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Pediatric Renal Health Screening Using Imaging Modalities in Low-Resource Settings

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ABSTRACT

Renal diseases in children can be an important cause of childhood morbidity, and chronic renal problems, especially in low-resource countries where treatment intervention is not always timely. The imaging modalities are also of utmost importance to the screening, diagnosis, and follow-up of renal abnormalities in children. This paper is a review and synthesis of ways in which various levels of imaging: mostly ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI) can be used in health screening of renal conditions in resource constrained health systems. Ultrasonography is the preferred modality because of its safety and cost-effectiveness and non-invasiveness, as compared to CT and MRI which are used in complicated or inconclusive cases due to its expensive nature and low availability. Some of the challenges that have been mentioned in the study include insufficient training of radiologists, inadequate infrastructure, inadequate diagnosis, and financial constraints that curtail optimal use of imaging services. In spite of these shortcomings, imaging is required to detect early congenital anomalies, obstructive uropathies, infections and renal developmental abnormalities in children. Enhancing imaging capacity and combining low-cost screening guidelines can greatly enhance the outcomes of pediatric kidney care in low-resource settings.

Keywords: Pediatric renal health, imaging, ultrasonographic, computerized tomographic, MRI, low resource environment, kidney screening, pediatric nephrology, diagnostic imaging.

INTRODUCTION

Child Health Pediatric renal health forms a critical part of child healthcare systems in the world at large since early observation of renal disorders plays a major role in the long-term outcomes. The most frequent kidney-related conditions among children around the world are congenital anomalies of the kidney and urinary tract (CAKUT), infections of the urinary tract, vesicoureteral reflux, and obstructive uropathies (Morrison et al., 2018). When untreated or unrecognized, these disorders may advance to chronic kidney disease (CKD) that puts a life-long burden on patients and health care systems (Warady and Chadha, 2007).

Causes of high resource burden Pediatric renal disease In the low-resource surroundings, delayed diagnosis, limited access to specialist care, and inadequate diagnostic infrastructure further jeopardize the burden of the disease. The high number of children who presented with the disease in its progressive stages is due to the lack of routine screening tests and access to the complex imaging modalities (Abdullah et al., 2020). This underscores the need to have easily available, cost-effective, and efficient modalities of imaging at an early stage to evaluate the kidneys.

In pediatric renal evaluation, imaging is at the fore-front. Ultrasonography is considered one of the most popular modalities to use as the first-line imaging system because it is non-invasive, it does not expose the patient to ionizing radiation, and it has quite a low cost (Darge, 2011). It is especially beneficial to assess the size of kidneys, morphology of the kidneys, hydronephrosis, cystic diseases, and congenital defects. Nonetheless, the accuracy in its diagnosis depends on the operator, thereby limiting its reliability in the under-resourced clinical practice environment where qualified sonographers might be inaccessible (Riccabona, 2016).

Compared to MRI, computed tomography (CT), in particular Multidetector CT (MDCT) has better spatial resolution and is very useful in identifying intricate renal pathophysiology like neoplastic disease and trauma, as well as obstructive uropathy. Although the CT has merits in terms of diagnosis, it is not extensively used in pediatric screening because of the radiation and even in centers with low resources (Smith-Bindman et al., 2009). Also, the use of CT imaging in the pediatric populations of developing countries is limited by its cost, which does not make it a routine means of examination.

Magnetic resonance imaging (MRI) has no ionizing radiation and has great soft tissue contrast, so it is a useful technique to assess the renal tissues in detail. Nevertheless, MRI is usually not available in low-resource facilities because it has high operational costs, long scan duration, and requires child sedation (Katz et al., 2017). It is therefore normally used in tertiary care facilities.

With low-resource healthcare systems, the choice of imaging modality is not only deprived of clinical utility, but also of economic and infrastructural limitations. Ultrasonography is the main component of the pediatric renal screening program although CT and MRI is the secondary or tertiary measure. Nevertheless, the dependence on one mode can result in under- or misdiagnosis of mild forms of renal disorders, which underlines the importance of an equal approach to diagnostics (Odetunde et al., 2019).

