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ORIGINAL ARTICLE

KIDNEY ULTRASONOGRAPHIC FINDINGS AND THEIR RELATIONSHIP WITH RENAL ARTERIAL RESISTIVE INDEX AMONG ADULTS LIVING WITH HUMAN IMMUNODEFICIENCY VIRUS IN SOUTHWESTERN NIGERIA

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ABSTRACT

Introduction
Kidney involvement is a common complication of human immunodeficiency virus (HIV) infection and contributes significantly to morbidity and mortality. This study evaluated renal ultrasonographic findings and their relationship with the renal arterial resistive index (RI) among adults living with HIV.

Methods
This hospital-based comparative cross-sectional study included 100 adults living with HIV and 100 age- and sex-matched apparently healthy controls. All participants underwent renal ultrasonography to assess renal dimensions, parenchymal echogenicity, renal arterial RI, and other renal abnormalities. Correlations between renal size, echogenicity, and RI were analysed using appropriate statistical methods, with statistical significance set at $p < 0.05$.

Results
Renal ultrasonography demonstrated normal, enlarged, and shrunken kidneys among participants with HIV. Increased renal RI was observed in 73.0% of participants, while increased renal parenchymal echogenicity was present in 77.0%. Other sonographic abnormalities included globular kidney, loss of corticomedullary differentiation, and simple renal cysts. A weak positive correlation was observed between renal size, renal parenchymal echogenicity, and RI. The strongest correlation was between right renal length and RI ($r = 0.29$, $p = 0.003$), whereas correlations involving other renal parameters were weak and not statistically significant.

Conclusion
Adults living with HIV demonstrate diverse renal ultrasonographic abnormalities, including altered renal size, increased renal echogenicity, and elevated renal arterial resistive index.

Keywords: Human immunodeficiency virus; HIV-associated nephropathy; renal ultrasonography; resistive index; renal echogenicity; kidney disease.

INTRODUCTION

Human immunodeficiency virus (HIV) infection remains a major global public health challenge despite significant advances in diagnosis, treatment, and prevention. In addition to opportunistic infections, HIV is associated with several renal complications, which contribute substantially to morbidity and mortality among affected individuals.[1–6] Renal involvement ranges from asymptomatic urinary abnormalities to chronic kidney disease (CKD) and end-stage kidney disease (ESKD), with HIV-associated nephropathy (HIVAN) being one of the commonest and most severe manifestations, particularly among individuals of African ancestry.[3,5–8]

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HIV-associated nephropathy is characterised histologically by collapsing focal segmental glomerulosclerosis with microcystic tubular dilatation and interstitial inflammation.[6,8,15,17–20] Progressive renal injury may result in deterioration of kidney function, leading to ESKD if not detected and treated early. Although laboratory investigations remain important in assessing renal function, imaging plays a complementary role by demonstrating structural and vascular changes that may precede significant functional impairment.[1,2,14]

Ultrasonography is an inexpensive, readily available, non-invasive, and radiation-free imaging modality for evaluating renal disease. It provides valuable information on renal size, cortical echogenicity, corticomedullary differentiation, parenchymal abnormalities, and intrarenal haemodynamics through Doppler assessment of the renal arterial resistive index (RI).[1,2,9,11,12,14] Increased renal echogenicity, alterations in renal size, elevated RI, loss of corticomedullary differentiation, and renal cysts have all been reported in patients living with HIV.[4,9,11,12,21,22,26]

The renal arterial resistive index reflects intrarenal vascular resistance and has been shown to correlate with the severity and progression of several renal diseases.[23–25] However, there is limited information regarding the relationship between renal arterial RI and sonographic renal abnormalities among people living with HIV in Nigeria and many other sub-Saharan African countries. Most previous studies have focused primarily on renal size or echogenicity without evaluating their association with intrarenal vascular resistance.[9,12,21,22,26]

A better understanding of these relationships may facilitate earlier recognition of HIV-associated renal disease and improve patient monitoring. Therefore, this study evaluated renal ultrasonographic findings among adults living with HIV and examined the relationship between renal size, renal parenchymal echogenicity, and renal arterial resistive index.

