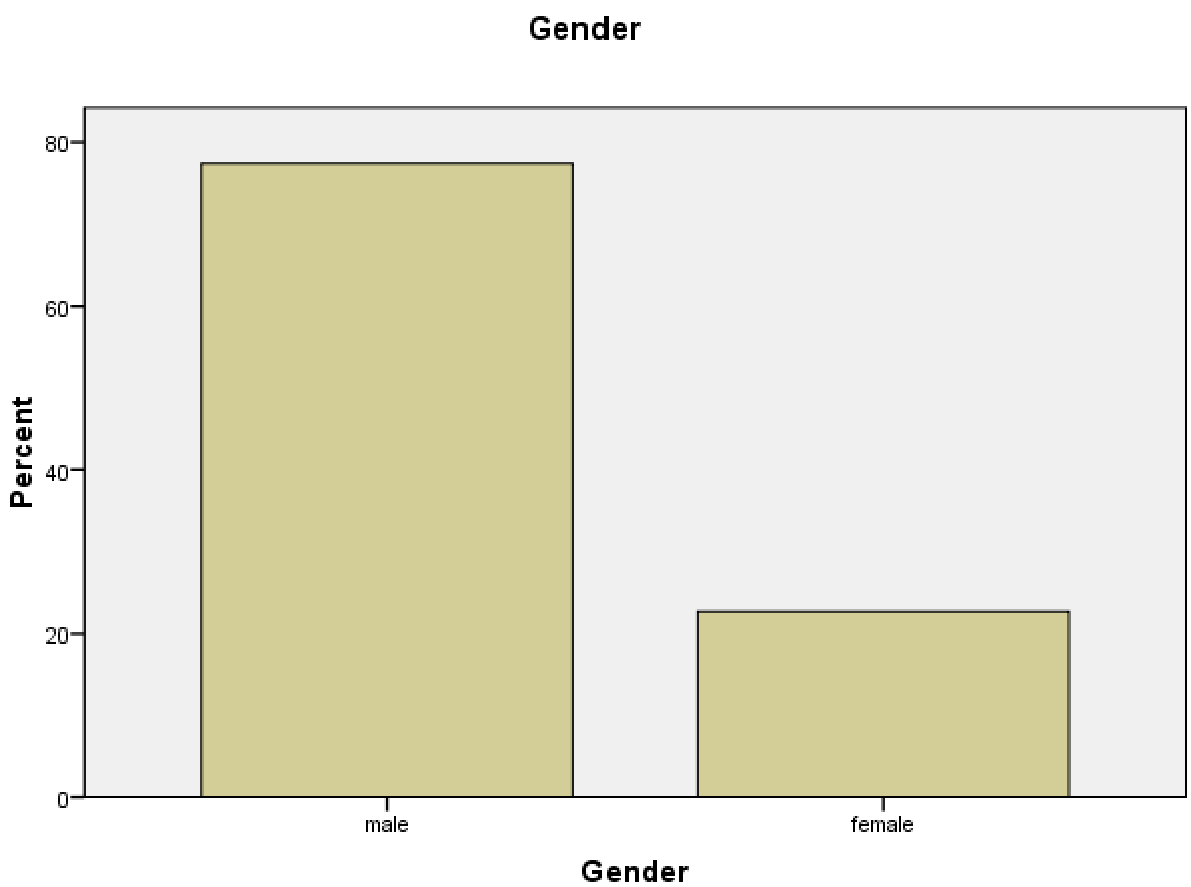

Figure 4-1: gender distribution of the study population

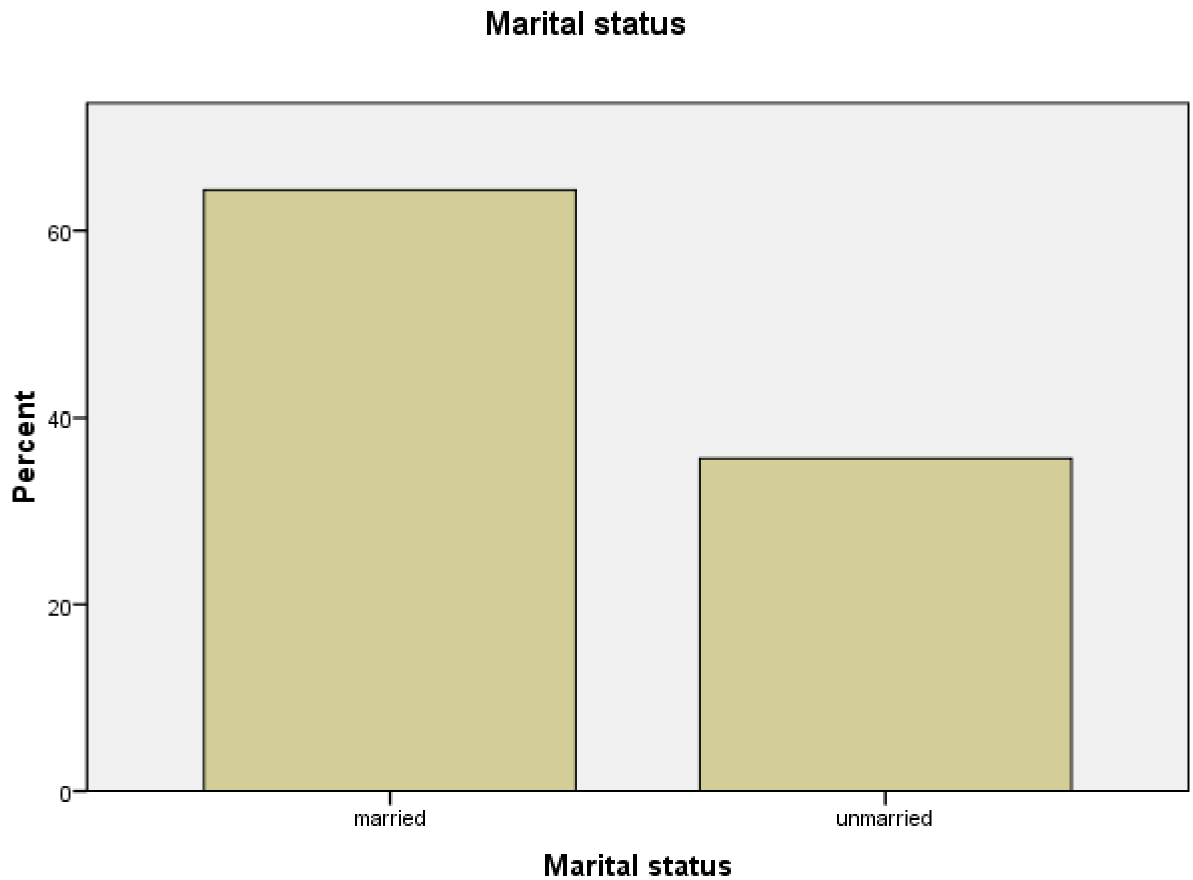

Figure 4-2: frequency of marital status of the study population

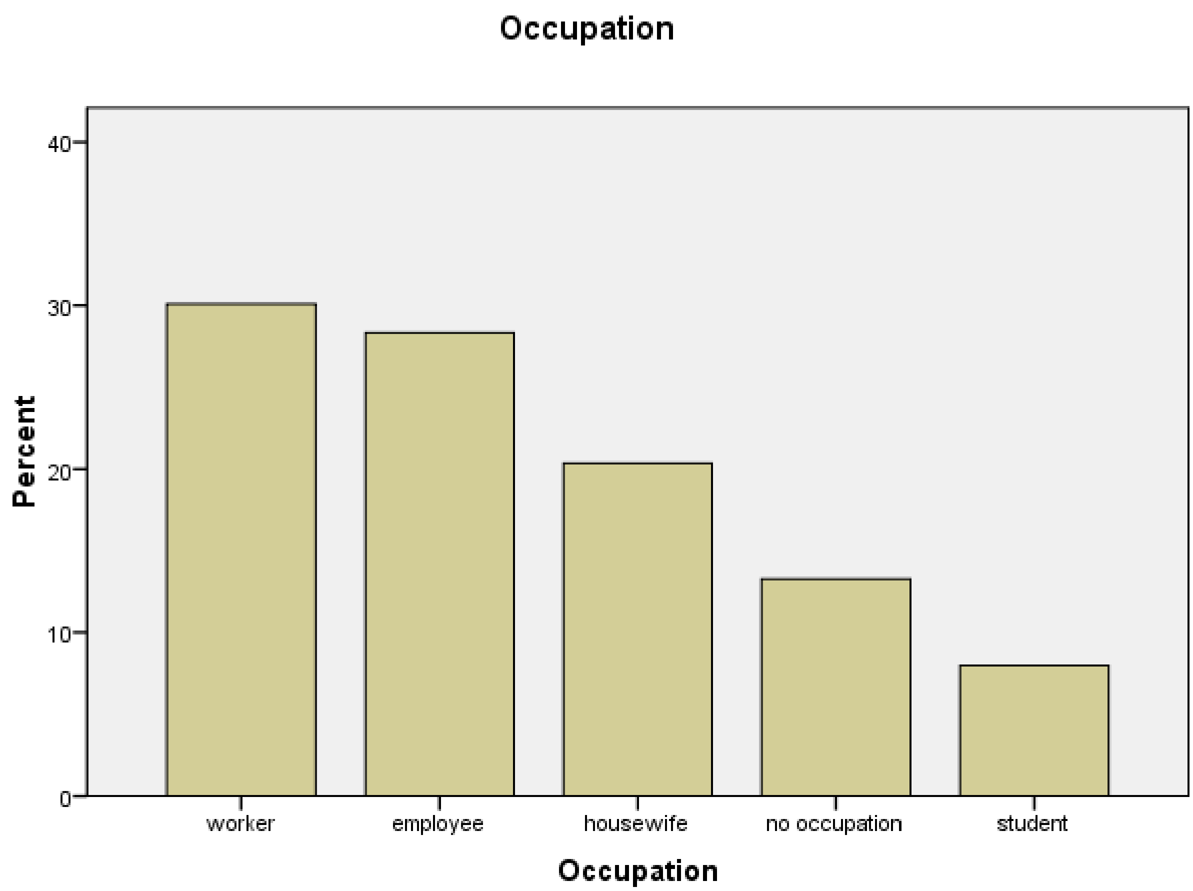

Figure 4-3: characteristics of the study population

Table 4-2: characteristics of the study population according to occupation

Occupation	**frequency**	**Percent %**
workers	35	30.43
employees	32	27.8
housewives	23	20.0
no occupation	15	13.0
students	10	8.70
Total	115	100

Table 4-3: Frequency according to regions of the study population

region	**frequency**	**Percent %**
south	5	4.3
east	8	7.0
west	19	16.52
middle	73	63.48
north	10	8.7
Unknown	7	6.08
Total	115	100

