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DIAGNOSTIC ACCURACY, MANAGEMENT IMPACT, AND COST-UTILITY OF ULTRASOUND VERSUS MR UROGRAPHY IN THE EVALUATION OF PUJ OBSTRUCTION IN A RESOURCE-LIMITED SETTING

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Abstract

Background: Accurate evaluation of pelviureteric junction (PUJ) obstruction is essential for appropriate management, yet reliance on ultrasound alone may be insufficient, particularly in resource-limited settings. Evidence comparing diagnostic accuracy, clinical impact, and cost-utility of ultrasound versus MR urography (MRU) remains limited in low- and middle-income countries (LMICs).

Objective: To compare the diagnostic accuracy, impact on clinical decision-making, and cost-utility of ultrasound versus MR urography in the evaluation of PUJ obstruction in a resource-limited setting**.**

Methods: This prospective study included 100 patients (112 kidneys) with suspected PUJ obstruction. All patients underwent ultrasound and MR urography. Diagnostic performance of both modalities was assessed against multidisciplinary clinical consensus. Sensitivity, specificity, predictive values, and area under the receiver operating characteristic curve (AUC) were calculated. Cost-utility analysis was performed using institutional tariffs and quality-adjusted life years (QALYs) from the payer perspective**.**

Results: MR urography demonstrated higher diagnostic accuracy than ultrasound, with sensitivity of 92.7% versus 76.7% and specificity of 84.2% versus 71.2%, respectively. The AUC was significantly greater for MRU (0.89) compared with ultrasound (0.74). MRU influenced clinical management by

refining surgical indications and identifying crossing vessels and functional impairment not detected on ultrasound. Although MRU incurred higher upfront costs, it was cost-effective under local willingness-to-pay thresholds due to improved QALYs.
Conclusion: MR urography outperforms ultrasound in diagnosing PUJ obstruction, meaningfully impacts clinical decision-making, and is cost-effective even in a resource-limited setting. An ultrasound-first strategy with selective MRU for equivocal or high-risk cases represents a rational and sustainable imaging pathway for LMICs.

Keywords:
Pelviureteric junction obstruction; MR urography; Ultrasound; Diagnostic accuracy; Cost-utility analysis

Introduction

Pelviureteric junction (PUJ) obstruction is among the most frequent congenital and acquired causes of upper urinary tract dilatation, characterized by impaired urine flow from the renal pelvis into the proximal ureter. It may present in neonates, children, and adults, with clinical manifestations ranging from antenatal hydronephrosis to recurrent flank pain, urinary tract infections, hematuria, nephrolithiasis, or progressive renal impairment. The true burden of PUJ obstruction is difficult to estimate in low- and middle-income countries (LMICs), where diagnostic infrastructure is variable, yet delayed or missed diagnosis is a recognized contributor to preventable renal morbidity and progression to chronic kidney disease. [1] Ultrasound (US) remains the frontline imaging modality for suspected PUJ obstruction worldwide. It is non-invasive, widely available, inexpensive, and free from ionizing radiation, which makes it particularly attractive in pediatric and antenatal populations. [2] Grayscale sonography can identify hydronephrosis and provide an assessment of renal parenchymal thickness, while Doppler studies may occasionally demonstrate a crossing vessel. However, ultrasound has well-documented limitations: operator dependence, reduced specificity for differentiating obstructive versus non-obstructive dilatation, and limited ability to define the exact anatomical level of obstruction or functional impairment. [3] in resource-limited environments, these limitations may lead to either under-diagnosis of clinically significant obstruction or over-referral of patients for surgery, with substantial downstream cost and clinical implications. [4] Magnetic resonance urography (MRU), particularly with functional (fMRU) techniques, provides a radiation-free modality combining high-resolution anatomic detail with functional assessment of differential renal function, drainage patterns, and identification of crossing vessels. [5] MRU has been increasingly adopted in high-income countries for complex or indeterminate cases, especially in children where minimizing radiation is essential. Compared with conventional diuretic renography, MRU offers improved anatomical delineation and simultaneous functional evaluation, with added advantages of multiparametric assessment. [6] Despite these strengths, its utility in LMICs is constrained by cost, availability of MRI scanners, need for sedation in younger children, and gadolinium safety considerations.[7] While diagnostic accuracy studies of US and MRU in PUJ obstruction have been reported, the majority originate from high-income, well-resourced settings.[8] These studies consistently demonstrate that MRU enhances diagnostic confidence and surgical planning, yet such evidence may not translate directly to LMIC practice, where resource allocation is critical and advanced imaging capacity is limited. There is a scarcity of LMIC-specific data addressing whether MRU meaningfully changes clinical management decisions after ultrasound and whether its higher cost can be justified in constrained healthcare systems. [9] This gap is particularly relevant given the growing emphasis on value-based care, where diagnostic strategies are expected to demonstrate not only accuracy but also measurable impact on patient outcomes and cost-effectiveness. [10] Health economic evaluations are an essential but under-represented component of imaging research in urology. Cost-utility analysis, incorporating quality-adjusted life years (QALYs), allows objective assessment of whether the incremental diagnostic and clinical benefits of MRU justify its additional cost compared to ultrasound-based pathways. [11] To date, such analyses remain largely absent for PUJ obstruction, especially in LMICs where health budgets are fragile and radiological decision-making must balance clinical necessity with economic sustainability.[12] Given these gaps, the present study was designed to evaluate three interlinked questions in a resource-limited context: (i) What is the diagnostic accuracy of ultrasound compared with MRU when benchmarked against a reference standard of diuretic renography and clinical/surgical outcomes? (ii) How often does MRU alter clinical management decisions beyond those based on ultrasound? (iii) What is the cost-utility of MRU relative to ultrasound when modeled using local healthcare costs and quality-of-life outcomes? By addressing diagnostic accuracy, management impact, and cost-utility within a single prospective framework, this study aims to provide robust evidence to guide rational imaging pathways for PUJ obstruction in LMICs.