METHODS

Study design

This was a hospital-based comparative cross-sectional study conducted among adults living with HIV attending the HIV clinic of the study institution and age- and sex-matched apparently healthy controls.

Study setting

The study was conducted at the HIV Clinic and the Department of Radiology of Lagos State University Teaching Hospital, Ikeja.

Study population

The study population comprised 100 adults living with HIV and 100 apparently healthy HIV-negative controls matched for age and sex.

Inclusion criteria

Participants with HIV aged 18 years and above who gave written informed consent were recruited consecutively during the study period. Controls were apparently healthy adults with no known history of renal disease or hypertension and who also consented to participate.

Exclusion criteria

Individuals with pregnancy, diabetes mellitus, hypertension, known chronic kidney disease unrelated to HIV, congenital renal abnormalities, obstructive uropathy, or other conditions known to affect renal morphology or haemodynamics were excluded. Participants with poor sonographic visualisation of the kidneys were also excluded.

Sample size
A total of 200 participants comprising 100 adults living with HIV and 100 age- and sex-matched controls were studied.

Study procedure
Relevant demographic and clinical information was obtained using a structured questionnaire. Each participant underwent renal ultrasonography using a real-time ultrasound scanner equipped with a curvilinear transducer. Both kidneys were evaluated in longitudinal and transverse planes.

The following renal parameters were assessed:

- Renal length
- Renal width
- Renal thickness
- Renal volume
- Renal parenchymal echogenicity
- Corticomedullary differentiation
- Presence of focal renal abnormalities
- Renal arterial resistive index (RI)

Renal length was measured as the maximum bipolar distance between the upper and lower poles. Renal width and thickness were measured on transverse images, while renal volume was calculated using the ellipsoid formula:

Renal volume = Length × Width × Thickness × 0.523.

Renal parenchymal echogenicity was assessed by comparing the renal cortex with the adjacent liver on the right and the spleen on the left. Echogenicity was categorised as normal, diffusely increased, patchily increased, or associated with loss of corticomedullary differentiation.

Doppler evaluation
Colour and spectral Doppler ultrasonography were performed to evaluate the intrarenal arteries. Resistive index measurements were obtained from the upper, middle, and lower pole interlobar arteries of each kidney, and the average value was recorded.

The resistive index (RI) was calculated using the formula:

RI = (Peak systolic velocity − End-diastolic velocity) / Peak systolic velocity.

An RI value greater than **0.70** was considered abnormal.

Statistical analysis
Data were entered and analysed using the Statistical Package for the Social Sciences (SPSS) software (version 20).

Continuous variables were summarised using means and standard deviations or medians and interquartile ranges, as appropriate, while categorical variables were expressed as frequencies and percentages.

Comparisons between groups were performed using the Student's *t*-test, Chi-square test, or Fisher's exact test where appropriate. Correlations between renal size, renal parenchymal echogenicity, and renal arterial resistive index were assessed using Pearson's correlation coefficient.

A p-value <0.05 was considered statistically significant.

Ethical considerations
Ethical approval was obtained from the Ethics and Research Committee of Lagos State University Teaching Hospital, Ikeja before commencement of the study Reference Number: LREC.06/10/909). Written informed consent was obtained from all participants prior to enrolment, and confidentiality of participants' information was maintained throughout the study.

RESULTS

Sociodemographic characteristics

A total of 200 participants comprising 100 adults living with HIV and 100 age- and sex-matched apparently healthy controls were recruited into the study. The sociodemographic characteristics of both groups were comparable, with no statistically significant differences in age or sex distribution ($p > 0.05$) (Table 1).