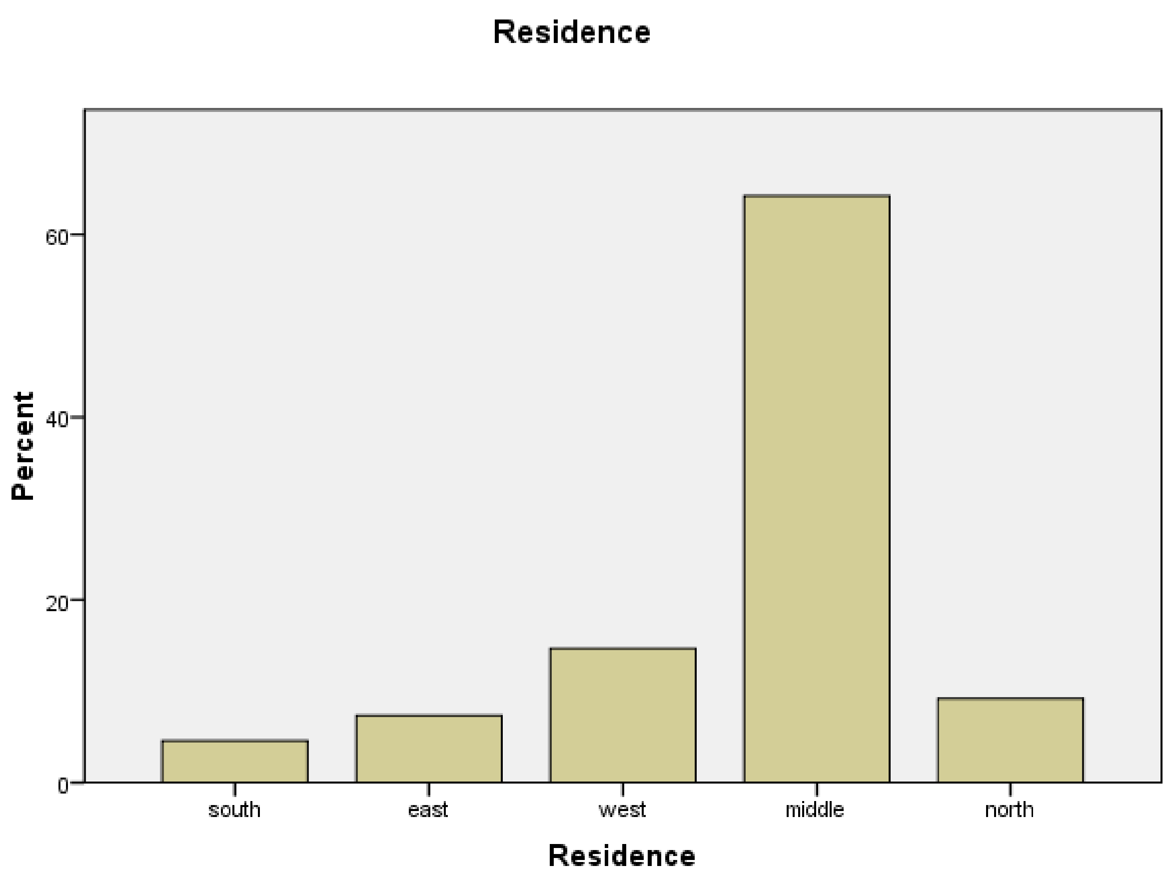

Figure4- 4: distribution of regions of the study population

Table 4- 4: Age groups distribution of patients with transplanted kidneys

Age groups (years)	**frequency**	**Percent %**
20-30 years	27	23.48
31-40 years	23	20
41-50 years	34	29.56
51-60 years	23	20
61-70 years	8	6.96
Total	115	100.0

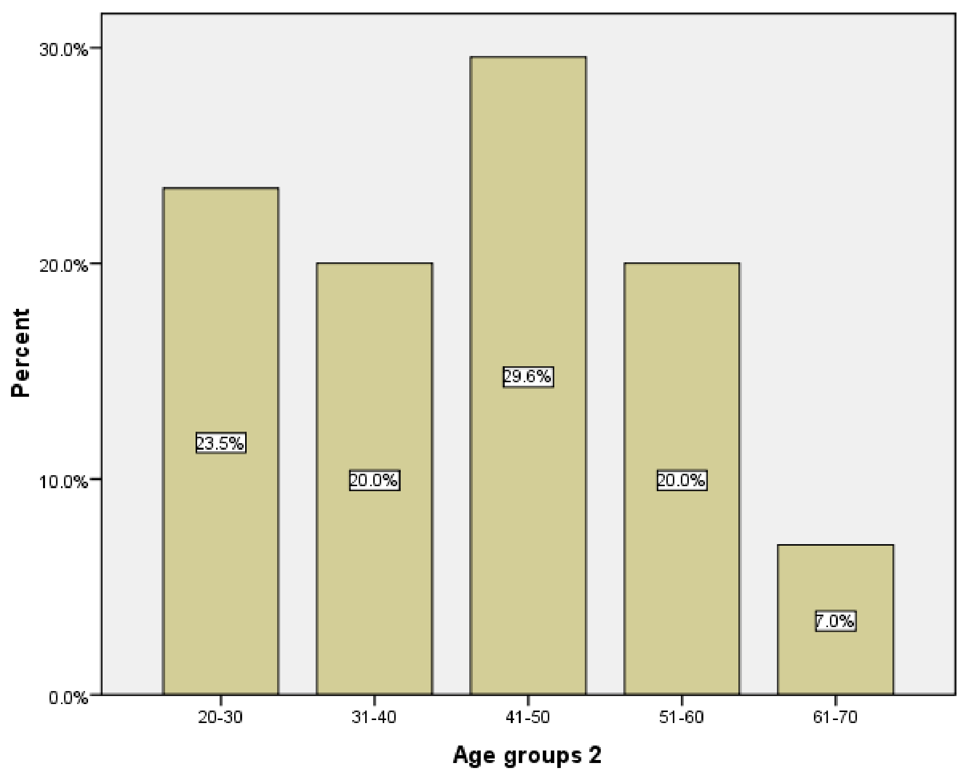

Figure 4-5: Age distribution of the study population

Table 4-5: clinical history of the patients with transplanted kidneys

region	**frequency**	**Percent %**
diabetic	6	5.2
hypertensive	68	59.1
recurrent UTI	4	3.5
Glomerulonephritis	1	.9
Nil	11	9.6
diabetes and hypertension	6	5.2
Total	96	83.5
Unknown	19	16.5
Total cases	115	100