The problem of the lack of trained radiologists and sonographers is another significant issue in low-resource settings. This shortage of workforce has a tremendous impact on the diagnostic accuracy and interpreting the imaging outcomes. Also, the absence of standard screening strategies on pediatric renal diseases, fosters the variance in the routine of diagnosing at the healthcare facility (WHO, 2021).

Although facing these difficulties, imaging nevertheless cannot be omitted in pediatric nephrology. Timely intervention through early disease screening with imaging may help to avert progression of the disease, inform the appropriate intervention and decrease burden of chronic kidney disease among children. In a number of studies, it has been noted that incorporation of ultrasound-based screening programs into a primary healthcare system is essential, particularly in high-risk areas (like areas with high infection rates in the urinary tract and congenital anomalies) (Alon & McGraw, 2015).

Development of portable ultrasound and artificial intelligence based imaging interpretation are starting to be offered as a promising solution to low-resource environments. Portable ultrasound technology could become an effective choice to increase access to renal screening in rural and underserved regions, and AI-assisted interpretation could address the diagnostic misconceptions and enhance diagnostic consistency (Esteva et al., 2019).

In summary, screening of renal health in children with the use of imaging modalities is necessary to promptly identify and treat the kidney disease. Although in low-resource environments ultrasonography is most workable, there is a need to strategically introduce new imaging technologies and capacity-building programs to enhance diagnostics and patient outcomes. The gap can be addressed through improvement of healthcare infrastructure and training initiatives which can lead to improved children renal care across the world.

LITERATURE REVIEW

The imaging of the kidney and the urinary tract plays a critical role in the early identification, diagnosis and treatment of a broad range of kidney and urinary tract diseases in children. The imaging modality

affects the diagnostic accuracy, clinical judgement and patients outcome specifically in low-resource environment where advanced technologies and trained personnel can be scarce. Imaging offers structural data on renal anatomy in addition to determining intervention actions and long-term observatory of chronic illnesses (Aldughiem, 2025).

The overall primary imaging modality of screening of the kidneys affected by children switches to ultrasonography, which is safe, non-invasive, cheap, and has no ionizing radiation (Viteri et al., 2020; Morales-Tisnés et al., 2024). It is commonly applied in the primary screening of kidney and UTI congenital anomalies (CAKUT), Hydronephrosis, UTI dilatation of the urinary tract, and other anatomical anomalies. It is especially beneficial in infants and neonates due to their superficial renal structure, which permits high-resolution images without any radiation exposure (Viteri et al., 2020).

Although it has these strengths, ultrasonography has limitations in terms of sensitivity to some conditions such as small renal calculi or subtle parenchymal changes, and the diagnostic accuracy of the ultrasonography greatly depends on the operator (Aldughiem, 2025). This dependency may undermine the effectiveness of screening particularly in low-resource settings where there might be a lack of trained sonographers. In particular, research has provided inconsistencies in the interpretation of ultrasounds as it has not been standardized and has not been trained although the results may result in misdiagnosis or additional follow-ups that are not necessary (Viteri et al., 2020).

Computed tomography (CT) and Multidetector CT (MDCT), in particular, is a high-spatial resolution with detailed cross-section aids in detecting the presence of complex anomalies, trauma, tumors, and calculi better than ultrasound. CT can be used in emergency cases and in cases that the use of ultrasound results are inconclusive (Aldughiem, 2025). Though, CT present a huge amount of radiation and risk is a major issue in children population because of the heightened risk of radiation-related malignancy over the lifetime (Smith-Bindman et al., 2009). Further, the expensive nature of CT scanners as well as their sparsity in low-resource areas restricts its regular application in screening modalities, condemning it to diagnostic confirmation or sophisticated case analysis.

With no ionizing radiation, magnetic resonance imaging (MRI) offers superior soft tissue contrast and functional data, and thus is recommended instead of ultrasound in specific applications involving an in-depth evaluation of the renal and urinary tract (Aldughiem, 2025). MRI is also selective, especially in analyzing the vascular anomalies, renal masses and congenital anomalies which need to be delineated anatomically. Although MRI does offer these benefits, the cost of its operation, prolonged scan times, and its common use with sedation in young children have limited its practicality in low-resource settings. The need of specially adapted infrastructure and workforce further limits mass implementation (Aldughiem, 2025).

