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Renal Length Discrepancy on Ultrasound Predicts Abnormal Kidney Scan in Children

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ABSTRACT

Background and Aim: A renal length discrepancy (RLD) of more than 10 mm by ultrasound (US) is accepted as a potential indicator of an underlying renal pathology. This study aimed to determine the predictive value of RLD detected by US for identifying abnormal findings on kidney radioisotope scans, specifically dimercaptosuccinic acid (DMSA) scans, in children.

Methods: The study involved a prospective data analysis of children who underwent renal US and DMSA scans. The positive and negative predictive values for renal RLD were calculated for values ranging from 6 to >10 mm.

Results: The left kidney was longer in 51.4% of cases, whereas the right kidney was longer in 35.7%; their lengths were equal in 12.9%. The results indicated that a specific degree of RLD in the US could predict abnormalities on DMSA scans with varying degrees of accuracy, depending on the age group. The cutoff ultrasound RLDs that resulted in the best specificity and sensitivity for an abnormality on DMSA scan were ≥5 mm in children whose right kidney was longer than the left, and ≥6 mm for children whose left kidney was longer than the right (specificity of 88% and 84%, respectively).

Conclusion: Renal length discrepancy observed via ultrasound can be a valuable, non-invasive tool in predicting renal abnormalities detectable by DMSA scan in children, aiding clinical decision-making and potentially reducing the need for more invasive procedures. However, ultrasound has moderate sensitivity and reasonable specificity for predicting positive DMSA scan results and detecting high-grade vesicoureteral reflux (VUR).

Keywords: Dimercaptosuccinic acid (DMSA) scan, Ultrasonography, Renal length discrepancy (RLD), pediatrics

Introduction

Renal length discrepancy (RLD) observed through ultrasound (US) imaging has long been considered a potential indicator of underlying renal pathology in pediatric patients. US, being a non-invasive and widely accessible diagnostic tool, is frequently employed in the evaluation of children presenting with urinary tract infections (UTIs), congenital anomalies, or suspected renal dysfunction. A difference in renal length between the right and left kidneys may reflect structural or functional abnormalities that warrant further investigation. Despite its everyday clinical use, the precise predictive value of

RLD for identifying abnormal findings on kidney radioisotope scans, such as dimercaptosuccinic acid (DMSA) scans, remains to be established in the pediatric population [1, 2].

Kidney radioisotope scans, particularly DMSA scintigraphy, provide detailed information regarding renal cortical integrity, function, and scarring. These are crucial for diagnosing pyelonephritis, congenital scarring, and differential renal function impairment in children. These scans are considered a gold standard in detecting renal cortical defects and evaluating the extent of renal damage. Nonetheless, it is impractical to perform DMSA scans universally in all pediatric patients suspected of having renal abnormalities due to considerations, such as radiation exposure and cost. Therefore, identifying reliable and easily obtainable US parameters, such as RLD, that can predict abnormal DMSA scan results could improve diagnostic efficiency and guide clinical decision-making [3].

Previous studies have suggested that an RLD of more than 10 mm could predict renal pathology in adults and children, with varying cutoff values based on age and the kidney side predominance. For instance, a right kidney longer than the left by ≥6 to 7 mm has demonstrated high positive predictive value (PPV) for abnormal DMSA findings in pediatric cohorts, while a left kidney longer than the right may require a larger discrepancy cutoff [2]. However, these studies show considerable heterogeneity in their methodologies and population characteristics, and validated, context-specific cutoff values for different pediatric subpopulations are still lacking. Discerning such cutoffs is essential for accurately predicting renal cortical defects and differential function impairments without over-reliance on radionuclide imaging. This significant need to validate these thresholds and their applicability across different age groups and clinical contexts justifies the present investigation [1, 2].

This study evaluated the predictive value of RLD on US for abnormal DMSA findings in children.

Materials and Methods

This retrospective cross-sectional study investigated the predictive value of renal RLD measured by US in detecting abnormal findings on kidney radioisotope scans, specifically renal scarring, in a pediatric population. It involved children referred for evaluation of renal pathology based on clinical indications, including UTI, suspected congenital renal abnormalities, or other signs of renal dysfunction.

Study population

The study was conducted retrospectively at a tertiary pediatric nephrology center, analyzing data collected from children referred for renal US and kidney radioisotope scans during the study period. The inclusion criteria involved pediatric patients between 6 months and 16 years (6 to 192 months) who underwent renal US and radioisotope scan within a clinically relevant timeframe, typically within one month to ensure contemporaneous evaluation of renal anatomy and function. A maximum interval of six months was allowed in a small number of cases where clinical stability was documented, as longer intervals could allow for the evolution of renal pathology and confound the correlation between anatomical and functional assessments. The study population was selected to reflect routine clinical practice scenarios where morphological and functional renal assessment was indicated.