Table 1: Socio-demographic characteristics of subjects

Variable	Category	Case	Control	Total
Age (Years)	≤ 20	1	4	5
	21 -35	15	15	30
	≥ 36	84	81	165
Gender	Male	16	24	40
	Female	84	76	160
Educational level	Primary	13	2	15
	Secondary	63	52	115
	Tertiary	19	35	54
	Post-Tertiary	5	11	16

Table 2: Mean comparison of right and left renal parameters in cases and controls

Renal Parameters	Right Kidney Cases (100)	Controls(100)	P-value	Left Kidney Cases (100)	Control (100)	P-value
Lenght	10.02± 0.95	9.86±1.18	0.297	10.38±0.88	10.45±0.69	0.546
Width	5.66±0.86	5.08±0.84	0.001	5.58±1.01	5.05±0.72	0.001
Anteroposterior	3.78±0.51	3.88±0.38	0.123	5.15±0.71	5.02±0.68	0.214
Volume	114.61±34.03	101.26±25.05	0.002	157.14±46.60	133.79±43.53	0.001
Resistive index	0.67±0.08	0.61±0.05	0.001	0.65±0.09	0.61±0.05	0.001

Table 3: Correlation of renal parameters among cases

Renal Parameters	Right Kidney		Left Kidney	
	r	p - value	r	p -value
Length vs RI	0.292	0.003	0.022	0.827
AP vs RI	0.142	0.160	- 0.147	0.143
Width vs RI	0.156	0.120	0.103	0.308
Volume vs RI	0.227	0.023	- 0.019	0.851
Volume vs Echogenicity	0.001	0.995	0.003	0.979
RI vs Echogenicity	0.139	0.169	- 0.012	0.902

r – pearson correlation coefficient, vs – versus, * - significant, AP – anteroposterior dimension, RI – resistive index

Renal dimensions

The renal dimensions among participants with HIV showed considerable variation (tables 2 and 3). Most participants had normal renal sizes, although enlarged and shrunken kidneys were also observed. Increased left renal length was found in **6 (6.0%)** participants, increased right renal length in **3 (3.0%)**, while **9 (9.0%)** participants had reduced right renal length (Figures 1).

The left kidney generally demonstrated slightly larger dimensions than the right kidney, consistent with normal anatomical variation.

Renal arterial resistive index

The renal arterial resistive index (RI) was significantly higher among participants living with HIV than in the control group (figure 2).

Thirty-eight (38.0%) participants had an increased right renal RI, while 35 (35.0%) had an increased left renal RI. Bilateral elevation of RI was observed in **19 (19.0%)** participants. Overall, **73 (73.0%)** participants had an RI greater than **0.70**, whereas only a few controls demonstrated elevated RI values.

Although the mean RI remained within the accepted normal range, a substantial proportion of participants demonstrated elevated intrarenal vascular resistance.

Renal parenchymal abnormalities

Renal parenchymal abnormalities were identified in **79 (79.0%)** participants living with HIV.

The commonest abnormality was increased renal parenchymal echogenicity, observed in 77 (77.0%) participants. Of these:

- 64 (64.0%) had diffuse homogeneous increased echogenicity;
- 13 (13.0%) had patchy (heterogeneous) increased echogenicity.

Other abnormalities included:

- Loss of corticomedullary differentiation in **1 (1.0%)** participant;
- Globular kidney in **1 (1.0%)** participant; and
- Simple renal cyst in **1 (1.0%)** participant.

Figures 3a and 3b show the distribution of renal parenchymal echogenicity while figures 4 to 6 are ultrasound images depicting other renal abnormalities found in patients with HIV.

