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SONOGRAPHIC FEATURES OF RADIOLOGICALLY NON-FUNCTIONING KIDNEYS ON INTRAVENOUS UROGRAPHY (IVU) IN KANO METROPOLIS, NIGERIA

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ABSTRACT

Background: Despite technological advancement in uro-radiology, renal ultrasonography remains the imaging modality of choice for evaluating various pathological conditions affecting urinary tract (GIT) system.

Aim: This study was aimed at evaluating sonographic features of radiologically non-functional kidneys in Kano metropolis, Nigeria.

Methods: A prospective study involving 94 each of disease and control group were conducted in Kano metropolis from January 2019 to January 2021. Renal scans were performed using a digital ultrasound imaging system; model DP-8800Plus fitted with a 3.5MHz curvilinear transducer. The maximum length, width, and thickness were measured. The renal echogenicity was assessed and graded. Data was analyzed using SPSS Version 22.0

Results: The mean values of the right and left renal volumes among adult patients was 400.5 ± 527.3 cm^3 and 177.6 ± 174.3 cm^3 respectively. For pediatric patients it was 272.3 ± 308.6 cm^3 and 241.6 ± 228.7 cm^3 for the right and left kidney respectively. The renal parenchymal echogenicity of the right kidney among adult patients were sored as grade II 2 (5.3%), grade III 27 (71%), and grade IV 9 (23.7%), while that pediatric patients were Grade 0 (11.1%), and 8 (88.9%) as grade III. The adults left kidney were scored grade II 2 (6%), and 16 (47%) each as grades III and IV, while the pediatric group scored 3 (25%) as grade II, and 9 (75%) as grade III.

Conclusion: Increased renal volume, shrunken kidney, increased renal parenchymal echogenicity, and severe hydronephrosis were strong sonographic indicators of non-functional kidneys.

Introduction

A non-functioning kidney can be defined as the one having a thin and increased parenchymal echogenicity on ultrasound or computed tomography, exhibiting no contrast visualization in the collecting duct system on intravenous urography (IVU) and having a split renal function of less than 10% on nuclear renal function studies. [1] The prevalence of kidney diseases is increasing globally and the cost of treating the disease represents an enormous burden on health systems worldwide. [2, 3] Diseases of the kidney are numerous, commonly occurring clinical conditions include acute kidney injury, chronic kidney disease, diabetic kidney disease, nephritis and nephrotic syndrome, polycystic kidney disease, urinary tract obstruction, urinary tract infection and renal cancer. When the renal function decreases such that the kidneys are no longer functioning to maintain health, patients sometimes

undergo dialysis and eventually kidney transplantation. [3] The early identification of patients with renal disease allows early intervention targeted at the reversing process of the renal injury or slowing down its progression, and ultimately reducing the morbidity and mortality from the disease. [4]

For many decades conventional IVU has been the primary imaging modality of choice for the evaluation of UTI disease.

However, it has been gradually replaced as the gold standard by other imaging modalities like ultrasonography (USS), computed tomography (CT), Magnetic resonance imaging (MRI), and nuclear medicine. [17, 18] Ultrasonography remains the imaging modality of first choice for investigation of the kidney disease because, it upper excellent anatomical detail, require no special patient preparation, readily available, less cost, and does not expose patient to ionizing radiation and or contrast agent. It allows clear visualization of the kidney in various planes, including the sagittal and transverse planes, both at rest and during dynamic maneuvers. [5] It allows the assessment of renal volume, and renal parenchymal volume. It also gives the detail of renal echogenicity and detect solid tumors, swelling, blockage of urine flow, and its useful in identifying cystic lesions. [6]

Chronic kidney disease remains a major challenge globally, about 10% of the population affected by it worldwide and millions died each year. [2,3] Chronic kidney disease was the 18th most common cause of death globally in 2010 and over 2millions people worldwide receive treatment with dialysis or kidney transplant to stay alive. [7, 8] Base on the researcher's experience, patients that have undergone IVU investigation experienced a lot of challenges during the course of the examination which includes: high level of stress, two days on non-oily light food and one-day overnight fasting prior to the procedure, high financial cost of the investigation, exposure to contrast agent and multiple x-ray exposures to the patient. The findings of the study could serve as a guide to the sonographer/sonologist and referring physician in the diagnosis and management of patient with non-functional kidney. This study was aimed at evaluating sonographic features of radiologically non-functioning kidneys on IVU in Kano metropolis Nigeria.

