Original Article

Renal Resistivity Index and its Relationship with other Markers of Renal damage in Sickle Cell Disease Patients in a Nigerian Tertiary Hospital

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ABSTRACT

Renal involvement in sickle cell disease (SCD) is common and often develops silently in early stages. Traditional markers such as proteinuria, serum creatinine and estimated glomerular filtration rate (eGFR) may not detect early renal damage. The renal resistivity index (RRI), derived from Doppler ultrasonography, offers a non-invasive means of identifying early intrarenal haemodynamic changes. The main aim was to evaluate renal resistivity index and its relationship with proteinuria and eGFR in patients with SCD attending a Nigerian tertiary health facility. It was a cross-sectional descriptive study was conducted among 313 individuals with confirmed SCD. Participants underwent renal Doppler ultrasonography to measure RRI, urinalysis and eGFR was calculated using serum creatinine. Clinical data, including blood transfusion, bone pain crises, and hospitalisations in the past year, were recorded. Associations were analysed using logistic regression, with statistical significance set at $p < 0.05$. The results are as follows: Of the participants, 67.1% had elevated RRI (≥0.7), while 11.0% had reduced eGFR (<60 mL/min/1.73 m²). An inverse but non-significant correlation was observed between RRI and eGFR ($r = –0.14$, $p = 0.812$). A significant association was found between elevated RRI and history of blood transfusion in the past year (OR = 1.682; 95% CI: 1.005–2.816; $p = 0.047$). No significant associations were observed between RRI and bone pain crises, hospitalisation, or proteinuria. In conclusion, Elevated RRI is common in SCD patients and may reflect early renal vascular changes not detectable by eGFR alone. Its association with blood transfusion suggests that RRI may serve as an early marker of disease severity. Renal Doppler ultrasonography could be integrated into routine monitoring of SCD patients for early detection of nephropathy.

Keywords: Doppler eGFR, Nigeria, Renal Resistivity Index, Sickle Cell Disease, Ultrasound, Zaria,

INTRODUCTION

Sickle cell disease (SCD) is a hereditary haemoglobinopathy characterised by the presence of abnormal sickle-shaped red blood cells that result in recurrent vaso-occlusion, chronic haemolytic anaemia, and multi-organ complications. It is of a significant public health concern in sub-Saharan Africa, with Nigeria bearing the highest global burden of the disease [1,2]. The disease affects approximately 2–3% of the Nigerian population, contributing to high childhood morbidity and mortality if not appropriately managed [2,3].

Renal involvement in SCD—commonly referred to as sickle cell nephropathy—is well recognised and ranges from early manifestations such as hyposthenuria and hyperfiltration to advanced

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complications including proteinuria, chronic kidney disease (CKD), and end-stage renal disease (ESRD) [4,5]. Studies in Nigeria have reported high rates of microalbuminuria, reduced creatinine clearance, and overt proteinuria even among apparently healthy individuals with SCD, suggesting early onset of renal injury [4–6].

While serum creatinine and eGFR are commonly used to evaluate renal function, these measures may not be sufficiently sensitive to detect early renal damage in SCD, particularly in individuals with low muscle mass or compensatory hyperfiltration [5]. Renal Doppler ultrasonography, particularly the measurement of renal resistivity index (RRI), offers a non-invasive method to assess intrarenal vascular resistance and detect subclinical renal changes [7]. A study by Okoye et al. in Lagos showed that renal Doppler assessment could reveal early signs of renal dysfunction in children with SCD, even in the absence of abnormal laboratory parameters [8].

Despite growing interest in the utility of RRI in detecting early renal involvement, data from Nigeria remain limited. This study, therefore, aims to evaluate the renal resistivity index and its relationship with eGFR and other markers of renal damage among individuals with SCD in a Nigerian tertiary health facility. Improved understanding of renal haemodynamics in this population may help guide timely interventions to mitigate progression to CKD.

MATERIALS AND METHODS

This was a cross-sectional descriptive study conducted at Ahmadu Bello University Teaching Hospital (ABUTH) Zaria, a tertiary health facility in Nigeria. The study aimed at assessing Renal Resistivity Index (RRI) using Doppler ultrasonography and evaluated its relationship with estimated proteinuria, glomerular filtration rate (eGFR) and other clinical markers of severity in individuals with sickle cell disease (SCD).

Study Population and Sampling

A total of 313 participants diagnosed with SCD, confirmed by haemoglobin electrophoresis, were consecutively recruited from the sickle cell clinic and haematology day-care unit between March to July 2023. Inclusion criteria were patients aged 5 years and above with confirmed HbSS, HbSS+F, or HbSC genotypes who provided informed consent (or assent where applicable). Individuals with known structural renal anomalies, acute illness, or ongoing treatment for renal disease were excluded.

Data Collection

Demographic and clinical data were obtained using a structured interviewer-administered questionnaire and review of medical records. Variables collected included age, sex, haemoglobin genotype, frequency of bone pain crises, history of blood transfusion, and hospitalisations in the past year.