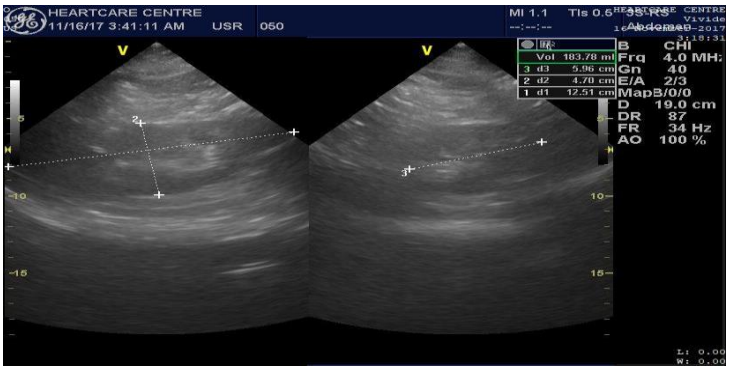

Figure 1: Longitudinal and transverse ultrasound images of an enlarged left kidney measuring 12.51 cm in a 60 year old female with HIV

Figure 2a: Duplex image spectral doppler waveform of the right main renal artery showing elevated resistive index of 0.75.

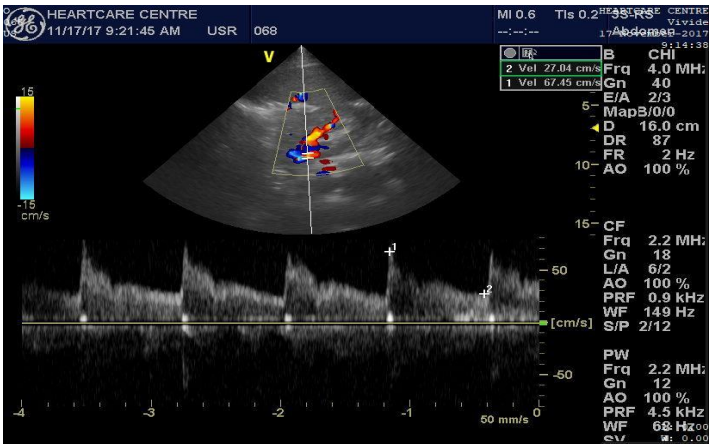

Figure 2b: Duplex image spectral doppler waveform of the right main renal artery showing normal resistivity index of 0.60.