Materials and Methods

This prospective study was conducted in Kano metropolis from January, 2019 to January, 2021. Ethical approval to conduct the study was obtained from the Research and Ethics Committee, Ministry of Health Kano. Data were obtained from Aminu Kano Teaching Hospital, Murtala Muhammad Specialist Hospital, Abdullaahi Wase Specialist Hospital, and Abubakar Imam Urology Centre. These were the centers that had functional facilities and performed IVU examination during the study period. Ninety-four disease and 94 control groups were studied. Exclusion criteria included patients with congestive cardiac failure, patients on renal replacement treatments, cirrhotic liver, fatty liver and patients with hepatitis. All the ultrasound scans were performed using a digital diagnostic ultrasound imaging system; model DP-8800Plus fitted with a 3.5MHz curvilinear transducer.

The right kidney was examined in supine position through the liver by angling the transducer obliquely. [9] The image of the right kidney was acquired with the liver, so as to made comparison of the liver echogenicity when assessing the right parenchymal echogenicity. Measurements were taken in longitudinal as well as axial image at the level of the renal hilum in static image. [10] With the patient in the right decubitus, the arm was extended over the head and using a coronal approach the left kidney was seen through the spleen. The image of the left kidney was acquired with that of the spleen for assessing the left renal echogenicity. [9] The kidneys were well demonstrated in prone position; the images of both kidneys were obtained with the patient in a prone position for corticomedullary differentiation and measurements. The maximum length of the kidney was measured in the longitudinal plane and represented the largest longitudinal section while the width and thickness were measured in the transverse plane perpendicular to the longitudinal axis of the kidney as the largest vertical and transverse dimensions. The machine automatically displayed the value of renal volume whenever the length width and thickness were measured. The values of the right and left renal volumes, renal parenchymal echogenicities and corticomedullary differentiation were recorded into the data capture sheet. Descriptive statistics was used in the data analysis; mean, standard deviation, frequency, and range were obtained. The obtained data was analyzed using Statistical Package for Social Sciences (IBM SPSS) Version 22.0.

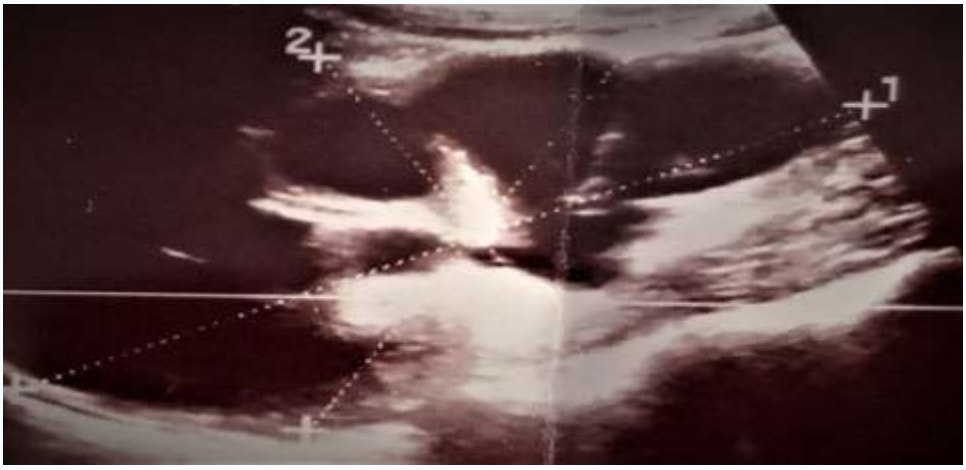

Figure 3: Sonograms of patients with right non-functional kidney showing the Longitudinal measurement

Figure 4: Sonograms of patients showing the Longitudinal and transverse measurement of the right kidney.

Results

Demographic Data

One hundred and eighty-eight (188); comprising of ninety-four (94) disease and ninety-four (94) control group participated in the study. Seventy-two (72) adults and 22 pediatrics in each group. Table 4.1. The mean age, BMI and BSA in male and female adult patients were 43.12±10.60years, 24.4±2.93kg/m^2, 1.75±0.13m^2, 44.47±11.97years, 25.93±3.48kg/m^2 and 1.73±0.14m^2 respectively. The mean age, BMI and BSA in male and female pediatric patients were 5.07±3.70years, 19.81±11.94kg/m^2, 3.11±0.71 m^2, 6.18±4.16years, 20.42±5.07 kg/m^2 and 1.97±0.5 respectively.