Renal Doppler Ultrasonography

All participants underwent renal Doppler ultrasonography using a standardized protocol. The RRI was measured using a convex transducer (3.5–5 MHz), with values obtained from the segmental arteries of both kidneys. The RRI was calculated using the formula:
RRI = (Peak Systolic Velocity−End Diastolic Velocity)/Peak Systolic Velocity
An RRI value ≥0.7 was considered elevated, indicating increased renal vascular resistance.

Assessment of Renal Function

Renal function was assessed using the estimated glomerular filtration rate (eGFR), calculated from serum creatinine levels using the appropriate age-specific equations (i.e., Schwartz formula for children[9] and CKD-EPI for adults[10]). An eGFR <60 mL/min/1.73 m² was classified as reduced kidney function.

Data Analysis

Data were analysed using Statistical Package for the Social Science (SPSS) version 25. Descriptive statistics were used to summarise demographic and clinical characteristics. Continuous variables were presented as medians with interquartile ranges (IQR), while categorical variables were expressed as frequencies and percentages. Correlation between RRI and eGFR was assessed using Pearson's correlation coefficient. Logistic regression was used to examine the association between elevated RRI and reduced eGFR, as well as clinical variables such

as frequency of hospitalisation, bone pain crises, and blood transfusion history. Odds ratios (OR) with 95% confidence intervals (CI) and p-values were reported. A p-value <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval for the study was obtained from the Health Research Ethics Committee of ABUTH Zaria. Informed consent was obtained from all participants or their legal guardians, and data confidentiality was ensured throughout the study.

RESULTS

A total of 313 participants were enrolled in the study. The median age of the study population was 17 years, with an interquartile range (IQR) of 9 to 25 years. The majority of participants were female, accounting for 65.0% (202 out of 311). Regarding haemoglobin genotype distribution, the predominant genotype was HbSS, observed in 289 participants (92.9%). Additionally, 7 participants (2.3%) had HbSS+F, and 15 participants (4.8%) had HbSC.

In evaluating renal function (Table 1), the Renal Resistivity Index (RRI) was found to be high (≥0.7) in 67.1% of the participants (210 individuals), while 32.9% (103 individuals) had a low RRI (<0.7). Regarding the estimated glomerular filtration rate (eGFR), 11.0% (33 participants) had values less than 60 mL/min/1.73 m², whereas 89.0% (267 participants) had eGFR values of 60 mL/min/1.73 m² or more. A weak inverse correlation was observed between RRI and eGFR, with a correlation coefficient (r^2) of -0.14; however, this was not statistically significant (p = 0.812).

Table 2 shows the association between high RRI and low eGFR yielded an odds ratio (OR) of 0.619 with a 95% confidence interval (CI) of 0.268–1.427, and a p-value of 0.257, indicating no statistically significant relationship. Proteinuria was also assessed among participants and its association with renal resistivity index (RRI) was evaluated. Among individuals with low RRI (<0.7), 90 had negative proteinuria while 13 tested positive. In contrast, among those with high RRI (≥0.7), 175 had no proteinuria and 33 tested positive. Although a higher proportion of proteinuria was observed in the high RRI group, the association was not statistically significant (Odds Ratio = 1.306; 95% Confidence Interval: 0.655–2.604; p = 0.449).

From analysis other clinical parameters (Table 2), a significant association was found between RRI and blood transfusion history. Participants who had received blood transfusions in the preceding year were more likely to have a high RRI, with an OR of 1.682 (95% CI: 1.005–2.816; p = 0.047). However, no significant associations were observed between RRI and bone pain crises or hospitalisation frequency. The odds of having a high RRI were not significantly different between participants who had fewer than three bone pain crises and those with three or more (OR = 0.915; 95% CI: 0.495–1.690; p = 0.776). Similarly, hospitalisation within the last year was not significantly associated with RRI (OR = 1.326; 95% CI: 0.820–2.114; p = 0.249).

Table 1: Frequency distribution and correlation of patients with RRI and eGFR

Parameter		Frequency	Percentage
RRI	Low (<0.7)	103	32.9
	High (≥0.7)	210	67.1
eGFR	<60	33	11.0
	≥60	267	89.0
		eGFR	RRI
eGFR	r^2	1	-0.14
	P		0.812
RRI	r^2	-0.14	1
	P	0.812	

eGFR: Estimated Glomerular Filtration Rate
RRI: Renal Resistivity Index

Table 2: Association between RRI and markers of renal damage and clinical severity of SCD