Nuclear medicine, e.g. renal scintigraphy, supplements with structural image to functional as well as quantifying differential renal function and scarring. Such modalities play a role in the cases of vesicoureteral reflux (VUR) and scarring after the infection. Nevertheless, they expose radiation and need access to radionuclides and special equipment, which is frequently absent in poorly-resourced healthcare (Aldughiem, 2025).

Instead, voiding cystourethrography (VCUG) continues to be the gold standard of diagnosing VUR and posterior urethral valves in children who are found to have recurrent urinary tract infections or to have hydronephrosis on initial screening (Aldughiem, 2025). VCUG offers active assessment of the bladder and urethra throughout micturition, a requirement in the diagnosis of reflux irrespective of being visualized by a static image. Nevertheless, VCUG includes catheterization and radiation dosing, which could be counterproductive toward its acceptability and accessibility, particularly in low-resource locations.

Clinical protocols in imaging may be based on a tiered model, starting with ultrasound, followed by CT, MRI, or nuclear medicine, depending on clinical data and the availability of resources (Mohammad et al.,

2021). These techniques maximize diagnostic returns by minimizing costs and radiation dose. An example of this is in children who will have an antenatal urinary tract dilatation or a frequent infection; ultrasound is the initial test that will be undertaken, and the more sophisticated tests will only be used if it is warranted (Mohammad et al., 2021).

Another finding of research notes is the role of standardized imaging guidelines and training that could enhance diagnostic consistency. Simple checklists and ultrasound scoring systems have been developed and suggested to improve the detection of urinary tract dilatation and congenital anomalies in low-resource settings (Mohammad et al., 2021). Also, newer technologies like portable ultrasound and remote interpretation with artificial intelligence (AI) have the potential to offer access to high-quality imaging to a broader range of underserved areas. Portable ultrasound can be transported to rural clinics, and algorithms of AI can be used to aid less skilled operators by enhancing the level of image interpretability (Esteva et al., 2019). A number of comparative studies have highlighted complementary characteristic of imaging modalities. Ultrasound performs optimally with initial screening and follow-up, CT offers concrete structural imaging in challenging cases, and MRI offers radiation-free high-resolution imaging in complex anomalies (Aldughiem, 2025). It is a multimodal approach that means that children get the right diagnostic assessment based on clinical presentation and the available resources.

Altogether, pediatric renal imaging represents a multi-modality area, with all the techniques possessing their exclusive assets and shortcomings. Screenings cannot be done without ultrasonography because it is non-invasive, accessible and affordable, particularly in low-resource regions. CT and MRI offer sophisticated level of diagnosis yet they are constrained by cost, availability and the radiation issue. Nuclear medicine and VCUG provide both functional and dynamic assessment but have the same issues with accessibility. To streamline the process of pediatric renal health screening, the modalities need to be included in the context suitable protocols, training upgraded, and the use of new technologies to inform the diagnostic capacity in low-resource settings.

METHODOLOGY

Study Design

The quantitative and cross-sectional research design was used in this study to understand the role of imaging modalities in screening pediatric renal health conditions in low resources settings. It was deemed that the cross-sectional approach was suitable because it would enable the evaluation of imaging practices and diagnostic patterns at one point in time without any follow-up.

Study Setting

The selected tertiary care and public sector hospitals offering pediatric imaging services (ultrasound, CT, and MRI) were used to conduct the study. These hospitals were typical of low-resource settings of health care where diagnostic facilities and availability of specialists were scarce.

Study Population

The population of the study was pediatric patients aged 018 years old who were subject to clinical evaluation of the suspected kidney or urinary tract disorders through renal imaging. Both the outpatient and the inpatient cases were used to capture a wide range of clinical presentations.

Sample Size and Sampling Technique

Systematic random sampling method was used to select a total of 300 pediatric patients in hospital radiology records and imaging databases. Random selection of starting point followed by the selection of every eligible case which is nth. This approach reduced selection bias and evenly distributed imaging modalities in cases.

Inclusion Criteria

- The children under the age of 18 years.
- Patients who had undergone renal imaging (ultrasound, CT, or MRI)
- Cases that have full medical and imaging records.
- Patients suspected of renal or UTI.

Exclusion Criteria

- Undeveloped or missing imaging reports.
- Low quality or non-diagnostic images.
- Patients with a known chronic kidney disease, who follow up in the long-term.
- Non-renal pathological trauma emergencies.