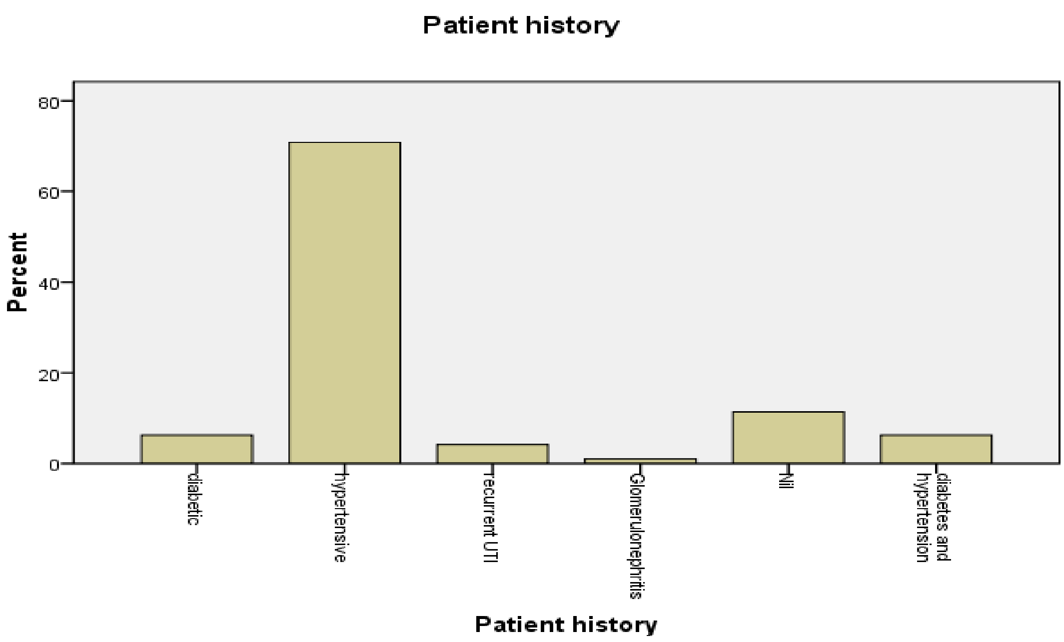

Figure 4- 6: clinical history of the patients with transplanted kidneys

Table 4-6: measurements of length of the transplanted kidneys

Measurements (cm)	**frequency**	**Percent %**	**Interpretation**
5-6.9	5	4.35	Small size
7-12.5	98	85.22	Normal size
12.6-14.8	12	10.43	enlarged
Total	115	100%	--

Table 4-7: Descriptive statistics of the Doppler indices and laboratory findings

Measurements (cm)	means	Standard deviation (SD)
RI	0.67	.13
Blood urea	76.04	46.36
Serum creatinine	3.4354	3.45
PSV	58.7cm/s	22.59
PI	.79	.43
Duration of transplanted kidney	11.06	5.64

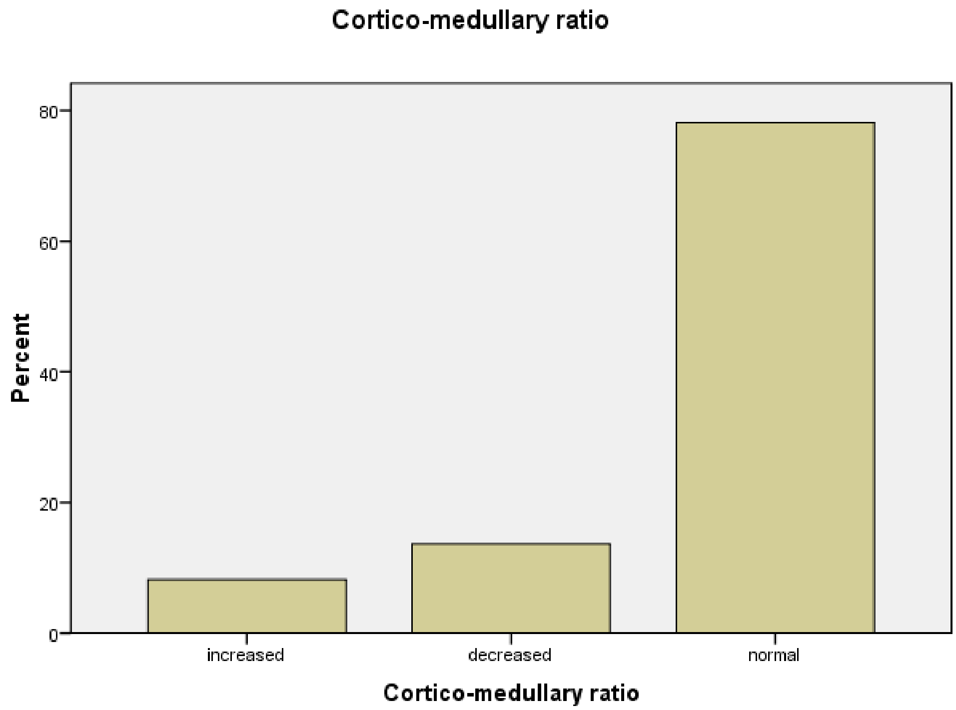

Figure 4-7: sonographic assessment of cortico-medullary ratio of the transplanted kidneys and associated mean RI values.

Table 4-8: sonographic assessment of CMR with RI in the transplanted kidneys

CMR	frequency	Percent	Mean RI	P-value
increased	12	10.43	0 .65±.10	**0.33**
decreased	17	14.78	0.68±.11	
normal	86	74.8	0.67±.13	
Total	115	100%		

Table 4-9: sonographic assessment of CMD with RI in the transplanted kidneys

CMD	frequency	Percent %	Mean RI	P-value
preserved	83	72.2	0.66±0.13	0.60
lost	8	6.95	0.63±.089	
disturbed	24	20.9	0.68±0.10	
Total	115	100%		

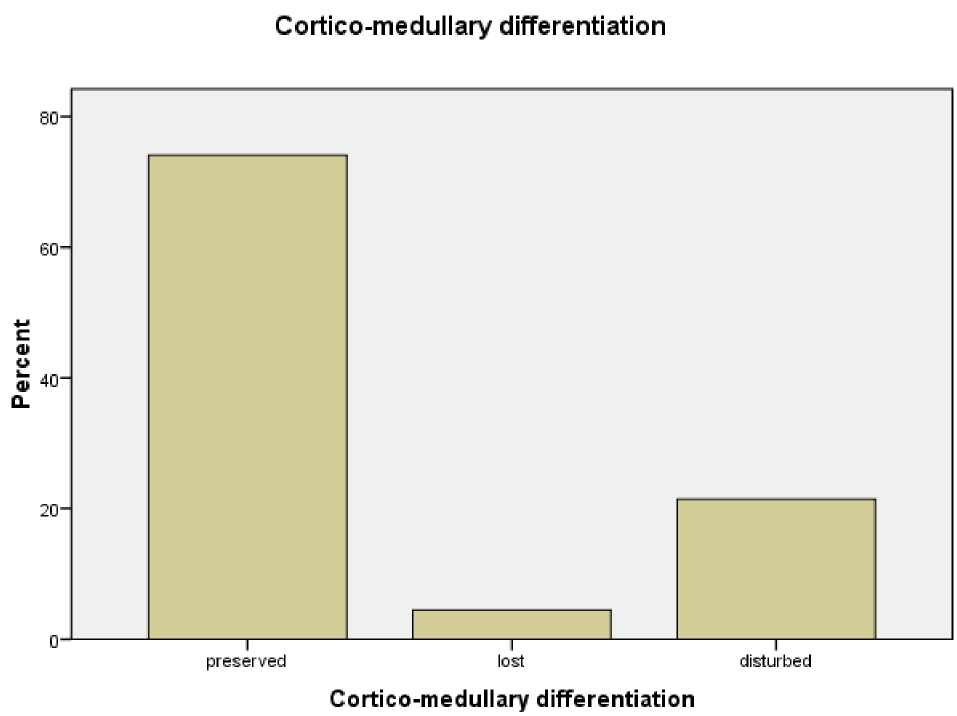

Figure 4- 8: sonographic assessment of cortico-medullary differentiation of the transplanted kidneys

Table 4-10: sonographic assessment of pelvocalyceal system of the transplanted kidneys