Exclusion criteria were applied to ensure the homogeneity and relevance of the sample. These included: 1) transplant kidneys; 2) duration of more than 6 month between US and renal scan; 3) significant renal parenchymal deformation, masses, cysts, abscesses, horseshoe kidney, cases of AP aspect of pelvis diameters more than 10 mm, affecting cortical morphology and renal contour; and 4) incomplete imaging or missing clinical data that would compromise measurement reliability or statistical analysis.

Demographic and clinical data were collated from electronic medical records, including age at the time of imaging, sex, clinical indications for imaging, and any relevant past medical or surgical history. The final sample included 140 children who met all criteria and had complete datasets for US renal length measurements and radioisotope scan findings.

Ultrasound imaging procedures

Renal US examinations were performed by an experienced pediatric sonographer using high-resolution ultrasound machines equipped with linear and curvilinear transducers appropriate for pediatric imaging. Equipment specifications were standardized to ensure image quality and comparability across examinations. The ultrasound machines used were modern systems with frequencies ranging from 6 to 12 MHz for linear probes and 3 to 6 MHz for curvilinear probes, optimized for detailed renal visualization in children of all ages.

US imaging followed a standardized protocol to measure maximal renal length, defined as the kidney's most significant pole-to-pole dimension. The child was positioned supine or prone depending on cooperation and ease of imaging, as literature indicates that position can marginally affect renal lengths, but standardized approaches reduce variability. The kidneys were first identified in longitudinal sections, with the probe aligned along the kidney's long axis.

Renal length was measured from the upper (cranial) to the lower (caudal) renal poles through the renal pelvis region, perpendicular to the kidney's hilum. Acoustic landmarks and sonographic characteristics were used to delineate the renal cortex, medulla, and sinus boundary to ensure accurate length determination. Both kidneys were measured during the same session under identical machine presets and ambient conditions.

Multiple measurements were taken when possible, and the most considerable value was used for analysis. Furthermore, detecting any renal contour irregularities, abnormalities of the pelvicalyceal system, and cortical echogenicity were documented as additional sonographic parameters. While a single experienced sonographer performed the measurements to minimize inter-observer variability, intra-observer reliability was not formally assessed, which is acknowledged as a study limitation.

RLD was calculated as the absolute difference in length between the right and left kidneys measured in mm. The larger kidney side was additionally noted to categorize patients into left kidney dominant or right kidney dominant groups, given the known physiological variation in kidney sizes and asymmetries across individuals.

Kidney radioisotope scan procedures

Kidney radioisotope scans were utilized to detect renal scarring and assess differential renal function, serving as the functional reference standard against which RLD's predictive value was evaluated. The renal scintigraphy was performed using Technetium-99 m-labeled DMSA (Tc-99m DMSA) radionuclide, which preferentially accumulates in the renal cortical tissue, allowing for detailed visualization of renal cortical integrity.

The scanning protocol followed international pediatric nuclear medicine guidelines to minimize radiation exposure and maximize diagnostic accuracy. Patients were injected intravenously with a weight-adjusted dose of Tc-99m DMSA (typically 0.05 mCi/kg up to a total maximum dose limit for children). Before image acquisition, the radiotracer was allowed sufficient uptake time, usually between 2 and 4 hours post-injection.

Static planar images of the kidneys were acquired using gamma cameras equipped with high-resolution pinhole collimators to enhance cortical detail and facilitate precise identification of cortical defects. Images were obtained in posterior and oblique projections. For patients with difficulty in maintaining position, sedation was sometimes employed under anesthetic supervision following institutional protocols.

Renal scarring was defined as focal or multifocal areas of decreased radiotracer uptake (photopenic defects) on the DMSA scan, indicative of cortical loss, fibrosis, or prior pyelonephritic damage. The presence, location (right or left kidney), and extent of renal scarring were assessed by nuclear medicine physicians blinded to the US findings. Consensus reading was performed in equivocal cases to ensure diagnostic accuracy.

Additional functional parameters were recorded, including differential renal function expressed as a percentage uptake for each kidney. A significant differential function impairment was defined as <45% for either kidney, a commonly used cutoff in clinical practice [3]. However, the primary outcome for this study was the dichotomous presence or absence of renal cortical scarring.

Data collection and management

All US and nuclear medicine images were reviewed retrospectively by qualified radiologists and nuclear medicine specialists, respectively, under the oversight of the principal investigator. Data on renal lengths, discrepancies, and radionuclide scan outcomes were extracted from imaging reports and verified by direct review of archived images when necessary.

Demographic details, including age and sex, were obtained from the hospital electronic health records. All data were anonymized and coded to maintain patient confidentiality, in accordance with institutional review board regulations.