Parameters		eGFR				
		<60	≥60	Odd ratio	95% CI	P value
RRI	Low (<0.7)	8	91	0.619	0.268-1.427	0.257
	High (≥0.7)	25	176			
		Proteinuria				
		negative	positive	Odd ratio	95% CI	P value
RRI	Low (<0.7)	90	13	1.306	0.655-2.604	0.449
	High (≥0.7)	175	33			
		RRI				
		Low (<0.7)	High (≥0.7)	Odd ratio	95% CI	P value
Blood transfusion in the last 1 year	Nil	75	129	1.682	1.005-2.816	0.047
	Yes	28	81			
Bone pain crises in the last 1 year	<3	84	174	0.915	0.495-1.690	0.776
	≥3	19	36			
Frequency of hospitalisation in the last 1 year	Nil	63	114	1.326	0.820-2.114	0.249
	Yes	40	96			

DISCUSSION

This study assessed renal resistivity index (RRI) and its relationship with estimated glomerular filtration rate (eGFR) in patients with sickle cell disease (SCD) in a Nigerian tertiary health facility. A substantial proportion of participants (67.1%) exhibited elevated RRI (≥0.7), while 11.0% had reduced eGFR (<60 mL/min/1.73 m²). Although an inverse correlation was noted between RRI and eGFR, it was not statistically significant. In addition, blood transfusion in the past year was significantly associated with elevated RRI, while bone pain crises, hospitalisation frequency, and proteinuria were not.

The high prevalence of elevated RRI in this population aligns with the growing recognition of early renal involvement in SCD, which often begins during childhood and remains asymptomatic in its initial stages. Nigerian studies have consistently shown that renal complications, including glomerular hyperfiltration, microalbuminuria, and declining eGFR, are prevalent among individuals with SCD, sometimes even in steady state [1–3]. Our findings support the use of renal Doppler ultrasonography as a non-invasive tool to detect early renal vascular changes before overt renal dysfunction becomes clinically evident.

The absence of a statistically significant correlation between RRI and eGFR may be due to the predominance of early-stage renal changes among participants. As reported by Nnaji et al. in Enugu, a large proportion of adults with SCD had normal serum creatinine despite underlying glomerular damage detectable via proteinuria or reduced creatinine clearance [2]. Similarly, Ijoma et al. found that proteinuria could be present in apparently healthy SCD patients with otherwise preserved renal function [3]. Thus, RRI might be identifying early vascular resistance changes not yet reflected in eGFR values, particularly in patients with hyperfiltration.

Of clinical interest is the significant association between elevated RRI and blood transfusion within the past year. Frequent transfusions may indicate a more severe disease phenotype or recurrent vaso-occlusive crises, both of which are implicated in renal microvascular injury. Studies in Nigeria have shown that recurrent anaemic crises and blood transfusion are associated with increased risk of renal impairment, possibly due to iron overload, oxidative stress, or chronic inflammation [4,5]. This association suggests that transfused patients may require closer renal monitoring with tools like Doppler ultrasonography.

Contrary to expectation, no statistically significant association was observed between RRI and proteinuria, although a higher proportion of participants with elevated RRI had proteinuria. While proteinuria is a recognised early marker of sickle cell nephropathy, its sensitivity in detecting renal damage may be limited in cross-sectional

studies due to transient increases unrelated to chronic renal injury. Okafor et al. noted that albuminuria in adult SCD patients may occur even in the absence of significant structural renal disease, and may fluctuate with hydration status or infection [6]. Furthermore, Okoye et al. found that while renal Doppler could detect early dysfunction, its correlation with urinary protein excretion was inconsistent, underscoring the complexity of interpreting RRI in isolation [7].

No significant relationships were found between RRI and frequency of bone pain crises or hospitalisation. This may suggest that renal impairment in SCD evolves through mechanisms independent of acute pain episodes. Akinyanju previously emphasised that organ damage in SCD is often progressive and subclinical, unrelated to the frequency of overt crises [8]. Our findings reinforce this view and advocate for routine renal monitoring regardless of crisis frequency.

The clinical implication of our findings is that Doppler ultrasonography can detect renal haemodynamic abnormalities before overt dysfunction becomes measurable via serum creatinine or eGFR. This is particularly valuable in low-resource settings like Nigeria, where renal biopsy and advanced biomarkers are not routinely available. Integrating this tool into SCD clinics could improve early detection and targeted management of renal complications.

Limitations

This study is limited by its cross-sectional design, which precludes causal inference. Additionally, reliance on eGFR and serum creatinine may underestimate early renal dysfunction in SCD due to hyperfiltration and reduced muscle mass. The study did not include biomarkers such as cystatin C or 24-hour urine protein, which could have strengthened renal assessment. Longitudinal follow-up is needed to determine the prognostic value of RRI in predicting progression to chronic kidney disease (CKD).

CONCLUSION

Elevated RRI is common among individuals with SCD in this Nigerian cohort and may reflect early intrarenal haemodynamic changes. Its association with blood transfusion history underscores the potential of RRI as an early marker of disease severity.

Recommendation

Renal Doppler ultrasonography should be considered for routine screening in SCD patients, even in the absence of overt renal impairment.

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