Pelvicalyceal system	frequency	Percent %
dilated and thick	5	4.35
dilated only	13	11.3
thickened only	2	1.74
no effect	95	82.6
Total	115	100

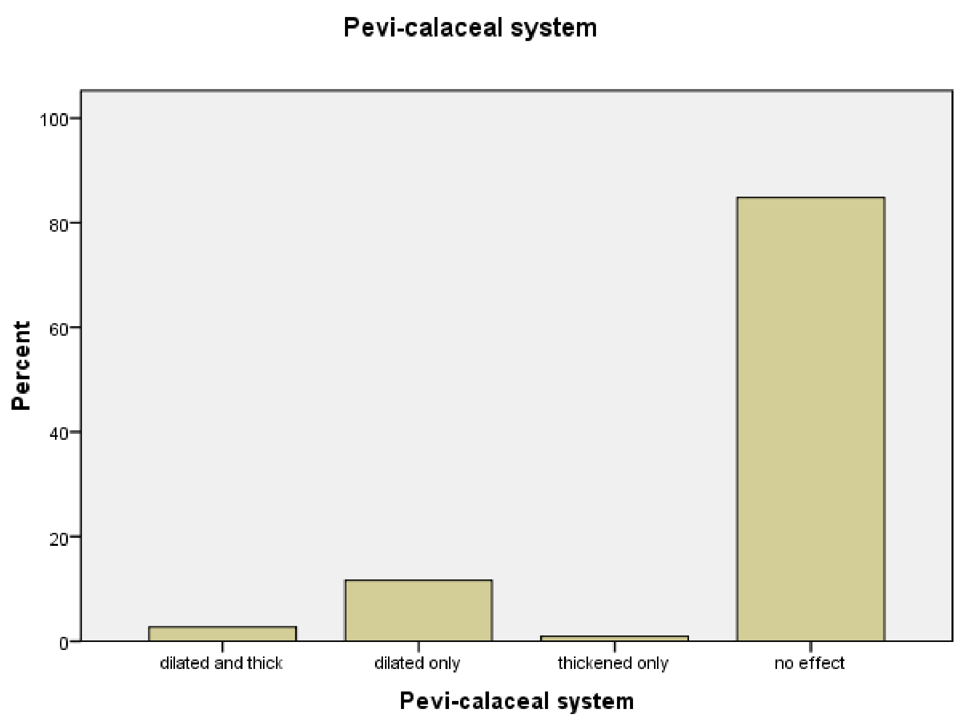

Figure 4-9: sonographic assessment of pelvicalyceal system of the transplanted kidneys

Table 4- 11: sonographic assessment of renal cortex with RI in the transplanted kidneys

Renal cortex	frequency	Percent%	Mean RI	significance between groups (p-value)
thin	11	9.6	0.68±.12	0.98
thick	3	2.6	0.75±0.11	
normal	101	87.8	0.67±.12	
Total	115	100		

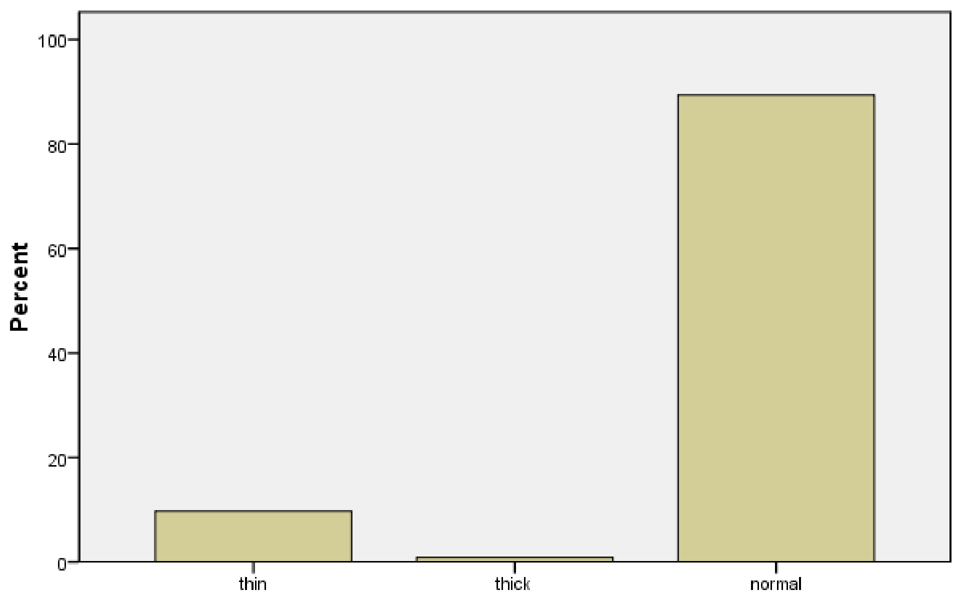

Figure 4-10: sonographic assessment of renal cortex of the transplanted kidneys

Table 4-12: Frequency of echogenicity of renal cortex with RI in the transplanted kidneys

Echogenicity of Renal cortex	**frequency**	**Percent%**	**Mean RI**	**significance between groups (p-value)**
increased	17	17.8	0.71±0.11	0.29
decreased	3	2.6	0.73±0.05	
normal	95	82.6	0.66± 0.12	
Total	115	100		

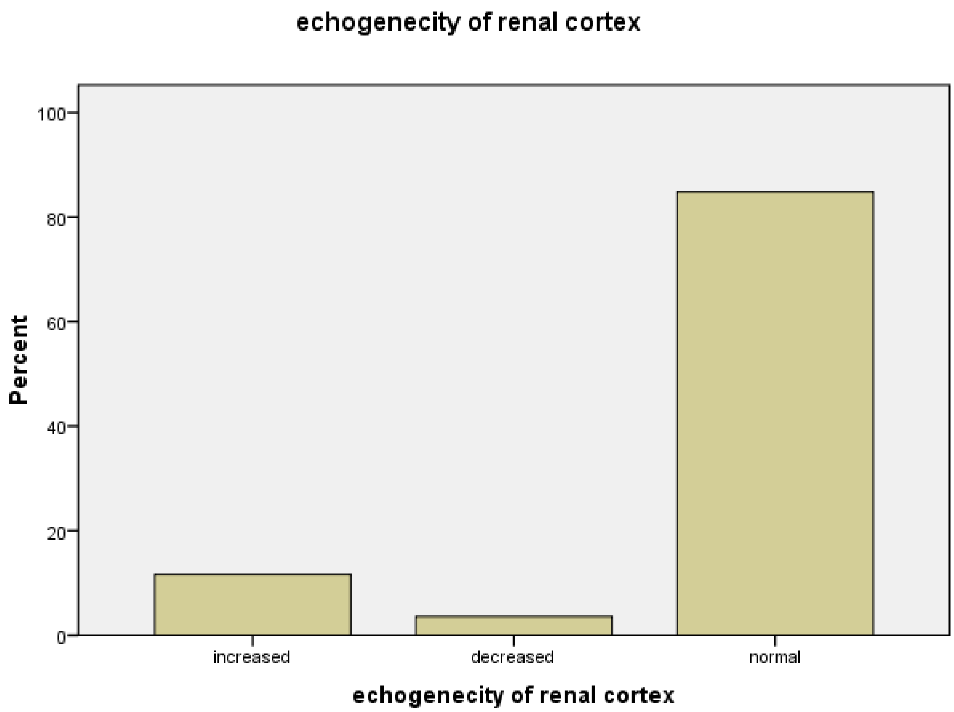

Figure 4-11: Frequency of echogenicity of renal cortex of the transplanted kidneys

Table 4-13: Frequency of echogenicity of renal parenchyma with RI in the transplanted kidneys

Echogenicity of Renal parenchyma	frequency	Percent %	Mean RI	significance between groups (p-value)
increased	13	11.3	0.71±0.11	0.16
decreased	8	7	0.74± 0.039	
normal	94	81.7	0.66± 0.12	
Total	115	100		