Data entry was performed using standardized case report forms, which were entered into a secure database designed for the study. Quality control checks were implemented to identify missing or inconsistent data and to verify measurement accuracy.

The study followed the Standards for reporting diagnostic accuracy studies (STARD) 2015 reporting guideline [4].

Statistical analysis

Descriptive statistics were used to summarize the baseline demographic and clinical characteristics of the study population. Continuous variables, including age and renal lengths, were reported as Mean±SD or medians with interquartile ranges (IQR), depending on distribution assessed by the Shapiro-Wilk test. Categorical variables, such as sex and the presence of scarring, were expressed as frequencies and percentages.

Comparisons between groups (children with and without renal scarring) were performed using the student's t-test or Mann-Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate. The normality of renal length measurements and RLD was assessed to justify parametric or nonparametric methods.

The primary analytic focus was on evaluating the predictive performance of RLD for detecting renal scarring identified by kidney radioisotope scans. Receiver operating characteristic (ROC) curve analysis was utilized to determine the optimal RLD cutoff value that best discriminates between scarring presence and absence by maximizing the Youden Index (sensitivity+specificity–1).

Diagnostic accuracy metrics, including sensitivity, specificity, PPV, negative predictive value (NPV), and the area under the curve (AUC) with 95% confidence intervals (CI), were calculated for the overall cohort and relevant subgroups stratified by kidney dominance (left vs right) and age groups (≤48 months vs >48 months). The decision threshold and Youden's j index were used to compare various levels of RLD to determine the best cutoff for RLD's predictive utility in subgroups.

Additional subgroup analyses investigated the relationship between RLD and scarring prevalence stratified by sex to understand demographic influences. For continuous variables, correlation coefficients were calculated to assess associations between RLD magnitude and the extent of renal scarring or differential renal function, when available.

All analyses were conducted using SPSS software, version 26 (IBM Corp., Armonk, NY) and R statistical environment version 4.2. Significance was set at a two-sided P<0.05. Missing data were handled by listwise deletion, given the completeness of key US and nuclear imaging datasets.

Ethical considerations

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and received approval from the National Committee for Ethics in Biomedical Research [5]. Because the study was retrospective and non-interventional, informed consent was waived. Patient privacy and data confidentiality were rigorously maintained throughout the study, with data anonymization before analysis.

Results

Demographic and clinical characteristics

The study included 140 children aged 6 to 180 months (69.3% were aged ≤48 months), with a higher proportion of females (68.6%). (Figure 1 and Table 1). The mean renal lengths were 69.41±13.82 mm for the right kidney and 70.52±16.19 mm for the left kidney. The left kidney was longer in 51.4% of cases, the right kidney in 35.7%, and both kidneys were equal in length in 12.9% (Table 1).

Renal scarring prevalence

Renal scarring was detected in 64 children (45.7%). Among the children with scarring, 29 (45.3%) were male and 35(54.7%) were female. Similarly, among those with scarring, 36(56.3%) were ≤48 months and 28(43.8%) were >48 months. Scarring was significantly more common in the left kidney (30.7%) than the right (22.1%). A significantly higher proportion of males had scarring compared to females (29/44, 65.9% vs 35/96, 36.5%; P=0.001). Scarring was also more frequent in children >48 months (28/43, 65.1%) compared to those ≤48 months (36/97, 37.1%; P=0.002) (Table 2).

Correlation between the demographic and RLD and renal scarring status

Using logistic regression, RLD was a significant independent predictor of scar development (OR=1.218; 95% CI, 1.102%, 1.347%; P<0.0001), with each unit increase in RLD associated with 22% higher odds of scar. Neither age nor sex showed significant associations with scar status in this cohort of 140 patients. The overall model significantly improved prediction over chance alone (G^2=49.88, P<0.0001) (Table 3).

Table 1. Baseline characteristics of study participants

Variables	Mean±SD (Min-max)/No. (%)
Age (m)	42.41±36.3 (6–192)
Sex (Male: Female)	44(31.4):96(68.6)
Age group (≤48 m)	97(69.3)
Age group (>48 m)	43(30.7)
Right kidney length (mm)	69.41±13.82 (45–108)
Left kidney length (mm)	70.52±16.19 (29–122)
Larger kidney (Left: Right)	72(51.4):50(35.7)

RLD and scarring

The mean RLD was significantly higher in children with scarring (13.58±13.18 mm) compared to those without (3.29±3.07 mm) (P<0.001). The wide standard deviations indicated substantial variability in RLD within groups. This trend persisted across sex and age subgroups (Table 4).