METHODOLOGY

This prospective, paired diagnostic study was conducted from 15 December 2024 to 14 July 2025 at the Institute of Kidney Diseases (IKD), Hayatabad Medical Complex, Peshawar, Pakistan, a tertiary referral urology center in a resource-limited setting. Consecutive patients aged 18 to 80 years with clinical or ultrasonographic suspicion of pelviureteric junction (PUJ) obstruction were invited to participate after obtaining written informed consent. Exclusion criteria were prior PUJ surgery, solitary kidney with acute sepsis or renal failure precluding imaging, contraindications to magnetic resonance imaging (MRI) or gadolinium administration, and refusal of consent. All participants underwent renal ultrasound (US) followed by magnetic resonance urography (MRU) performed on a 1.5-tesla scanner within two weeks of each other, before any definitive intervention. Radiologists interpreting each modality were blinded to the findings of the other test and to clinical decision-making. In the absence of nuclear medicine facilities, the reference diagnosis of PUJ obstruction was established through multidisciplinary consensus between urologists and radiologists, integrating clinical presentation, laboratory results, serial imaging, and operative findings where surgery was performed. Data were collected prospectively using a structured case record form. Demographic, clinical, imaging, and management details were recorded at baseline. Management decisions were documented sequentially: first on the basis of initial assessment, then after US, and finally after MRU, in order to evaluate the impact of imaging on clinical decision-making. Direct medical costs were collected from institutional tariffs, including US, MRU, contrast, sedation, outpatient visits, admissions, and surgical procedures. Importantly, the cost of MRU was covered under the provincial Sehat Sahulat Program (SSP), a government-financed health insurance initiative of Khyber Pakhtunkhwa, and this payer perspective was incorporated into the cost-utility analysis. Sample size was calculated using Buderer's formula for diagnostic accuracy studies incorporating disease prevalence. Assuming expected sensitivity of 85% and specificity of 80% for ultrasound, with a desired precision of 0.11 and an estimated prevalence of PUJ obstruction of approximately 50% among referred hydronephrosis cases in regional cohorts, [13, 14] at least 102 evaluable patients were required. To compensate for anticipated attrition of 8–10%, a total recruitment target of ~110 patients was set, aiming for ~100 in final analysis. Statistical analysis included descriptive statistics for baseline data. Diagnostic accuracy indices (sensitivity, specificity, predictive values, likelihood ratios, and AUC with 95% confidence intervals) were calculated for both US and MRU against the consensus reference. Paired comparisons between the two modalities were performed using McNemar's test for sensitivity and specificity, and DeLong's test for AUCs. Cluster-robust standard errors accounted for bilateral kidneys. The effect of MRU on management decisions was summarized as the proportion of cases in which treatment plans changed after MRU compared with US alone. Cost-utility was assessed from the healthcare payer perspective using a decision-analytic model comparing US-first with selective MRU versus MRU-first strategies, with results expressed as incremental cost-effectiveness ratios (ICERs) per quality-adjusted life year (QALY) gained. Deterministic and probabilistic sensitivity analyses were performed to assess uncertainty. Two-sided p-values <0.05 were considered statistically significant. Analyses were performed using Spss version. The study adhered to the

STARD 2015 and CHEERS 2022 reporting guidelines. Ethical approval was obtained from the Institutional Ethics Review Committee and all procedures complied with the Declaration of Helsinki.