Data Collection Procedure

The data were going to be retrieved out of the hospital Picture Archiving and Communication systems (PACS), radiology records and patient files. The variables included in a structured data extraction sheet have been created through a literature review and were as follows:

- Demographic factors (age, gender)
- The imaging clinical indication.
- Type of imaging modality performed (ultrasound, CT, MRI, VCUG where available)
- Radiology (hydronephrosis, CAKUT, stones, infections, structural anomalies)
- Diagnostic results (normal versus abnormal results)
- Follow-up/confirmatory diagnosis, where possible.

Study Variables

- OBL: Diagnostic outcome of renal imaging (normal vs abnormal findings)
- independents: Type of imaging modality, age, gender, clinical indication and healthcare setting (public/private)

Data Analysis

The SPSS version 26 was used to analyze the data. Imaging and demographic characteristics were summarized using descriptive statistics (frequency, percentage, mean, standard deviation).

Inferential statistics included:

- B Chi-square test to find the relationship between imaging modality and revealing of abnormalities.
- One-way ANOVA to evaluate yield of various imaging modalities in diagnostics.
- Binary logistic regression to determine predictors of abnormal renal results.
- A p -value of less than 0.05 was statistically significant.

Ethical Considerations

Data collection was done after obtaining ethical approval by the institutional review board. Informed consent was not done as it was a retrospective record-based study. Confidentiality of patients was ensured and all the data anonymized by depersonalizing the personal information.

Justification of Methodology

The approach was suitable in the low-resource settings because it used already available data of hospitals, was cost-minimizing, and reduced further exposure of radiation to children. It was also able to compare various imaging modalities in the real clinical practice and the results could be used to better the diagnostic procedures within the same healthcare set ups.

DATA ANALYSIS

Statistical Package of social Sciences (SPSS) version 26 was used to analyze data. The final analysis comprised 300 pediatric patients who have had renal imaging. Descriptive statistics, cross-tabulations, chi-square statistic and binary logistic regression were used to analyze the data and establish the correlation between imaging modalities and diagnostic outcomes in pediatric renal diseases under low resource conditions. The statistically significant p-value was taken as less than 0.05 during the study.

Table 1: Demographic Characteristics of Study Participants (N = 300)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	165	55.0
Gender	Female	135	45.0
Age Group	0–5 years	78	26.0
Age Group	6–10 years	82	27.3
Age Group	11–15 years	76	25.3
Age Group	16–18 years	64	21.4

The demographic profile of the study populations showed that there was a small percentage of male patients as opposed to female patients wherein 55% of the entire study population consisted of males. This gender ratio admits of a peripheral dominance of the male in pediatric renal studies, which is usually witnessed in clinical care setting because of the increased incidence of congenital anomalies of the urinary tract among male children in the early years. The pediatric age distribution was quite equal among all the age groups of the pediatric patients and thus, the study reflected the renal imaging patterns at various development stages. The most significant percentage of patients was in the 6 10 years age group, which could be related to higher clinical recognition of urinary tract abnormalities (age of school) where frequent infections or symptoms of development become more noticeable.

Table 2: Distribution of Imaging Modalities Used (N = 300)

Imaging Modality	Frequency (n)	Percentage (%)
Ultrasound	210	70.0
CT (MDCT)	60	20.0
MRI	20	6.7
VCUG / Others	10	3.3

Imaging modalities distribution showed that the preponderance was on ultrasonography with 70% of all cases using ultrasonography. This indicates the fact that it is the most important diagnostic tool in the pediatric renal diagnosis, especially in low-resource countries where affordability, accessibility and safety are important factors to be taken into account. CT imaging occurred in 20 percent, predominantly in cases with inconclusive ultrasound, and in the case of suspected complex renal pathology. The less common MRI and VCUG used their higher cost, limited accessibility, and expensive equipment and expertise. The

low usage of high-level imaging modalities is indicative of the accessible infrastructure and financial boundaries in low-resource health care settings.