Predictive performance of RLD

The ROC curve showed an AUC of 0.78; 95% CI, 0.7%, 0.85% (Table 5, Figure 2). Reporting on the increase in discrimination using the ROC curve and an AUC of 0.78 is relevant for obtaining insight into the incremental value of RLD and defining the prediction model [6]. However, defining a decision threshold or cutoff, i.e. representing a prediction model as a prediction rule, is crucial to using the prediction test for decision-making in clinical practice [7, 8]. The optimal threshold value or cutoff point for RLD was determined to be 6 mm as shown in the decision threshold curve (Youden's J index =0.47, t^*=6) (Figure 3 and Table 5). At this point, the estimated specificity and sensitivity were 0.895 and 0.578, respectively. Subgroup analyses revealed generally consistent performance but with two notable variations (Table 5). For right kidney dominant cases, a lower cutoff (≥5 mm) yielded the highest sensitivity (73%) and AUC (0.85) (Figures 4 and 5). Conversely, in children older than 48 months, a substantially higher cutoff (≥10 mm) was required to achieve perfect specificity (100%), albeit with reduced sensitivity (Figures 6 and 7).

Discussion

The present study investigated the predictive value of RLD measured by US in identifying renal scarring detected on kidney radioisotope scans in a pediatric population. Our findings demonstrated that RLD is significantly higher in children with renal scarring than in those without, with an optimal cutoff of ≥6 mm providing moderate sensitivity and high specificity overall. This relationship persisted across various subgroups defined by sex, kidney dominance, and age, underscoring the clinical utility of RLD as a non-invasive triage parameter to predict renal cortical damage.

Table 2. Distribution of renal scarring by sex and age group

Variables		No. (%)		P
		Without Scar	With Scar	
Sex	Male	15(34.1)	29(65.9)	0.001
	Female	61(63.5)	35(36.5)	
Age (m)	≤48	61(62.9)	36(37.1)	0.002
	>48	15(34.9)	28(65.1)	

Table 3. Association between clinical variables and scar development

Factors		Mean±SD/No.	Adjusted OR (95% CI)	P
Age (m)		41.9±36.6	1.011 (0.999, 1.024)	0.077 (NS)
Sex	Male	44	1.00	-
	Female	96	0.665 (0.262, 1.686)	0.390 (NS)
RLD (mm)		7.7±10.2	1.218 (1.102, 1.347)	<0.001

Model fit: $\chi^2(3) = 49.88$, $P<0.0001$; N=140.

Abbreviations: RLD: Renal length discrepancy; OR: Odds ratio; CI: Confidence interval; NS: Non-significant.

Table 4. Mean RLD in children with and without scarring

Subgroups	Mean±SD (mm)		P
	Without Scar	With Scar	
Overall	3.29±3.07	13.58±13.18	<0.001
Male	4.67±4.82	19.17±15.48	0.003
Female	2.95±2.39	7.66±7.26	0.003
≤48 months	3.05±2.96	12.06±12.57	<0.001
>48 months	4.27±3.36	13.93±13.64	0.006

RLD: Renal length discrepancy.

Interpretation of the major findings

Demographically, our cohort consisted predominantly of younger children (≤48 months) and females, with mean renal lengths approximating 70 mm on both sides, consistent with normative data reported in pediatric populations [9]. The observed prevalence of renal scarring was substantial, found in nearly half of our participants, and notably more common in left kidneys. Although females were more prevalent in the sample, a significantly higher proportion of males had scarring (65.9% of males vs 36.5% of females), which aligns with previous research suggesting male sex as a risk factor or indicator for more severe renal parenchymal damage [10]. Additionally, scarring was more frequent among children older than 48 months, (65.1% in older children vs 37.1% in younger children), signaling potential cumulative injury or delayed diagnosis in this age group. These demographic findings highlight the importance of considering age and sex when interpreting correlations between RLD and renal scarring.

Table 5. Diagnostic accuracy of RLD for predicting renal scarring

Subgroups	Cutoff value (mm)	% (95% CI)		Youden's Index	AUC (95% CI)
		Sensitivity	Specificity		
Overall	≥6	58 (45, 70)	90 (82, 95)	0.473	0.78 (0.7, 0.85)
Left kidney dominant	≥6	59 (44, 73)	84 (71, 92)	0.430	0.73 (0.62, 0.84)
Right kidney dominant	≥5	73 (52, 88)	88 (71, 96)	0.606	0.85 (0.74, 0.96)
Age: ≤48 months	≥6	53 (38, 67)	93 (84, 98)	0.51	0.76 (0.66, 0.85)
Age: >48 months	≥10	46 (29, 65)	100 (78, 100)	0.54	0.77 (0.64, 0.9)

RLD: Renal length discrepancy; CI: Confidence interval.