Table 1: Demographic characteristics of the patients

Variables	Adults			Pediatrics		
	Male (n=42)	Female (n=30)	Total (n=72)	Male (n=15)	Female (n=7)	Total (n=22)
Age(years)	43.12±10.60	44.47±11.97	43.8±11.3	5.07±3.70	7.29±4.61	6.18±4.16
	(27-76)	(27-68)	(27-76)	(1-13)	(2-15)	(1-15)
BMI(Kg/m^2)	24.40±2.93 (18-35)	25.93±3.48 (17-35)	25.17±3.2 (8-50)	19.81±11.94 (15-28)	20.42±5.07 (8-50)	20.12±8.5 (17-31)
BSA(m^2)	1.75±0.13 (1.5-2.0)	1.71±0.15 (1.37-1.98)	1.73±0.14 (1.37-2.0)	3.11±0.71 (2-4.2)	0.84±0.28 (0.15-1.27)	1.97±0.5 (2-4.2)

Data presented as mean ±SD (range). BSA: body surface area, BMI: body mass index

Table 2: The mean age, BMI and BSA in male and female adult control group were 44.12±11.70years, 22.9±2.90kg/m^2, 1.72±0.13m^2, 43.17±11.29years, 23.22±2.46kg/m^2 and 1.63±0.12m^2 respectively. The mean age, BMI and BSA in male and female pediatric control group were 5.33±3.52years, 19.9±12.7kg/m^2, 0.68±0.28 m^2, 7.86±4.1years, 17.3±2.6kg/m^2 and 0.77±0.2 respectively.

Table 2: Demographic characteristics of the control group

Variables	Adults			Pediatrics		
	Male (n=42)	Female (n=30)	Total (n=72)	Male (n=15)	Female (n=7)	Total (n=22)
Age(years)	44.12±11.70 (27-76)	43.17±11.29 (27-68)	43.6±11.5 (27-76)	5.33±3.52 (1-13)	7.86±4.1 (2-15)	6.6±3.81 (1-15)
BMI(Kg/m^2)	22.9±2.90 (17-28)	23.22±2.46 (18-29)	23.1±2.7 (17-29)	19.9±12.7 (4-48)	17.3±2.6 (14-21)	18.6±7.7 (4-48)
BSA(m^2)	1.72±0.13 (1.5-2.0)	1.63±0.12 (1.37-1.83)	1.68±0.13 (1.37-1.83)	0.68±0.28 (0.3-1.2)	0.77±0.2 (0.5-1.2)	0.73±0.3 (0.3-1.2)

Data presented as mean ±SD (range). BSA: body surface area, BMI: body mass index

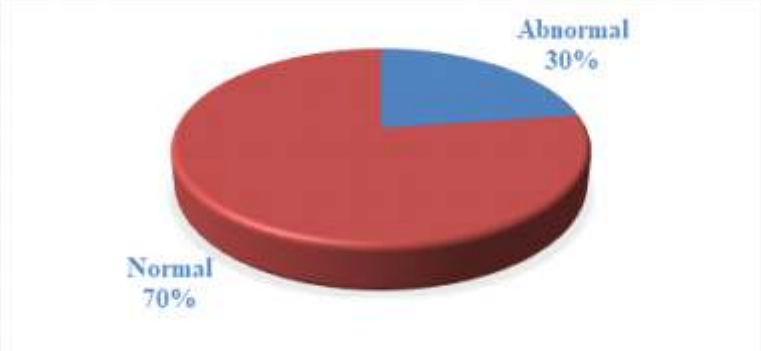

Figure 1: Overall frequency distribution of normal and abnormal IVU among Adults and Pediatrics.

Two hundred and twenty-four (70%) had normal finding, while 94 (30%) patients had either right or left non-functional kidney.

Table 3: The mean values of the right and left renal volumes in adult patients were 400.5±527.3cm^3 and 177.6±174.3cm^3 respectively. The mean values of the right and left renal volumes in pediatric patients were 272.3±308.6cm^3 and 241.6±228.7 cm^3 respectively.

Table 3: Values of sonographic measurements of total renal volume of non-functional kidneys

Renal Volume (cm^3)	Adults (n=72)			Pediatrics (n=22)		
	Male	Female	Total	Male	Female	Total
Right Kidney	539.6±887.3 (67-2778)	261.4±167.2 (64-852)	400.5±527.3 (64-2778)	138.3±68.9 (9.7-208)	406.3±548.6 (121-1229)	272.3±308.6 (9.7-1229)
Left Kidney	219.3±218.5 (14.4-809)	136.0±130.0 (60-416)	177.6±174.3 (14.4-809)	251.5±405.0 (30.8-1276)	232±52.3 (196-292)	241.6±228.7 (30.81276)

Table 4: The mean values of the right and left renal volumes in adults control group were 104.0±13.7cm^3 and 118.6±15.0cm^3 respectively. The mean values of the right and left renal volumes in pediatrics control group were 40.6±15.2cm^3 and42.6±31.2cm^3 respectively.