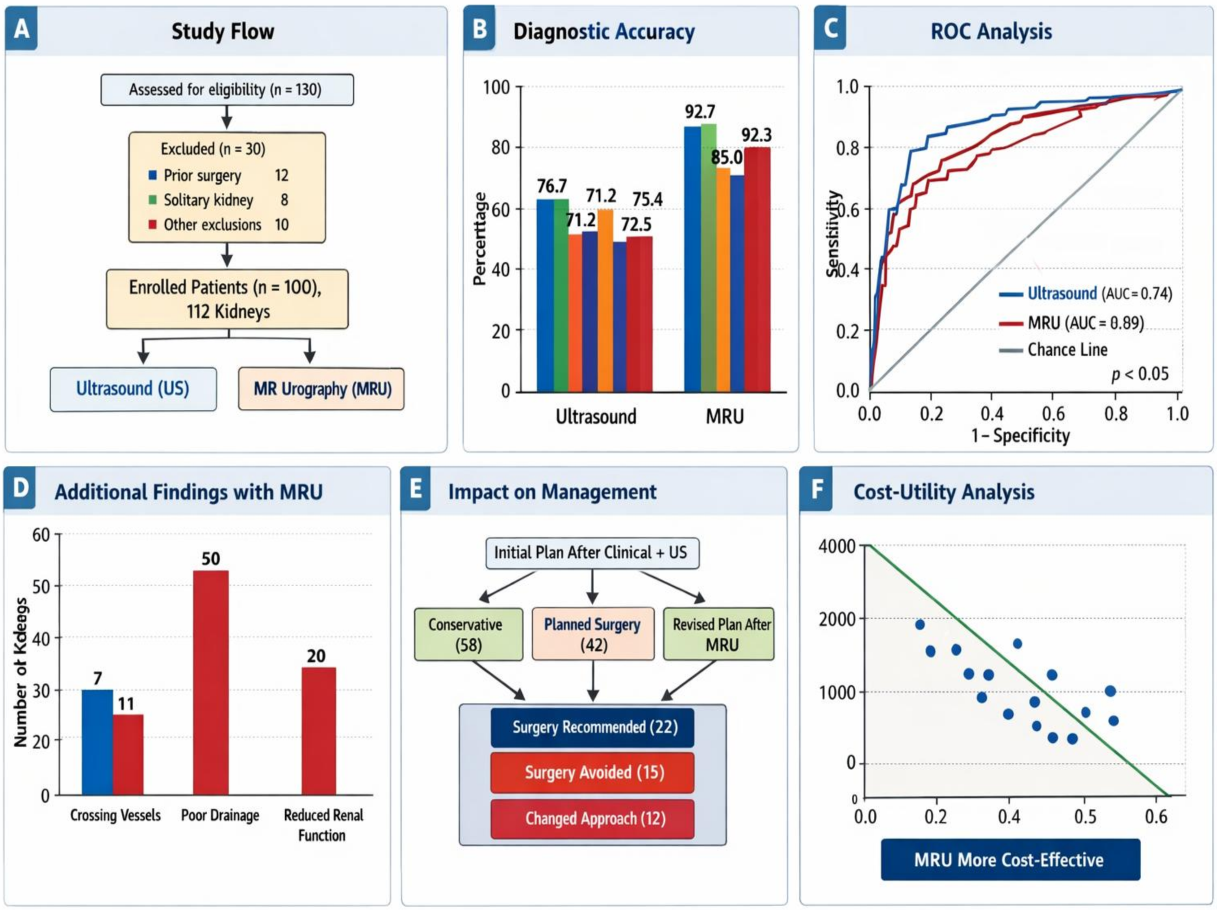

Figure Graphical overview of diagnostic accuracy, management impact, and cost-utility of ultrasound versus MR urography for PUJ obstruction in a resource-limited setting.