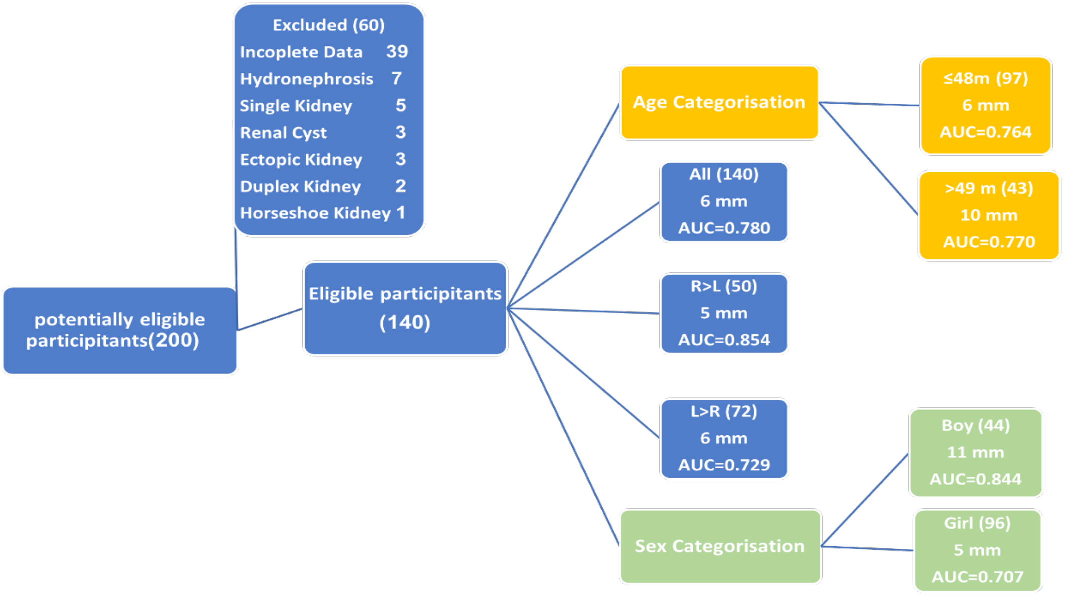

Figure 1. STARD flowchart to evaluate the prognostic value of RLD with the DMSA renal scan

Abbreviations: STARD: Standards for reporting diagnostic accuracy; AUC: Area under curve; R>L: Right kidney dominant; L>R: Left kidney dominant; DMSA: Dimercaptosuccinic acid.

The core observation that children with renal scarring had significantly greater mean RLD (13.58±13.18 mm) than those without (3.29±3.07 mm) is pivotal. Despite substantial variability in RLD values (as indicated by the wide standard deviations), this significant difference reinforces that RLD reflects differential renal growth or atrophy secondary to scarring or functional impairment. Importantly, subgroup analyses confirmed this association across males and females, as well as younger and older children, thereby generalizing the utility of RLD irrespective of demographic variations. Male children with scarring exhibited the highest mean RLD, more

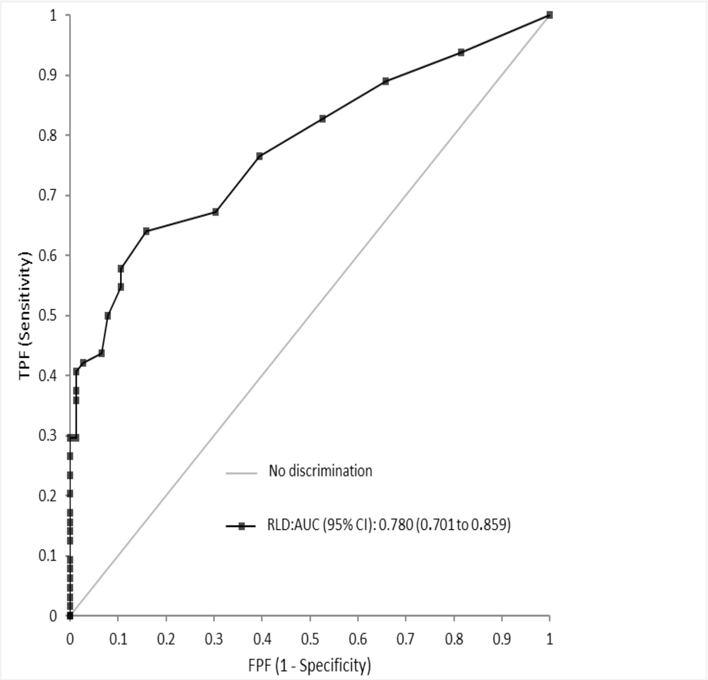

Figure 2. ROC curve for different levels of RLD in patients with kidney scars

Abbreviations: ROC: Receiver operating characteristic; RLD: Renal length discrepancy; TPF: True positive fraction; FPF: False positive fractio; AUC: Area under curve; CI: Confidence interval.