Table 4: Values of sonographic measurements of total renal volume of the control group

Renal Volume (cm^3)	Adults (n=72)			Pediatrics (n=22)		
	Male	Female	Total	Male	Female	Total
Right Kidney	110.21±16.12 (90-176)	97.6±11.3 (90-133)	104.0±13.7 (90-176)	41.4±15.6 (21-72)	39.8±13.8 (25.5-61)	40.6±15.2 (21-72)
Left Kidney	123.31±16.7 (100-180)	114.3±13.3 (100-148)	118.8±15.0 (100-180)	44.4±17.6 (21.5-76)	40.8±13.6 (27-61)	42.6±31.2 (21.5-76)

Tables 5 and 6: The frequency distribution of normal and abnormal values of the sonographic measurement of the renal volumes for male and female adult patients with non-functional kidney. Table 4.5. Twenty-four (57.1%) of male patients had a renal volume of >190 cm^3 while 18 (42.9%) had a renal volume between 110-190cm^3. Table 4.6. Ten (33.3%) of the female patient had a renal volume of > 150 cm^3 while 20 (66.7%) had a renal volume between 90-150cm^3.

Table 5: Frequency distribution of normal and abnormal renal volume for male adults

Renal volume (cm^3)	Right kidney, n (%)	Left kidney n, (%)	Total n, (%)
110-190	10(45.5)	8(40.0)	18(42.9)
>190	12(54.5)	12(60.0)	24(57.1)
Total	22(100.0)	20(100.0)	42(100.0)

Table 6: Frequency distribution of normal and abnormal renal volume for female adults

Renal volume (cm^3)	Right kidney, n (%)	Left kidney n, (%)	Total n, (%)
90-150	9(75.0)	11(61.0)	20(66.7)
>150	3(25.0)	7(39.0)	10(33.3)
Total	12(100.0)	18(100.0)	30(100.0)

Tables 7: The frequency distribution of renal parenchymal echogenicity of non-functional kidneys among adult patients. The right kidneys of 2 (5.3%) patients among adults were scored Grade II, 27 (71%) Grade III and 9 (23.7%) as Grade IV. The left kidneys of 2 (6%) patients among adults were scored Grade II, 16 (47%) as Grade III and Grade IV each.

Table 7: The frequency distribution of renal parenchymal echogenicity of non-functional kidneys among adult patients

Renal grades	Right kidney			Left kidney		
	Male	Female	Total	Male	Female	Total
0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)

Renal grades	Right kidney			Left kidney		
	Male	Female	Total	Male	Female	Total
II	2(10.0%)	0(0.0%)	2(5.3%)	2(9.1%)	0(0.0%)	2(6.0%)
III	12(60.0%)	15(83.3%)	27(71.0%)	12(54.5%)	4(33.3%)	16(47.0%)
IV	6(30.0%)	3(16.7%)	9(23.7%)	8(36.4%)	8(66.7%)	16(47.0%)
Total	20(100%)	18(100%)	38(100%)	22(100%)	12(100%)	34(100%)

Table 8: The right kidney of 1 (11.1%) among pediatric patient was scored as Grade 0, and 8 (88.9%) as Grade III. The left kidney of 3 (25%) among pediatric patients was scored as Grade II, and 9 (75%) as Grade III.

Table 8: The frequency distribution of renal parenchymal echogenicity in non-functional kidneys among pediatrics patients

Renal grades	Right kidney			Left kidney		
	Male	Female	Total	Male	Female	Total
0	1(16.7%)	0(0.0%)	1(11.1%)	0(0.0%)	0(0.0%)	0(0.0%)
I	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
II	0(0.0%)	0(0.0%)	0(0.0%)	3(33.3%)	0(0.0%)	3(25.0%)
III	5(83.3%)	3(100%)	8(88.9%)	6(66.7%)	3(100%)	9(75.0%)
IV	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
Total	6(100%)	3(100%)	9(100%)	9(100%)	3(100%)	12(100%)