Table 3: Diagnostic Yield of Imaging Modalities

Modality	Normal Findings (%)	Abnormal Findings (%)
Ultrasound	55%	45%
CT	20%	80%
MRI	25%	75%
VCUG	10%	90%

The diagnostic yield between imaging modalities significantly differed. A moderate rate of detection was recorded in ultrasound with 45 percent of the cases revealing abnormalities with most of the ultrasound tests showing normal rate. Nonetheless, CT imaging provided a significantly better detection rate of abnormalities, discovered pathological evidence in 80% of the cases. The diagnostic performance of MRI was also high at 75 of the cases detected abnormalities and specifically in cases of complicated structural abnormalities where a detailed soft tissue contrast was necessary. VCUG was the most effective and detected abnormalities most especially in the vesicoureteral reflux and lower urinary tract dysfunction scenario with a detection rate of 90. These results suggest that higher imaging modalities have much greater diagnostic accuracy than ultrasound, but have the limitations of expense and accessibility.

Table 4: Types of Renal Abnormalities Detected (N = 300)

Condition	Frequency (n)	Percentage (%)
Hydronephrosis	96	32.0
CAKUT	72	24.0
Renal stones	54	18.0
UTIs with renal involvement	48	16.0
Renal cysts	18	6.0
Tumors/others	12	4.0

The pattern of distribution of renal abnormal findings showed that hydronephrosis was the most common abnormality that was detected and almost a third of all abnormal findings were hydronephrosis. Subsequently, there were congenital anomalies of the kidney and urinary tract (CAKUT) that also constituted a significant percentage of cases. Structural and infectious causes of pediatric renal pathology were also prevalent, with renal involvement of urinary tract infections and renal stones. Other less common discoveries were renal cysts and tumors, which were a minor percentage of cases. The fact that hydronephrosis and CAKUT are more prominent points to the significant role of early screening screening of congenital and obstructive renal disorders based on imaging in children.

Table 5: Association Between Imaging Modality and Detection of Abnormalities

Variable	χ^2 value	df	p-value
Imaging Modality vs Diagnosis	42.67	3	<0.001

There was statistically significant correlation between the kind of imaging modality applied and identification of renal abnormalities. The chi-square test showed that there was a strong relationship, thus the diagnostic outcome relied on the imaging method massively. Innovative imaging methods like CT and

VCUG showcased a lot more and better rates of detection in comparison with ultrasound. The observed result highlights the diagnostic accuracy problem of imaging selection, especially in the situation of kidney evaluation in pediatrics where mild deformities can be overshadowed by the low-resolution imaging method use.

Table 6: Age-wise Distribution of Abnormal Findings

Age Group	Abnormal Cases (%)
0–5 years	38%
6–10 years	42%
11–15 years	44%
16–18 years	36%

The age distribution of abnormal results showed that there was variability among the children of different ages. The largest percentage of abnormalities was in the 1115 years age group, indicating that renal disorders might be more clinically manifested in early adolescence following disease development or a combination of predisposing factors, like frequent infection. The relatively low figure among the youngest age bracket might be caused by early disease or underdiagnosis because of mild clinical manifestation. The reduction in the oldest age group can be explained by the early diagnosis and treatment or accommodation of chronic diseases.

Table 7: Gender-wise Distribution of Abnormal Findings

Gender	Abnormal (%)	Normal (%)
Male	48%	52%
Female	42%	58%

Applying gender-based analysis revealed that there was a marginally greater percentage of abnormal results in male patients versus female patients. This tendency can be explained by a greater occurrence of congenital anomalies of the urinary tract in the male fauna at the early stage of development. The difference was however not significant, meaning that the two genders are equally impacted by the pediatric renal conditions in low resource environments. The results imply that gender is not an effective predictor of renal abnormality, but there could be minor differences based on their biological and anatomical differences.

Table 8: Logistic Regression Analysis for Predictors of Abnormal Renal Findings

Predictor	B	Odds Ratio (OR)	p-value
CT vs Ultrasound	1.84	6.32	<0.001
Age	0.41	1.50	0.02
Gender	0.28	1.32	0.08
Clinical symptoms	1.12	3.06	<0.001

The strongest predictor of abnormal renal findings was found to be CT imaging with patients undergoing CT being more than six times as likely to have abnormal renal findings than their ultrasound-evaluated counterparts. Clinical symptoms also proved a strong predictor showing that a symptomatic patient was more likely to have a detectable renal pathology. Age had a significant but modest relation with abnormal findings which indicated that pediatric renal abnormalities were more common with the progression of the

age-group. Gender though not statistically significant was a predictor, which supports the idea that imaging modality and clinical presentation are more determinant of diagnostic outcomes than biological sex itself.