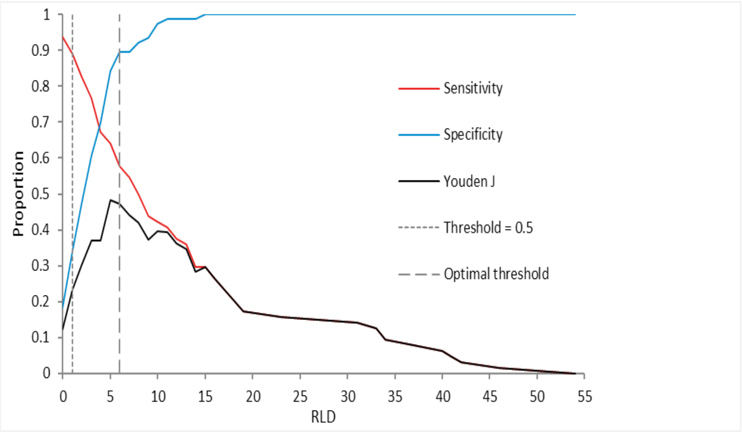

Figure 3. Decision threshold curve for optimal threshold level of RLD in patients with kidney scars

RLD: Renal length discrepancy.

than twice that of females with scarring, suggesting potential sex-linked pathophysiological differences in response to renal injury or compensatory mechanisms.

Comparison with previous studies and existing literature

Our findings corroborate and extend earlier reports wherein RLD greater than established thresholds predicted abnormalities on 99mTc-DMSA renal scans in children. Khazaei et al. identified cutoffs of ≥7 mm when the right kidney was longer and ≥10 mm when the left kidney was longer as predictive of DMSA abnormalities with high PPVs [2]. Similarly, our study suggests cutoffs of ≥6 mm for the left kidney dominant group and ≥5 mm for the right kidney dominant group, illustrating side-dependent thresholds. The slightly lower cutoff for the right kidney dominant subgroup in our study compared to Khazaei et al. (≥5 mm vs ≥7 mm) may reflect population-specific characteristics, such as the younger mean age and different clinical indications in our cohort, or methodological variations in US measurement protocols. Still, the overall superior specificity in both groups affirms RLD's utility as a discriminative diagnostic measure [2].

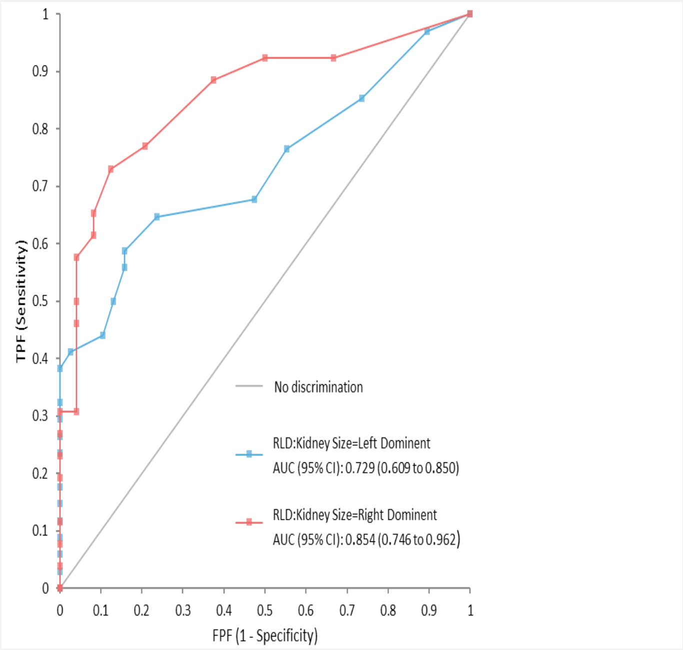

Figure 4. ROC curve for different levels of RLD categorized by right or left kidney dominance in patients with kidney scars

Abbreviations: ROC: Receiver operating characteristic; RLD: Renal length discrepancy; TPF: True positive fraction; FPF: False positive fraction; AUC: Area under curve; CI: Confidence interval.

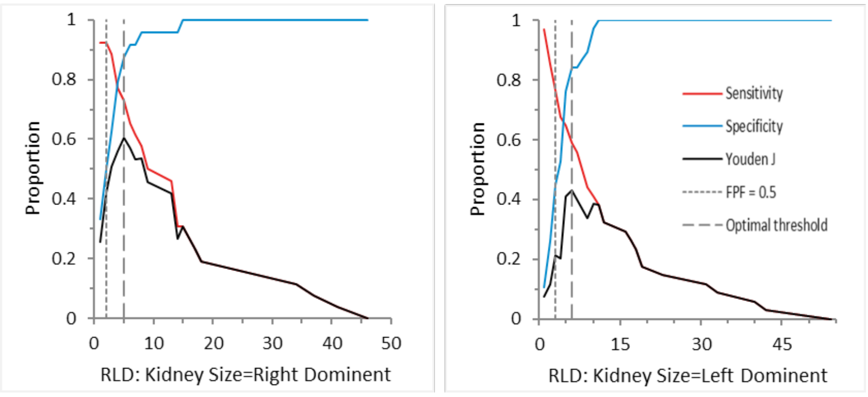

Figure 5. Decision threshold curve for optimal threshold level of RLD categorized by right or left kidney dominance in patients with kidney scars

RLD: Renal length discrepancy.