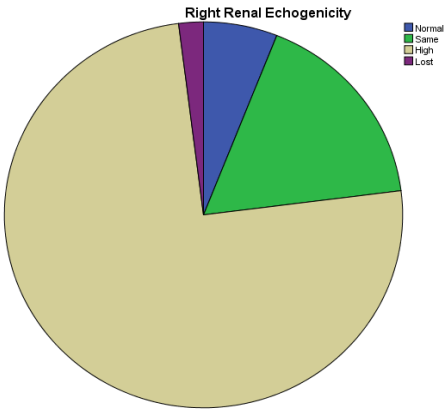

Figure 3a: Right renal echogenicity distribution

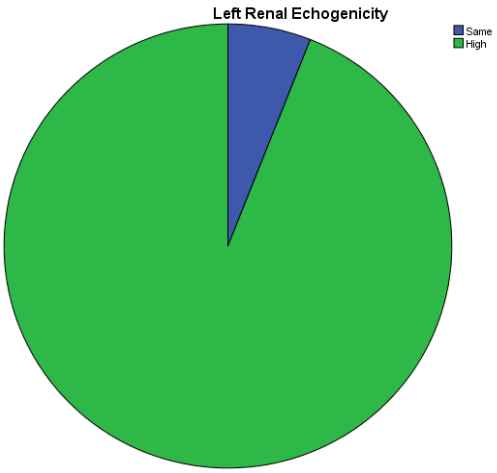

Figure 3b: Left renal echogenicity distribution

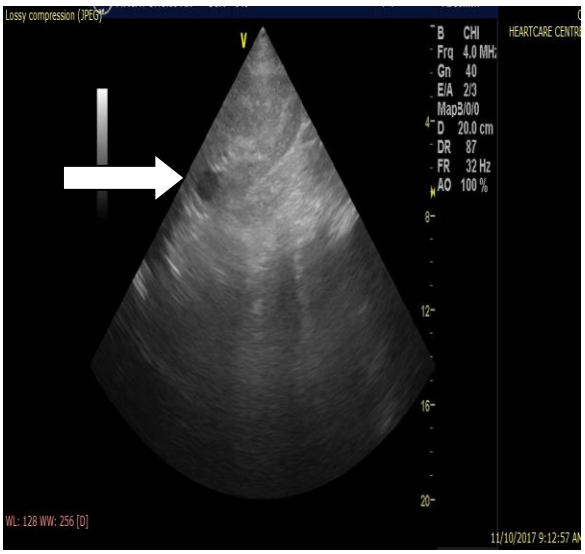

Figure 4: Longitudinal ultrasound scan image showing a simple renal cyst (white arrow) in the superior pole of the right kidney in a 32 year-old female with HIV

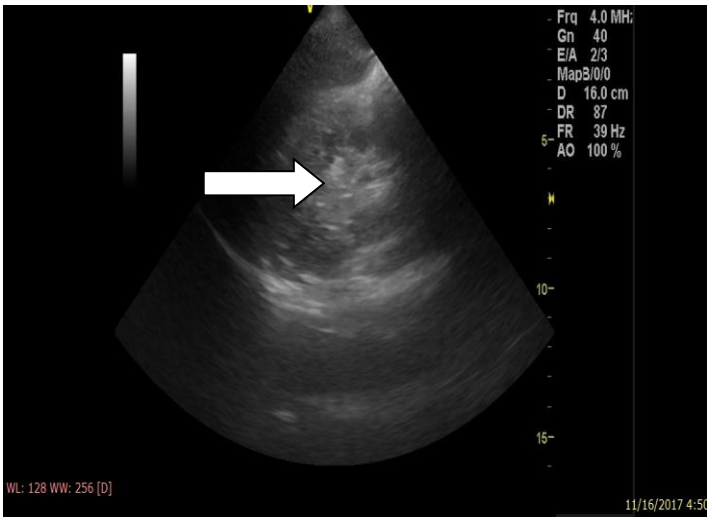

Figure 5: Longitudinal ultrasound scan image of a globular left kidney (white arrow) with diffuse echogenicity in a 45-year-old female with HIV-associated nephropathy.

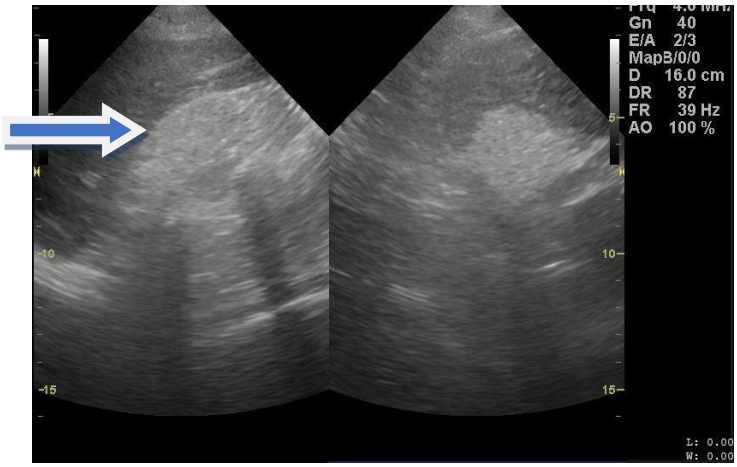

Figure 6: Longitudinal ultrasound scan image of grade (III) renal echogenicity with loss of central sinus echogenicity (blue arrows) and corticomedullary differentiation in a 64-year-old male with HIV- associated nephropathy. Note the shrunken kidney.

Correlation between renal ultrasonographic parameters and resistive index

Correlation analysis demonstrated a **weak positive relationship** between renal size, renal parenchymal echogenicity, and renal arterial resistive index.