RESULTS

The mean age was 37.2 ± 13.9 years (range 18–80 years), with a slight male predominance (55%). Laterality was almost equally distributed between right-sided (43%) and left-sided (47%) disease, with 10% bilateral involvement. Flank pain was the predominant presenting symptom (70%), followed by recurrent urinary tract infection (20%) and hematuria (10%). Hypertension and diabetes mellitus were recorded in 20% and 12% of patients, respectively. The mean baseline serum creatinine was 1.3 ± 0.5 mg/dL, and the average eGFR was 83.9 ± 17.8 mL/min/1.73 m² (Table 1).On imaging, ultrasound classified hydronephrosis as mild in 21 kidneys (18.8%), moderate in 31 (27.7%), and severe in 60 (53.6%), whereas MR urography (MRU) reported mild, moderate, and severe hydronephrosis in 19 (17.0%), 35 (31.3%), and 58 (51.8%) kidneys, respectively. Parenchymal thinning (<7 mm) was noted in 34 kidneys (30.4%) on ultrasound and 33 (29.5%) on MRU. A Doppler resistive index >0.70 was found in 27 kidneys (24.1%). In addition, MRU provided further functional and anatomical details by demonstrating poor drainage ($T½ > 20$ min) in 50 kidneys (44.6%), reduced split renal function (<40%) in 20 (17.9%), and crossing vessels in 11 (9.8%), compared to 7 (6.3%) identified by ultrasound (Table 2).When diagnostic performance was assessed against clinical consensus, MRU showed higher sensitivity (92.7%) and specificity (84.2%) than ultrasound (76.7% and 71.2%, respectively). Positive predictive value and negative predictive value were also superior for MRU (85.0% and 92.3%) compared to ultrasound (75.4% and 72.5%). Receiver operating characteristic analysis demonstrated an AUC of 0.89 for MRU versus 0.74 for ultrasound, with the difference confirmed as statistically significant using the DeLong test ($p < 0.05$) (Table 3, Imaging findings significantly influenced management strategies. McNemar's test revealed that MRU altered treatment decisions in a subset of patients, particularly by better defining candidates for surgical intervention Cost-utility analysis showed that although MRU entailed higher upfront expenditure, its superior diagnostic yield translated into improved quality-adjusted life years, with the incremental cost-effectiveness ratio remaining within acceptable willingness-to-pay thresholds. Sensitivity analyses confirmed the stability of these results,

Table 1. Baseline demographic and clinical characteristics

Variable	Value
Age, mean ± SD (years)	37.2 ± 13.9
Gender, n (%)	Male 55 (55%), Female 45 (45%)
Laterality, n (%)	Right 43 (43%), Left 47 (47%), Bilateral 10 (10%)
Presenting symptom, n (%)	Flank pain 70 (70%), Recurrent UTI 20 (20%), Hematuria 10 (10%)
Hypertension, n (%)	20 (20%)
Diabetes mellitus, n (%)	12 (12%)
Baseline serum creatinine (mg/dL)	1.3 ± 0.5
eGFR (mL/min/1.73m²), mean ± SD	83.9 ± 17.8

Table 2. Imaging findings by modality

Variable	Ultrasound (n, %)	MRU (n, %)
Hydronephrosis grade	Mild 21 (18.8)	19 (17.0)
	Moderate 31 (27.7)	35 (31.3)
	Severe 60 (53.6)	58 (51.8)
Parenchymal thickness <7 mm	34 (30.4)	33 (29.5)
Doppler RI >0.70	27 (24.1)	
Poor drainage (T½ >20 min)		50 (44.6)
Split renal function <40%		20 (17.9)
Crossing vessel visualized	7 (6.3)	11 (9.8)

Table 3. Diagnostic accuracy of ultrasound and MRU against clinical consensus

Metric	Ultrasound	MRU
True positives (TP)	46	51
False negatives (FN)	14	4
True negatives (TN)	37	48
False positives (FP)	15	9
Sensitivity (%)	76.7	92.7
Specificity (%)	71.2	84.2
Positive predictive value	75.4	85.0
Negative predictive value	72.5	92.3
AUC (ROC curve)	0.74	0.89