Age-stratified analyses support previously observed slower renal growth after 48 months and highlight that younger children may show significant renal length differences at a lower threshold than older children, who require a higher cutoff (≥10 mm) to predict scarring with perfect specificity [2]. This nuanced approach to cutoff selection prevents overestimation of pathology in younger patients with normal developmental renal size disparities and reduces false positives in older children. The sensitivity and specificity values observed in this study for different subgroups (sensitivities ranging from 46% to 73%, specificities from 84% to 100%) align with the diagnostic strength reported in comparable pediatric cohorts and emphasize that RLD should ideally be integrated with additional clinical and imaging findings for comprehensive evaluation [11, 12].

However, despite RLD's evident predictive power for scarring, the moderate sensitivity values indicate that this parameter alone may miss a proportion of renal

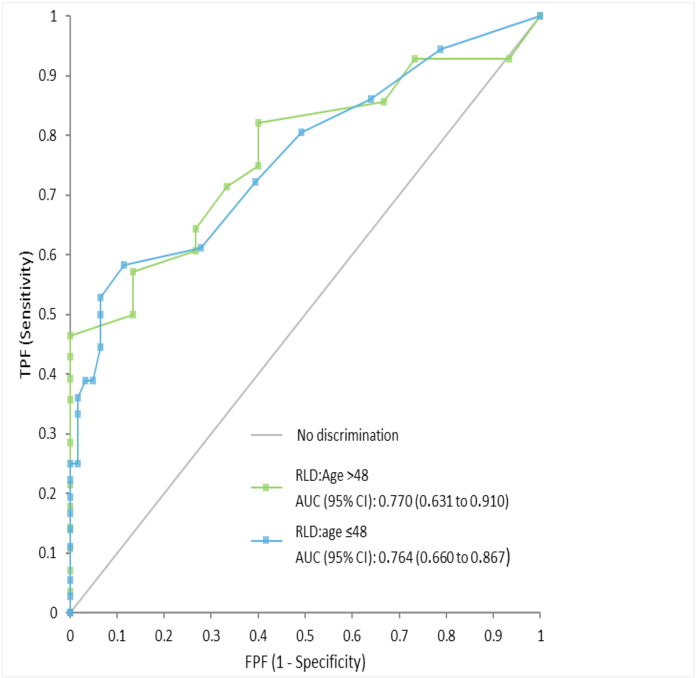

Figure 6. ROC curve for different levels of RLD categorized by age in patients with kidney scars

Abbreviations: ROC: Receiver operating characteristic; RLD: Renal length discrepancy; TPF: True positive fraction; FPF: False positive fraction; AUC: Area under curve; CI: Confidence interval.

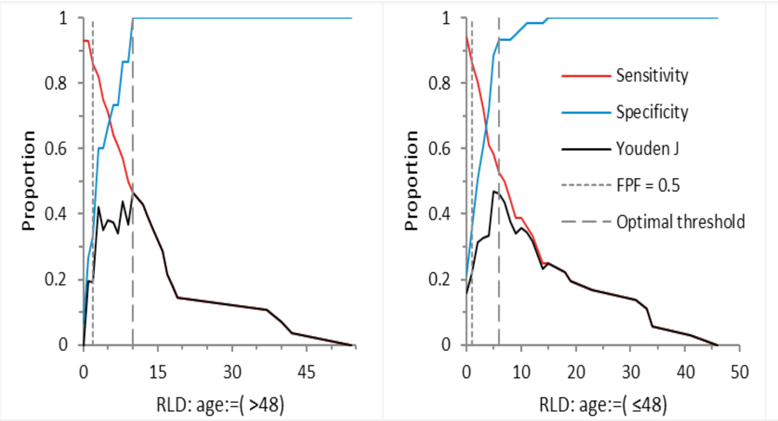

Figure 7. Decision threshold curve for optimal threshold level of RLD categorized by age in patients with kidney scars

RLD: Renal length discrepancy.

scars, suggesting the complementary role of other US parameters or investigative modalities. Previous studies have documented the superior accuracy of peak systolic velocity and other duplex sonographic parameters over simple length measurements for assessing renal pathology [13]. Furthermore, conventional renal US has shown limited sensitivity for direct scar detection compared to DMSA scintigraphy, with sensitivities as low as 5.2% in some cohorts, underscoring RLD as an indirect but valuable surrogate marker rather than a definitive diagnostic tool [14, 15].