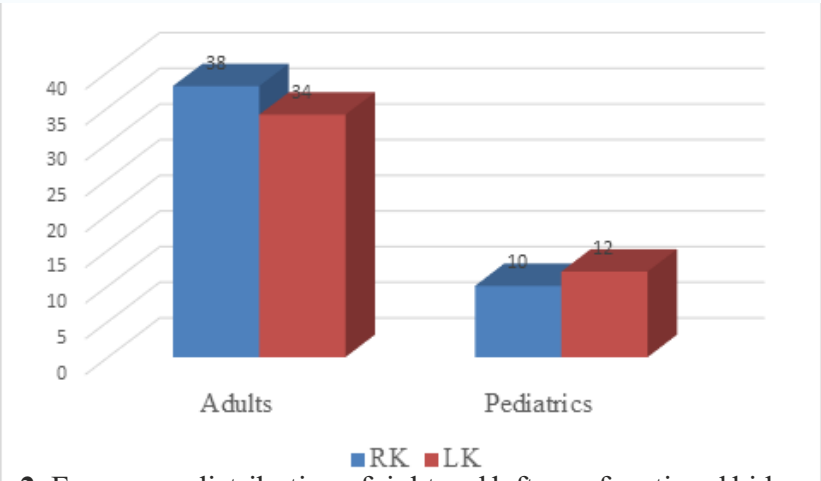

Figure 2: Frequency distribution of right and left non-functional kidneys among Adults and Pediatrics.
Right kidney 38 (52.8%) has the highest frequency among adults while left kidney 12 (24.3%) has the highest frequency among pediatrics patients.

Table 9: Right renal parenchymal disease has the highest frequency in adults 20 (27.8) followed by left renal parenchymal disease 11 (55%). Among pediatrics patient severe left Hydronephrosis has the highest frequency 7 (31.8%) followed by severe right Hydronephrosis 6 (27.3%).

Table 9: The frequency distribution of sonographic findings for non-functional kidneys among adults and pediatrics

FIND-INGS	Adults			Pediatrics		
	Male F(%)	Female F(%)	Total F(%)	Male F(%)	Female F(%)	Total F(%)
LRPD	11(26.2)	3(10.0)	14(19.4)	1(6.7)		1(4.5)
RRPD, H	2(4.8)		2(2.8)			
RPCK	3(7.1)		3(4.2)			
RHPK				1(6.7)		1(4.5)
RHUN		6(20.0)	6(33.3)			
SRHN	3(7.1)	8(26.7)	11(15.3)	2(13.3)	4(57.1)	6(27.3)
SRHUN		1(3.3)	1(1.4)	2(13.3)		2(9.1)
SRHN, LHN	1(2.3)		1(1.4)			
RRPD	12(28.5)	8(26.7)	20(27.8)	4(26.7)		4(18.2)
LRPD, H	1(2.3)	1(3.3)	2(2.8)			
SLHN	8(19.4)	3(10.0)	11(15.2)	4(26.7)	3(42.9)	7(31.8)
SBHN				1(6.7)		1(4.5)
SLHUN	1(2.3)		1(4.5)			
Total	42(100)	30(100)	72(100)	15(100)	7(100)	22(100)

Data presented as frequency and (%).

Keys:

RRPD: Right renal parenchymal disease
RRPD, H: Right renal parenchymal disease, Hydronephrosis
RPCK: Right poly-cystic kidney
RHPK: Right Hypo-plastic kidney
RHUN: Right Hydro-uretronephrosis
SRHN: Severe right Hydronephrosis
SRHUN: Severe right Hydro-uretronephrosis
SRHN, LHN: Severe right Hydronephrosis, left Hydronephrosis
LRPD: Left renal parenchymal disease
LRPD, H: Left renal parenchymal disease, Hydronephrosis
SLHN: Severe left Hydronephrosis
SBHN: Severe bilateral Hydronephrosis
SLHUN: Severe left Hydro-uretronephrosis

Discussion

The findings of this study as shown in Figure 1 revealed that, the majority of the patients that underwent IVU examination had a normal finding. while some of the patients presented with either right or left non-functional kidney. Considering the high dose of ionizing radiation associated with IVU and the high proportion of cases that ended as normal studies. The referring physicians and radiologist should consider other modalities for the diagnosis of non-functional kidney. Previous studies did not report the percentages of the patients that had normal studies but, reported only the percentage that had non-functional kidney.