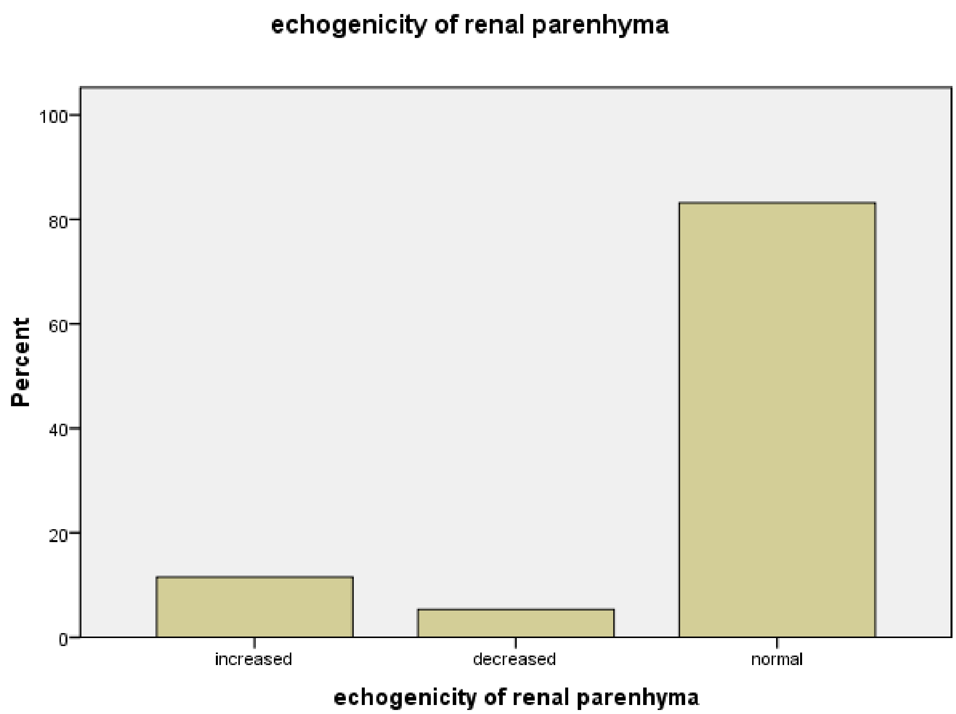

Figure 4-12: Frequency of echogenicity of renal parenchyma of the transplanted kidneys

Table 4-14: Characterization of RI values for predicting rejection of renal transplant depending on RI values

Resistive indices	**frequency**	**Percent %**	**Interpretation**
RI ≥.9	6	5.56%	Rejection highly likely
RI = 0.80-0.89	4	3.70%	Rejection likely
RI= 0.70-0.79	34	31.48%	Indeterminate
RI < 0.70	64	59.26%	Rejection unlikely

Table 4-15: Association of RI values of the grafts with gender

RI categorization	Gender		Total	P-value
	males	females		
0.40-0.69	53	11	64	**0.02**
0.70-0.79	25	9	34	
0.80-0.89	4	0	4	
0.90-1.95	2	4	6	

Table 4-16: correlation of RI with duration of transplantation

RI categorization	Duration of transplantation				Total	P-value
	2-6 month	7-12 month	13-18 month	19-30 month		
0.40-0.69	13	30	12	6	61	**0.65**
0.70-0.79	3	19	3	2	27	
0.80-0.89	0	2	0	0	2	
0.90-1.95	1	2	2	1	6	
Total	17	53	17	9	96	

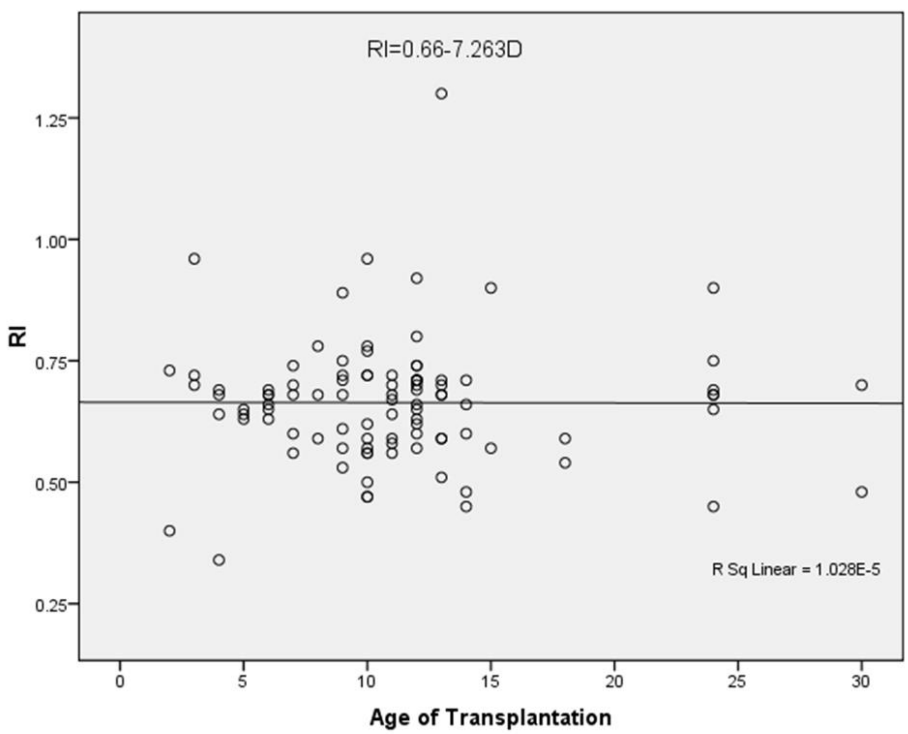

Figure 13: correlation of RI with age of transplantation

Table 4-17: correlations of RI with echogenecity and morphological changes of the grafts.

findings	**Correlation coefficient R**	**P-values**
Echogenicity of kidney parenchyma	-.18	**0.02**
Echogenicity of renal cortex	-.14	0.07
Thickness of renal cortex	-.065	0.42
Cortico-medullary differentiation	.13	0.10
Cortico-medullary ratio	.053	0.50
Size of allograft	-0.13	0.185
Serum creatinine	.012	0.91
Blood urea	-.081	0.466

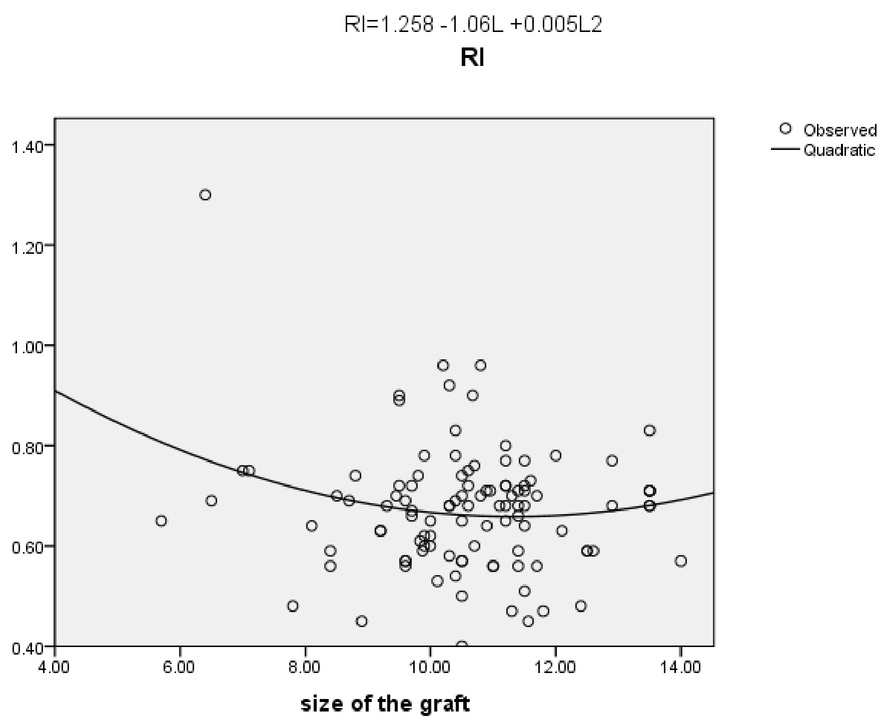

Figure 14: correlation of RI with renal length of the grafts. The regression equation is RI=1.258 -1.06L +0.005L2 whereas RI: resistive index, L: length of the kidney