The strongest statistically significant correlation was observed between right renal length and RI ($r = 0.29$, $p = 0.003$).

Positive but weaker correlations were observed between RI and right renal volume (r = 0.23, p = 0.023), right renal width (r = 0.16, p = 0.120), and right renal echogenicity (r = 0.14, p = 0.160). These latter correlations did not reach statistical significance.

Overall, the findings suggest that although renal ultrasonographic abnormalities are common among adults living with HIV, the relationships between renal morphology, echogenicity, and intrarenal vascular resistance are generally weak.

DISCUSSION

Ultrasonography is a readily available, affordable, reliable, and non-invasive imaging modality for evaluating renal disease in people living with HIV. Renal manifestations of HIV infection are diverse and include HIV-associated nephropathy (HIVAN),[15] membranoproliferative glomerulonephritis, membranous glomerulopathy,[16] amyloidosis, immune-complex glomerulopathy, minimal change disease, and IgA nephropathy. HIVAN is the commonest histological renal lesion in HIV infection[17] and is characterised by collapsing focal segmental glomerulosclerosis (FSGS)[18] with microcystic tubular dilatation on histological examination.[19,20] Progressive collapse of the glomerular capillary tuft eventually results in sclerosis, which manifests sonographically as increased renal parenchymal echogenicity of varying patterns. Clinically, HIVAN commonly presents with nephrotic-range proteinuria and progressive deterioration of renal function, frequently progressing to end-stage kidney disease (ESKD) within 10 months if untreated.[20]

Renal ultrasonographic findings in the present study included normal, enlarged and reduced renal sizes, increased renal arterial resistive index (RI), increased renal parenchymal echogenicity, weak positive correlations between renal size, RI and parenchymal echogenicity, as well as less frequent abnormalities such as globular kidneys and renal cysts.

The findings demonstrate that renal size in patients with HIV may be normal, enlarged, or reduced. Increased left and right renal lengths were observed in 6% and 3% of participants, respectively, while 9% had reduced right renal length. These findings are comparable with those reported by Adeyekun *et al.*,[12] who documented enlarged and reduced kidneys in 8% and 7% of patients, respectively. Higher frequencies of enlarged kidneys have, however, been reported by Garko *et al.*,[9] Igbinedion *et al.*,[21] and Fiori *et al.*,[22] who documented enlarged kidneys in 28%, 18.7%, and 19.7% of their study populations, respectively.

The variation in renal size reported across studies may reflect differences in disease stage, timing of presentation, antiretroviral therapy (ART) uptake, and the underlying pathological processes affecting the kidneys. Enlargement of the kidneys has been attributed to tubular dilatation with numerous microcysts and interstitial oedema,[9,20] whereas reduction in renal size reflects progressive glomerulosclerosis, destruction of glomerular capillary architecture, and chronic parenchymal scarring.[23] Earlier presentation and better adherence to ART among participants in the present study may explain the lower proportion of enlarged kidneys compared with studies in which patients presented later in the course of HIV infection.[9]

Consistent with normal anatomical variation, enlargement was more evident in the left kidney than the right, similar to the observations of Emamian *et al.*,[20] who demonstrated larger left kidneys in healthy adults. This difference has been attributed to the shorter, straighter course of the left renal artery, resulting in relatively greater blood flow, as well as the smaller size of the spleen compared with the liver, which provides more space for left renal growth.[20]

The findings on the renal arterial resistive index (RI) suggest increased intrarenal vascular resistance among patients living with HIV. Elevated RI values were observed in 38% and 35% of participants in the right and left kidneys, respectively, compared with 3%

and 2% among controls. Although the mean RI remained within the accepted normal range (0.67), 73% of participants had an RI >0.70, while 19% demonstrated bilateral elevation. These findings are comparable to those reported by Gunawan *et al.*[24] and Sidi *et al.*,[25] who similarly demonstrated increased RI values among patients with HIV.