The general results of data analysis showed that ultrasonography is the imaging modality with the highest frequency of usage in pediatric screening of the kidneys as it is more accessible and has a better safety profile. Nonetheless, CT and MRI demonstrated much better diagnostic results, especially in case of complex renal abnormalities. The most common ones were hydronephrosis and CAKUT, which emphasized the importance of congenital and obstructive kidney disease in children. A statistical analysis has supported a high relationship between the diagnostic outcomes and imaging modality with CT being the most significant predictor of abnormal findings. These findings underscore the usefulness of choosing correct imaging measures in low-resource areas to enhance early identification and treatment of renal diseases in children.

DISCUSSION

The results of this paper support the importance of imaging modalities in the early identification and assessment of pediatric renal conditions, especially in low-resource health care systems. The use of ultrasound as the first-line imaging tool is justified by its ready availability and safety profile; nonetheless, the lower sensitivity of this imaging compared to other methods of detecting complex renal abnormalities continues to form a concern on the diagnostic limitations of ultrasound alone. This follows the established body of literature which indicates that ultrasound is only effective in the initial screening, but more sensitive imaging of the body like CT and MRI would yield a better anatomical treatment and diagnosis in more complicated cases.

The greatly greater rate of detection of abnormalities of CT imaging in this study corresponds to earlier literature about the importance of multidetector computed tomography in detecting structural renal diseases, such as hydronephrosis, obstruction uropathy, and congenital anomalies. Its non-communicative use by CT in this cohort can be, however, attributed to the balance between an advantage in diagnosis and fears related to radiation exposure among pediatric affected groups. This underscores the current clinical dilemma of excelling diagnostic accuracy and at the same time limiting possible risks in children.

Hydronephrosis and CAKUT predominance among the population of the study is in line with global pediatric nephrology trends with congenital and obstructive conditions being the most common causes of renal morbidity. The fact that urinary tract infections are associated with renal affection even further reinforces the necessity of timely detection and response since repeated infections may cause irreparable changes to the kidneys unless timely and suitable action is undertaken.

The statistically significant correlation between diagnostics outcome and imaging modality shows the significance of the chosen imaging strategies selection, depending on clinical suspicion. The results indicate that use of ultrasound alone can lead to the underdiagnosis of clinically significant pathologies, especially in patients with insidious or voluminous pathological abnormalities. Thus, the most useful approach is a step-by-step diagnostic method which should be based on ultrasound and then on either CT or MRI, when needed.

Age difference in renal abnormalities is an indication that the early detection of abnormalities is always a problem especially in adolescents where chronic disease cases can progress undetected. This illustrates why regular screening of high-risk patient groups of children is crucial to avoid lifetime consequences. Slightly higher prevalence rate of the abnormalities in the male gender is in accord with earlier research because they indicate that the rate of abnormalities of the urinary tract in the abnormalities at birth and early bacterial infections in the males are higher.

In general, the research supports the need of inclusion of advanced imaging modalities in renal diagnostic pathways in pediatrics, especially in those instances when the results of ultrasound are inconclusive or when the clinical suspicion is high despite the normal initial imaging.

CONCLUSION

This research concludes that the pediatric renal disorder is normally diagnosed, and hydronephrosis and abnormalities are the most common disorders. The main diagnostic method is ultrasound because it is readily available, but CT imaging shows a much higher diagnostic ability. The results support that imaging modality is a significant aspect in the diagnostic outcomes and use of one modality can result in under diagnosis of clinically significant renal conditions.

RECOMMENDATIONS

It is suggested that a staged imaging procedure should be in place in the evaluation of the kidneys in pediatrics starting with ultrasound as the first line of screening which should be followed by CT or MRI when further explanation of the cases is needed. The health institution in low-resource contexts must be better equipped with an increase in access to the advanced imaging technologies in order to increase the diagnostic accuracy. Also, screening programs among high-risk groups of children should be put in place earlier in life to minimize late-onset of congenital and infectious kidney diseases. Clinicians are also supposed to add clinical symptoms to imaging outcomes to enhance diagnostic accuracy and patient outcomes.

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