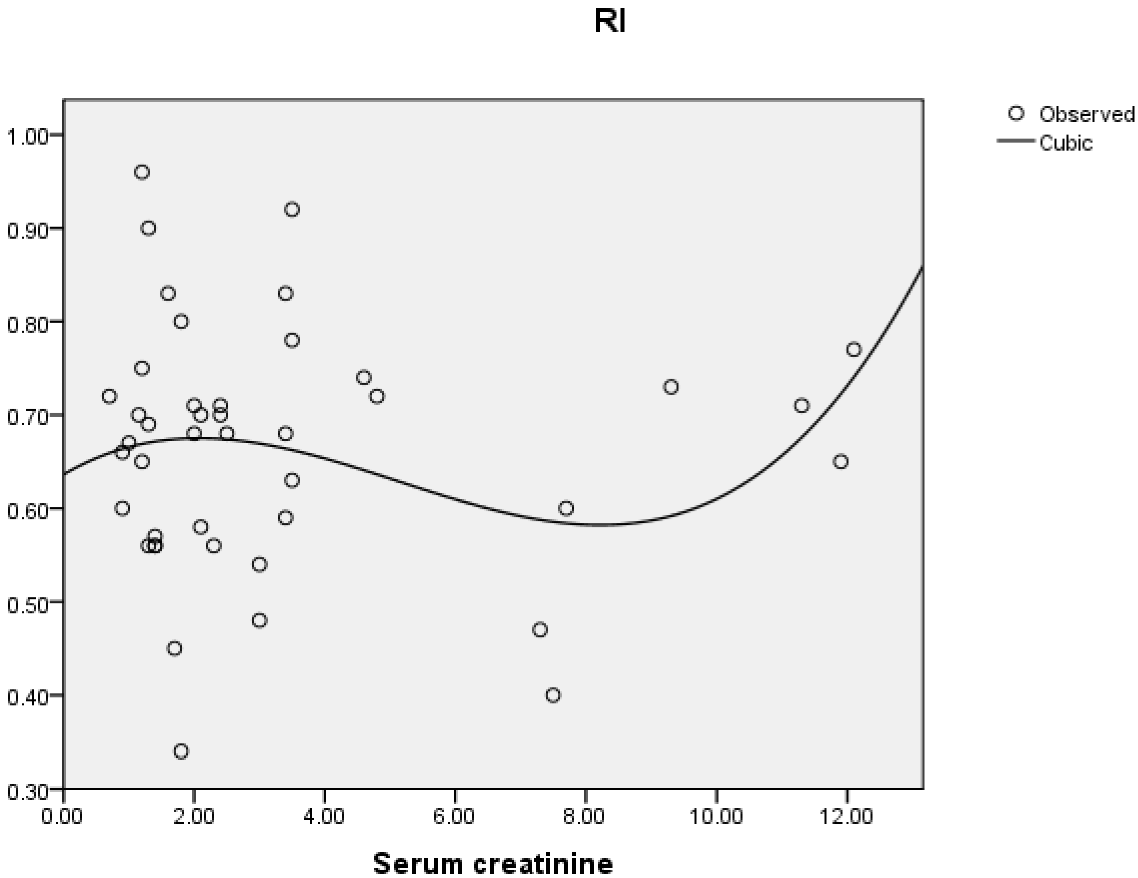

Figure 15: correlation of RI with serum creatinine in patients with transplanted kidneys

Table 18: Association of RI values with duration of transplantation

RI categorization	Duration of transplantation				Total	P-value
	2-6 month	7-12 month	13-18 month	19-30 month		
0.40-0.69	13	30	12	6	61	**0.65**
0.70-0.79	3	19	3	2	27	
0.80-0.89	0	2	0	0	2	
0.90-1.95	1	2	2	1	6	
Total	17	53	17	9	96	

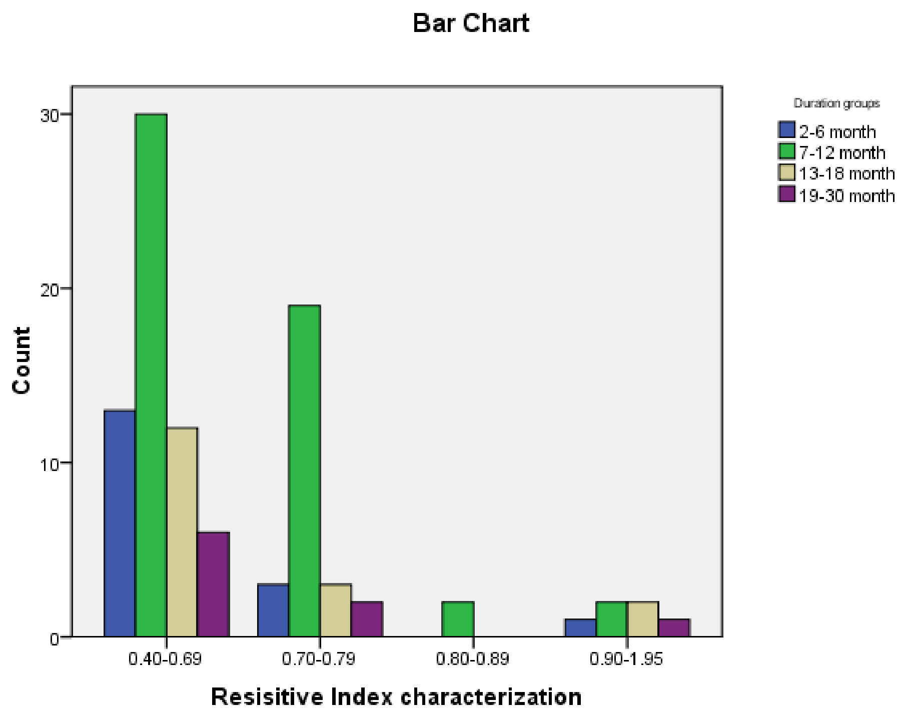

Figure 4-16: RI values of the transplanted kidneys and duration of the allografts

Chapter Five

5-1. Discussion:

Ultrasound is a noninvasive and relatively inexpensive diagnostic method providing accurate information about renal location, contour and size. Doppler ultrasonography shows morphological changes of kidney and hemodynamics (Al-Khulaifat, 2008). It is widely used to assess the graft complications such as hydronephrosis, perirenal collection or vascular complications such as rejection or renal arterial/venous thrombosis (Tublin, 2003) (Sandhu et al., 2004)

Resistive index (RI) has been shown as the best ultrasonographic parameter to assess renal dysfunction (Friedewald et al., 2005) (Radermacher et al., 2003).

It is used as a marker of microcirculation injury and a sequel of interstitial edema of any etiology (Vallejos et al., 2005; Herrler et al., 2010)

Other parameters such as the PI and graft dimensions are also used in this circumstance. It was believed that ultrasonography is used just for discrimination of acute rejection episodes or other complications but in recent years, literatures have shown that RI and some other ultrasonographic parameters are utilized to predict long-term graft function. These parameters consist of RI, PI, EDV, PSV and graft length. In this study, we utilized the RI since it was available in the selected sample and the other Doppler parameters was not satisfied. RI with a normal value immediately after transplantation is a good predictor of the future graft function. RI not only reflects resistance at the arterial blood flow of renal arteries, but also shows proximal pathology such as systemic blood pressure (Kolonko et al., 2012)

In this study, the RI, PI and PSV were measured and we mainly used RI as predictor of signs of rejection rather than the other parameters. Therefore, RI parameter as a sole element in distinguishing various causes of graft dysfunction has great role. On the other hand, an increase in RI can be induced by any interarenal condition such as acute renal failure or urinary tract obstruction that induces a reduction in diastolic renal perfusion (Mastorakou et al., 1994) (Mohammadi et al., 2013). In the present study, we correlated RI with the echogenicity of the allografts, CMD, CMR, cortical thickness and gender.

In the present study, we found the renal transplantation was common in males more than females and most common in workers, employee and housewives respectively. These findings agreed with Hanaa Algori, (2005) who reported that renal transplantation was common in males more than females in Khartoum State. We found most of the patients were from middle of Sudan, Gezira State and then the west of Sudan. The main cause of renal transplant is chronic renal failure (CRF). In the study we found hypertension is the most common clinical history in transplanted kidney-patients. This finding is consistent with Moawia et al. (2013) who reported that hypertension was the common cause of CRF and it was significantly associated with CRF in Sudanese patients. In previous studies, diabetes mellitus and hypertension were risk factors of acute kidney injury (AKI) which may develop to chronic kidney disease (CKD) that ended in renal failure (Matthew et al., 2015). As the common etiology of renal failuire common in male more than female, consequently the frequency of transplantation in males will be elevated.