The increased renal vascular resistance observed in HIV may result from vascular scarring secondary to fibrotic changes associated with collapsing focal segmental glomerulosclerosis (FSGS), the characteristic histopathological lesion of HIVAN.[23] Other proposed mechanisms include vascular intimal hyperplasia and altered intrarenal vascular reactivity.[23]

Renal parenchymal abnormalities were identified in 79% of participants. The commonest finding was increased renal parenchymal echogenicity, occurring as diffuse homogeneous (64%) and patchy heterogeneous (13%) patterns. Other abnormalities included loss of corticomedullary differentiation, globular kidney, and simple renal cysts. Similar sonographic findings have been reported by Obajimi *et al.*,[26] Garko *et al.*,[9] Adeyekun *et al.*,[12] Igbinedion *et al.*,[21] and Fiori *et al.*,[22] although with varying frequencies.

The prevalence of increased renal echogenicity (77%) in the present study is consistent with previous reports.[9,12,21,22,26] Increased renal echogenicity has been attributed to glomerulosclerosis associated with HIVAN, together with interstitial inflammatory infiltration and tubular cast formation, which alter normal renal architecture and increase ultrasound reflectivity.[23,27,28]

In contrast, globular kidney and loss of corticomedullary differentiation were each observed in only one participant, compared with the much higher frequencies reported by Garko *et al.*[9] and Fiori *et al.*[22] This discrepancy may reflect earlier diagnosis, prompt initiation of antiretroviral therapy, and improved treatment adherence among participants in the present study, thereby limiting progression to advanced structural renal disease. Similarly, the finding of a solitary renal cyst is comparable with that reported by Igbinedion *et al.*[21] Renal parenchymal abnormalities generally reflect progressive structural and functional renal damage associated with chronic HIV-related nephropathy.[23]

Previous studies have demonstrated strong correlations between renal size and biochemical markers of renal function, including serum creatinine, urea, and estimated glomerular filtration rate.[29] Adeyekun *et al.*[12] reported poor correlation between renal size and CD4 count but found a strong positive relationship between renal size, renal echogenicity, and serum creatinine.

In the present study, only weak positive correlations were observed between renal size, renal echogenicity, and RI. The strongest association was between right renal length and RI ($r = 0.29$, $p = 0.003$), followed by right renal volume ($r = 0.23$, $p = 0.023$), whereas correlations with right renal width and echogenicity were weaker and not statistically significant.

These findings suggest that changes in renal size and intrarenal vascular resistance may occur through partly independent pathological mechanisms in HIV-associated renal disease. Nevertheless, the significant association between right renal length and RI indicates that right renal length may serve as a useful ultrasonographic marker for monitoring renal disease progression in patients with HIV. Anatomically, the right kidney is generally smaller than the left and may demonstrate pathological changes earlier as disease progresses.

The present study also addresses an area with limited published data by evaluating the relationship between renal arterial RI, renal size, and renal parenchymal echogenicity in patients living with HIV. The findings support the potential role of Doppler ultrasonography as a valuable adjunct in the early detection and monitoring of HIV-related renal involvement.

CONCLUSION

Kidney ultrasonography in patients living with HIV demonstrated a wide spectrum of abnormalities, including enlarged and reduced renal size, increased renal arterial resistive index, increased renal parenchymal echogenicity with varying patterns, and occasional globular kidneys. Correlations between renal size, parenchymal echogenicity, and resistive index were generally weak, with only the association between right renal length and RI reaching statistical significance. These findings suggest that changes in renal size and intrarenal vascular resistance may occur through partly independent mechanisms in HIV-associated nephropathy.

RECOMMENDATION

Periodic renal ultrasonographic assessment, including Doppler evaluation of the renal arterial resistive index, should be incorporated into the routine care of people living with HIV to facilitate early detection, monitoring, and timely intervention for renal complications, thereby reducing progression to end-stage kidney disease.

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