Clinical implications and relevance

Given the considerable specificity observed, an RLD surpassing the recommended cutoff values can confidently identify children likely harboring renal scarring, thus prioritizing them for further confirmatory investigations, like DMSA scans. In a proposed clinical pathway, children with an RLD ≥6 mm (or ≥5 mm if right kidney is dominant) could be selectively referred for a DMSA scan, especially in the context of a history of UTI or other risk factors. This targeted approach is particularly valuable in resource-limited settings, where minimizing radiation exposure and cost is imperative. For younger children who more commonly undergo diagnostic imaging due to acute infections and renal insults, adopting a 6 mm cutoff for RLD can improve screening accuracy by balancing sensitivity and specificity, reducing unnecessary invasive procedures. In contrast, the stricter threshold (≥10 mm) with maximum specificity for older children can appropriately exclude those unlikely to have significant scarring, limiting overtreatment or overtesting [16].

The correlation between higher RLD and renal scarring provides insight into underlying pathophysiological processes. Renal scarring commonly results in parenchymal loss and compensatory hypertrophy of the contralateral kidney, leading to length discrepancies detectable on US [17]. Monitoring RLD longitudinally may offer a noninvasive means to track disease progression or response to therapeutic interventions, offering clinicians a practical biomarker of renal health. Furthermore, awareness of demographic influences, such as sex and age on scarring prevalence and the magnitude of RLD can guide individualized patient assessment and follow-up strategies to attenuate the risk of chronic kidney disease (CKD) development [18].

Consideration of study limitations and potential biases

This study’s retrospective nature and relatively small sample size may influence the generalizability of the findings. Selection bias may be present as participants included were those who underwent both US and DMSA scans, potentially representing patients with higher clinical suspicion of renal injury. This can inflate prevalence estimates and affect sensitivity and specificity calculations for RLD cutoffs [19, 20]. Moreover, despite standardized protocols, inherent inter-operator variability was minimized by using a single sonographer; however, the lack of a formal intra-observer reliability assessment could contribute to measurement error and impact RLD accuracy. Longitudinal studies with larger cohorts and multicenter designs are warranted to validate and refine RLD cutoff thresholds.

Another important consideration is the lack of direct comparison with other US indices indicative of renal damage, such as cortical thickness, parenchymal echogenicity, or duplex Doppler flow parameters. Integrating these may enhance predictive capabilities beyond RLD alone [13, 21]. Finally, while DMSA scans remain the reference for detecting cortical scarring, their availability and radiation exposure necessitate cautious interpretation of US surrogates in clinical practice.

Recommendations for future research

Further prospective studies should examine the longitudinal relationship between RLD changes and progression or regression of renal scarring, ideally incorporating functional outcomes, such as glomerular filtration rates and blood pressure measurements to connect imaging findings to clinical prognosis. Investigations into combining RLD with other sonographic biomarkers or machine learning algorithms may improve diagnostic precision and allow automated risk stratification in pediatric populations. In addition, evaluating the impact of early detection using RLD on therapeutic interventions and long-term renal outcomes could solidify its role in clinical decision-making.

While the observed sex differences in scarring prevalence and RLD magnitude suggest potential biological mechanisms, the underlying reasons remain unclear and warrant further investigation through targeted molecular and genetic studies. Also, addressing methodological standardization in US measurements across centers will enhance reproducibility and clinical applicability.

Conclusion

In conclusion, this study substantiates RLD measured by US as a clinically practical triage tool for identified renal scarring on kidney radioisotope scans in children. Establishing distinct cutoff values based on kidney dominance and age enhances the precision of RLD as a screening tool for renal pathology. While RLD alone cannot replace the comprehensive evaluation, including nuclear imaging, it is a valuable, non-invasive parameter that can guide the judicious use of further diagnostic investigations. Integrating RLD into pediatric renal imaging protocols can improve early detection and management of renal scarring, ultimately reducing the burden of CKD in affected children.

The findings advocate for careful consideration of patient demographics, methodological rigor, and complementary imaging features to optimize the utility of US in pediatric nephrology. Future research should assess the accuracy and predictive power, facilitating better clinical outcomes through timely diagnosis and intervention.

Ethical Considerations

Compliance with ethical guidelines

This research was approved by the Research Ethics Committee of Mashhad Branch, Islamic Azad University, Mashhad, Iran (Code: IR.IAU.MSHD.REC.1403.094).

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Authors' contributions

Conceptualization, study design, data analysis, and Writing: Fatemeh Gholami and Mahmood Reza Khazaei; Data collection: Fatemeh Gholami; Investigation: Mahmood Reza Khazaei.

Conflict of interest

The authors declared no conflict of interest.

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