In the current study, the mean RI value was 0.67, PI =0.79 and PSV was 58.7m/s. In previous studies, normal RI in transplanted kidney should be below 0.70 to 0.80 (Lockhart and Robin, 2007). However, some previous studies reported elevated RI (>0.8) is used as a nonspecific parameter of renal dysfunction (Vallejos et al., 2005; Lockhart and Robin, 2007). But the majority of studies considered RI is an indicator of morphologic changes in renal grafts (Ahmed et al, 2014). A PI of <1.5 or RI <0.7 can be regarded as normal, whilst a PI >1.8 or RI of 0.9 should be regarded as abnormal. Although both acute tubular necrosis (ATN) and acute rejection (AR) cause PI & RI rise, the likelihood of AR is greater with higher levels. In literature, An RI of less than 0.7 to 0.8 is considered normal (Don et al., 1989; Grant and perrela, 1990). In the study, we used RI values as criteria for diagnosis of transplant rejection (Matthew et al., 1987). We found the RI was normal in the majority of cases (RI< 0.70). So, in these cases the rejection was unlikely. Similar to our findings, previous reports considered RI exceeds 0.8 or 0.9, is an indicator of transplant dysfunction(Khatir and khauli, 2013).

Rejection is indeterminate in 34 cases of which RI = 0.7-0.79 and it is likely in 4 cases. We found rejection highly likely in 6 cases of which RI ≥ 0.9. Progressive elevation of the RI, reaching 0.9 or above indicates renal dysfunction, but is often nonspecific and must be interpreted in the context of time of onset of dysfunction, clinical status and biochemical tests (Samih, 2008)

The sonographic findings of chronic rejection are those of a small graft with thinned echogenic cortex, the RI is normal to slightly elevated. Biopsy is often required to exclude superimposed and potentially treatable AR (Samih, 2008).

In the present study, we observed no significant linear correlation of RI with urea and creatinine values. However, in previous studies there strong significant between these variables. This may be attributed to the nature of the retrospective study that depended on patients' records.

The CMR is an important sonographic parameter which is useful in evaluating allografts. In a previous study, CMR was used as a quantitative marker for assessment of renal allograft cortical fibrosis (Gao et al., 2013). The sonographic assessment of CMR in our study revealed that the CMR increased in 7.8% of the cases, decreased in 13% and normal in 74.8%. In literature the loss of CMR and CMD is attributed to various etiologies. The loss of CMD has been associated with renal insufficiency secondary to a variety of etiologies such as edema, renal atrophy, and renal scarring (Marotti et al., 1987) (Terrier et al., 1985). We observed the RI elevated in grafts with increased CMR and disturbed CMD. Although the rise was not statistically significant (<0.05), but clinically it was very important because it reflects the intrarenal pathological processes.

The echogenicity and size of allograft were sonographic parameter that had been evaluated in this study. It was observed that the echogenicity of cortex and parenchyma of allografts increased by 11.3%. In the current study, 8.7% of the allograft was enlarged, 2.7% small and 85.2 % normal in size. These findings were reported in previous studies as features of delayed graft function due to acute tubular necrosis (ATN) and rejection. Asif Sharfuddin reported graft swelling or enlargement, obscured corticomedullary differentiation, decreased echogenicity, and scattered heterogenous areas of increased echogenicity were features of delayed graft function due to ATN and rejection (Asif, 2014).

In the present study, we found a significant negative correlation between echogenicity of allograft and RI (r= -0.16, p-value = 0.02). This indicates RI values increased with changes in echogenicity of allografts. However, this finding was consistent with a previous study performed by Qureshi et al who reported that RI was found to be raised in increased echogenicity of allograft (Qureshi et al., 2006). In the study, it was observed some morphologic change are not statistically significant with RI, this attributed to the short-term duration of the transplantation (3-30 months) which is not enough to cause changes in the graft. But the study confirmed that RI elevated with morphologic changes in the grafts. Similar to our findings Gao et al, 2011, reported significant correlation of Doppler indices with histopathologic types in renal transplant dysfunction. In general, every change in graft morphology is clinically significant even though appeared insignificant in statistical analysis.

In the current study, it was observed significant difference of RI between males and females (P-value = 0.02). In literature, to our knowledge, we found no relationship between RI values and gender in studies of transplanted kidneys. In a previous study performed by Mastorakou et al, 1994 who studied pulsatility and resistance indices in intrarenal arteries of normal adults. They reported that no differences were found in the mean values of both indices between males and females, upper and lower poles, right and left kidneys.Because the physiology transplanted kidney is not like as the normal one, a significant difference is well established.

In the present study, there was no significant correlation between RI and size of the transplanted kidneys (p-value =0.47). There was also no significant association between size of kidneys and creatinine (p-value = 0.91). This finding is consistent with Mohammad et al who reported no significant correlation between RI and serum creatinine (Mohammadi et al., 2013). Although, our findings revealed that there was no staistical significant correlation of RI with CMD, CMR and corical thickness; but RI increased in grafts with increased CMR, disturbed CMD and thin and thick cortices. However, in a previous study, parenchymal thickness and kidney size were significantly increased soon after (1-week) transplantation. This increase in size correlated significantly with serum creatinine 1-year after transplantation (Mohammadi et al., 2013). Therefore, the elevation of mean RI values associated with graft morphological changes, and this formed the essential characteristics of predicting rejection.

Limitation of the study

The study faced great limitations. The sample size was not large enough and limited to Khartoum State, and there were no available reference values of RI, PI, and PSV in Sudanese adults. Some ultrasound reports were not complete, such data of RI and morphological changes of the kidneys were missed. Further studies with large sample size were recommended to confirm the initial results.

5-2 Conclusion:

A total of 115 cases of transplanted kidneys had been retrospectively reviewed. The findings of the study revealed that the renal transplantation is common in males more than females and in married more than unmarried individuals. Workers are the most common patients with transplanted kidneys, then employee and housewives. Middle east of Sudan, specifically Gezira region, is the most common region of patients underwent renal transplantation. The west of Sudan is the second region. The majority of cases have had history of hypertension. Diabetes mellitus is the second cause and recurrent UTI is third cause.

The mean RI of transplanted kidney was o.67, PI was 0.79, PSV was 58.7cm/s. The mean serum creatinine was 3.44, blood urea was 76.04 and the duration of transplantation was 11.06 month. The gray-scale sonographic findings revealed that the CMR was increased in 7.8%, decreased in 13% and normal in 74.8%. The CMD was preserved in 72.2% of the cases, disturbed in in 20.9% and lost in 4.3%. There was no effect on pelvicalyceal system(PCS) in 82.6% of the cases, dilated in 11.3% and dilated and thick in 2.6 %. The renal cortex was thin in 9.6% of the cases and normal in 87.8%. The echogenicity of the transplanted kidneys increased in 11.3%, decreased in 3.5% and normal in 82.6%.

The criteria for diagnosis of rejection was highly likely in 5.56 % of the cases that RI $\geq$ 0.9. Rejection was likely in 3.7 of the cases that RI =0.80-0.89, and rejection was indeterminate in 31.48% of which RI= 0.70-0.79. However, rejection was unlikely in 59.26% of the cases that RI< 0.70. The RI had significant correlation with echogenicity of the kidneys and had no significant correlation with size of allograft, CMD, CMR, duration of transplantation and serum creatinine levels.

Finally, the study evaluated the transplanted kidney and suggested signs of rejection. However, the signs of rejection of transplanted kidneys were thinning renal cortex, increased echogenicity, decreased size, disturbed or loss of CMD and CMR and raised RI.

5-3 Recommendations

- Color Doppler ultrasuond-laboratories with histopathology unit should be available in all hospitals that provide renal transplantation for helping patients and researchers in this field
- Routine periodic follow up of patients every three months. Doppler ultrasound and laboratory tests should be done for transplanted kidney and comparing them with previous results.
- All Doppler measurements should be routinely performed to assess allograft dysfunction which help to predict the rejection as early as possible.
- There are lack in Sudanese studies regarding referent values of the Doppler indices in healthy people, therefore further studies with suitable sample size were needed to confirm the normality of hemodynamics of the kidneys
- Further studies were needed in this topic to add more information about the features and signs of the rejection

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Appendices

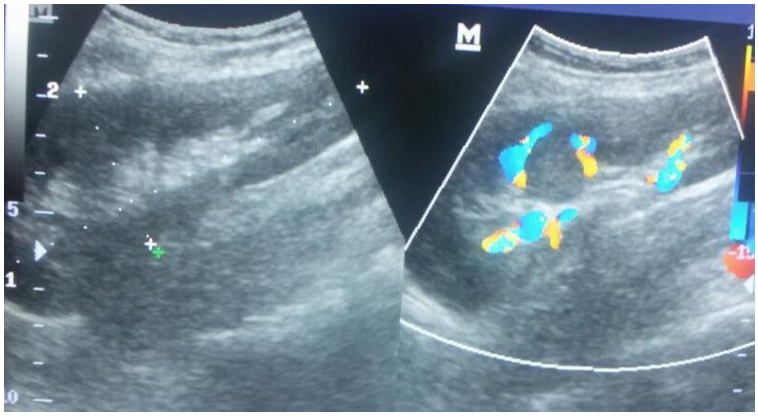

Image 1: longitudinal scan shows a normal transplanted kidney measurement and parenchymal flow of a 27-years old male