The findings of the current study as shown in Table 3 indicated that, the mean values of the right and left renal volumes among adult and pediatric patients were significantly above the upper normal limit respectively. Renal diseases are diagnosed at sonography using combination of changes in renal sizes and echogenicity. [6, 11] The possible reason for the increased in renal volume might be, as a result of severe hydronephrosis and poly-cystic kidney disease as the cause of non-functional kidney. Majority of patients with hydronephrosis, poly-cystic kidney disease and acute pyelonephritis have an enlarged and poorly functioning kidney due to renal parenchymal edema, while in some cases, patients with chronic pyelonephritis, renal parenchymal disease grade IV present with decreased/shrunken renal size due to parenchymal atrophy. [12] Medullary pyramid thickness and parenchymal thickness progressively decreased with the increase severity of hydronephrosis. [13] However, the previous studies did not categorize the patients diagnosed with non-functional kidney into males and females or pediatrics and adults. Furthermore, none of the previous studies, studied renal volume of the non-functional kidney or the normal one. The renal volume remains an important parameter in the diagnosis of shrunken kidney. Furthermore, the findings of the present study as shown in Table 4 were almost similar to the findings of the previous study conducted by Ya'u *et al.* [14] who reported the mean right and left renal volume of apparently normal adults individuals

were found to be 109.56 ± 13.52 cm^3 and 123.03 ± 13.88cm^3 respectively. The possible reason for the agreement between the two studies may be both studies were conducted in same geographical location. Furthermore, the findings this study indicated that mean left renal volume was higher than that of mean right renal volume. It is in agreement with the studies conducted by Ya'u *et al.* [14] and Yunus *et el.* [15] The possible reason for the difference in size may be because; left kidney has more space to grow that the right kidney. Among pediatrics control group, the mean values of right and left kidney measured 40.6 ± 15.2 cm^3 and 42.6 ± 31.2 cm^3 respectively.

The findings of this study as shown in Tables 5 and 6 indicated that, majority of the male patients had a renal volume of greater than 190 cm^3. Among female patient majority had a renal volume of greater than150cm^3. The upper limit of renal volume for male adult individuals is 190 cm^3 while for female adult individuals is 150 cm^3. [6] The proportion of the male patients with abnormal renal volume was higher than the proportion of the female patients with abnormal renal volume. This shows that male patients are more at risk of developing renal failure when compared to their female counterparts. Increased renal volume was observed in both non-functional kidneys and the functional ones among the patients studied. The possible reason of the increased renal volume in the non-functional kidney was as results of hydronephrosis while the increased renal volume in the normal contra lateral kidney could be as a result of compensatory hypertrophy and hyperplasia.

The findings of the current study as shown in table 7 are similar to the findings of a related studies conducted by Sidi *et al*. [6] and Eze *et al*. [16] on renal parenchymal changes on patients with HIV/AIDS. Both reported an abnormal renal parenchymal echogenicity in males more than in females and the right kidneys more than the left kidneys. The possible reasons for the agreement between the three studies may be, both studies were conducted in the same country and both consider patient with renal pathology. This means that males are more at risk of developing renal failure when compared to their female counterparts and the right kidney is more at risk than the left kidney. Increased renal parenchymal echogenicity could be strong indicator of a non-functional kidney. However, Table 8 indicated that, some proportion of pediatrics patients with non-functional kidneys, had normal parenchymal echogenicity and Grade 1 renal parenchymal echogenicity. This shows that the prognosis will better in pediatrics when compared to adults if the condition is reversible. Furthermore, the previous studies did not categorize the studied patients into pediatrics and adults.

In this study, the right renal parenchymal disease was the most frequent finding in adults followed by left renal parenchymal disease. Among pediatrics patient severe left Hydronephrosis was the most frequent finding, followed by severe right Hydronephrosis. These findings show that, the prognosis will be better in pediatrics when compared to adults; this is because the hydronephrosis observed in pediatrics could be reversed easily when compared to the renal parenchymal disease observed in adult patients.

Conclusion

Increased renal volume, shrunken kidney and increased renal parenchymal echogenicity were strong sonographic indicators of adult patients with non-functional kidney. However, in pediatrics patients increased renal volume and hydronephrosis were the indicators of the non-functional kidney.

Limitations of the study

- Renal function test was not performed on the selected subjects
- Histopathology was not performed on the selected subjects

Areas of further studies

- Further studies should consider using larger sample size
- Further studies should perform renal function test
- Further studies should perform histopathology
- Further studies should use renal Doppler indices

Recommendation

- Ultrasound is recommended as an adjunct in the diagnosis of non-functional kidney

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