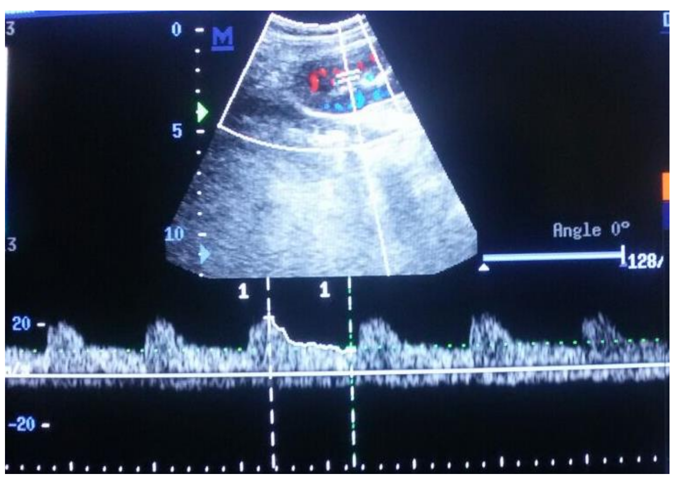

Image2: A sonogram of a 17-year-old male shows the normal RI for renal transplant

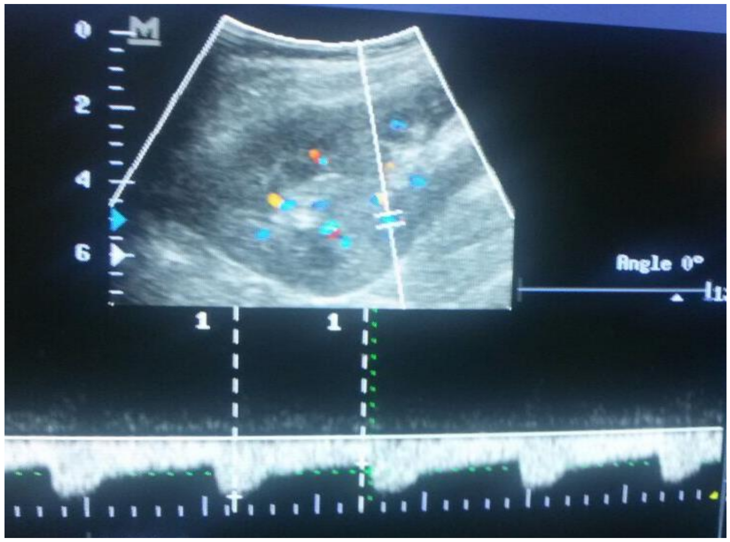

Image 3: a sonogram of a 37-year female shows inflammatory process of transplanted kidney with RI=0.54

Image 4: sonogram of an enlarged allograft with minimal perinephric fluid collection of a 50 years old man

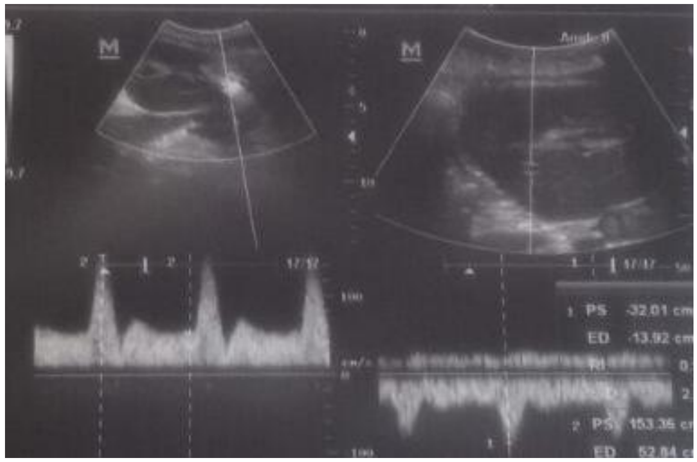

Image 5: a sonogram shows spectral Doppler of a nephritic transplanted kidney

Image 6: a sonogram of a 45-year old male shows hydronephrosis of the transplanted kidney

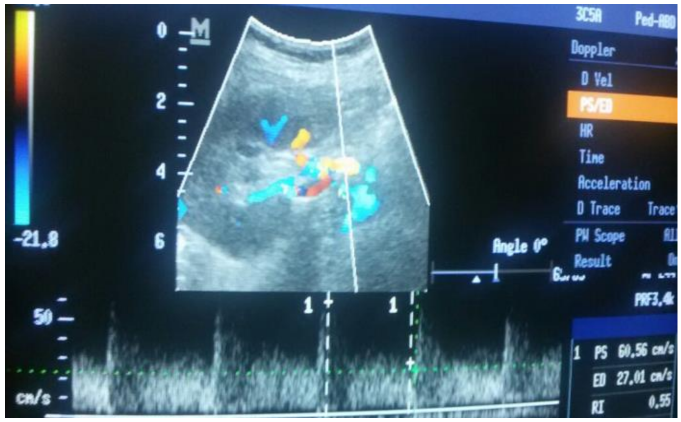

Image 7: a sonogram of a 35-year old male shows a normal RI for transplanted kidney (0.55)

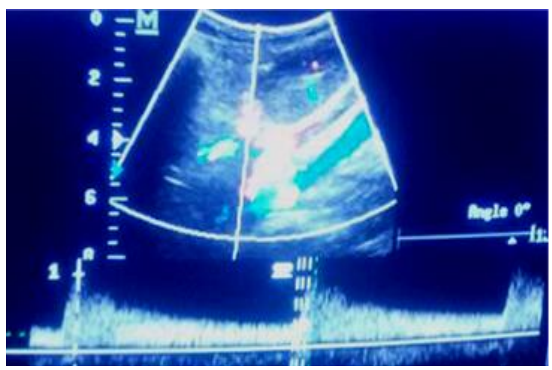

Image 8: a sonogram reveals normal blood flow in a transplanted kidney

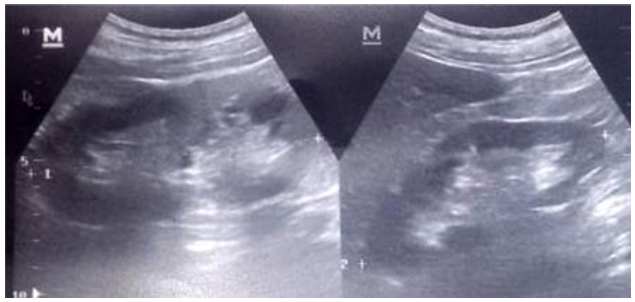

Image 9: a sonogram reveals normal sonographic appearance of a transplanted kidney in a 34-year old male

Image 10: Doppler image reveals elevated resistive index of the renal artery (RI=0.95) with reduced cortical perfusion. The case was interpreted as features of rejection.

Part 2: data collection sheet

Sudan University for Science and Technology

College of Graduate Study

Sonographic signs of rejection of transplanted kidney in Sudan

Data collection sheet

Demographic data:

1- Gender: male ☐ female☐

2- Age:

…………………………………………………

3- Residence:

…………………………………………..

4- Occupation: employer ☐ non-employer ☐

5- History of transplantation: ……………………..

6- -Hypertension yes ☐ no ☐

7- Diabetic mellitus yes ☐ no ☐

8- Urologic causes ☐ g- Others ☐

Results of Lap investigations:

9- Blood Urea level

…………………………………………………………………

….

10- Serum creatinine level**: ……………..**

11- Duration of the graft (transplantation):

…………………

Sonographic findings:

12- Size of the kidney: ……………….

13- Collecting(pelvicalyceal) system finding:

………………………………………………………………
………

14- Echogenicity of renal cortex:

a- increased ☐ b- decreased ☐ c- normal☐

14-Cortico-medullary differentiation: a- preserved ☐ b- lost☐ c- disturbed☐

15- corticoedullary ratio: a- increased ☐ b- decreased☐ c- normal☐

16- Perirnephric fluid collection: present not present

17- Other renal parenchymal findings:

………………………………………………………………
………………………………………………………………
………………………………………………………………
…………………………………………………….

Doppler findings:

18- RI of the renal artery: ………………….

19- PI of the renal artery: ………………….

20- PSV of the renal artery …………………

Comment……………………………………………………………………
………………………………………………………………………………