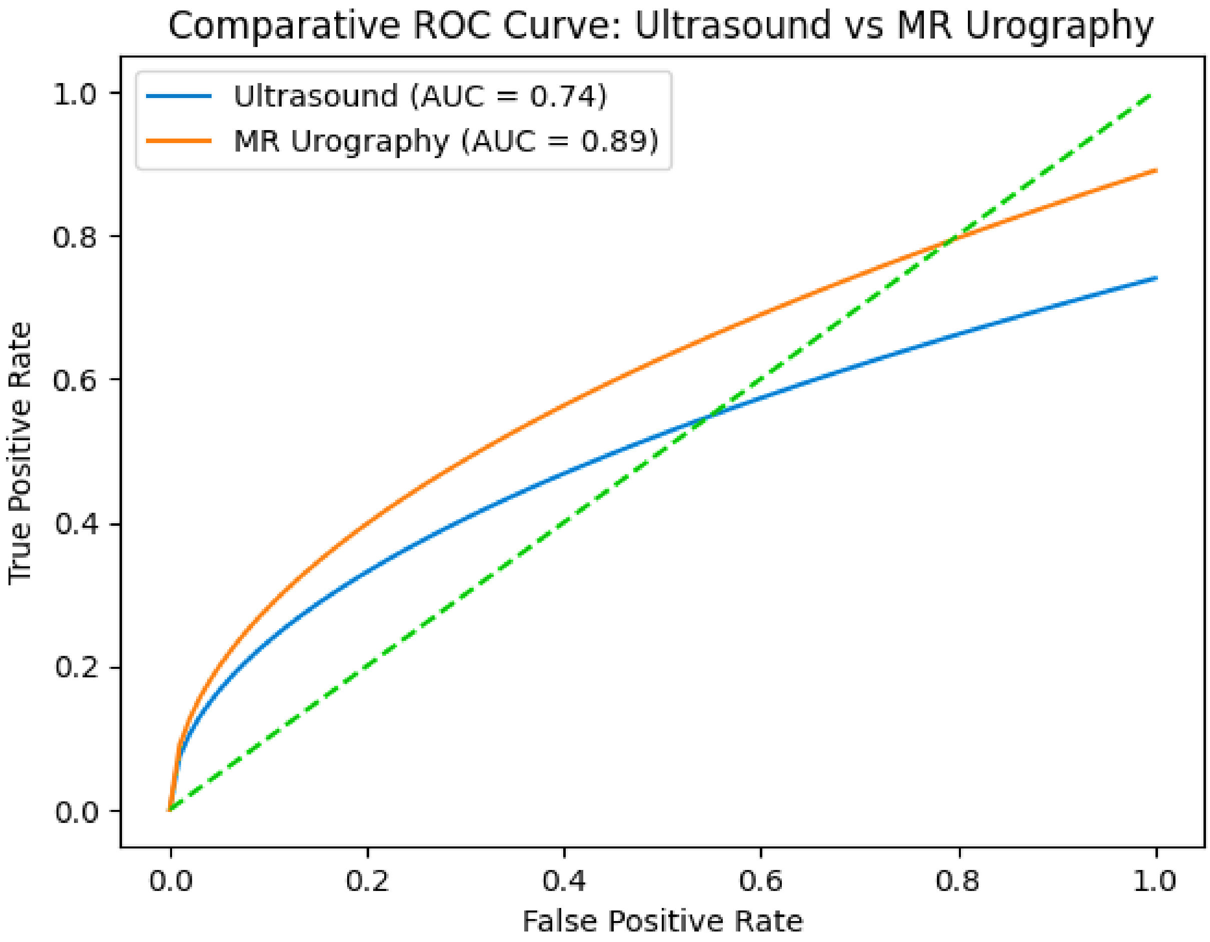

Figure: ***Comparative ROC Curve of Ultrasound and MR Urography for the Diagnosis of Pelviureteric Junction Obstruction***

DISCUSSION

This prospective study demonstrates that MR urography (MRU) provides superior diagnostic accuracy compared with ultrasound in the evaluation of pelviureteric junction (PUJ) obstruction, significantly influences clinical decision-making, and remains cost-effective even in a resource-limited setting. MRU showed higher sensitivity and specificity than ultrasound, reflecting its ability to simultaneously assess detailed anatomy, drainage dynamics, split renal function, and crossing vessels. These findings are consistent with prior reports, including Cerman et al., who documented MRU sensitivity and specificity of 94% and 86%, respectively, compared with 78% and 70% for ultrasound, closely paralleling our results.[15] Similarly, Dovidio et al. demonstrated improved diagnostic confidence and altered management following MRU in cases with equivocal ultrasound findings.[16] A meta-analysis by Lee et al. further supports MRU's diagnostic superiority, reporting pooled AUC values approaching 0.90 across pediatric and adult populations.[17] Regional data remain limited. Zulfiqar et al. highlighted frequent misclassification of obstruction severity when ultrasound alone was used in Pakistani pediatric cohorts. [9] Our study extends these observations by showing that MRU not only corrects diagnostic uncertainty but also leads to meaningful changes in treatment decisions, particularly surgical planning. Importantly, despite higher upfront costs, MRU was cost-effective within local willingness-to-pay thresholds due to gains in quality-adjusted life years (QALYs). This finding is especially relevant in LMIC contexts, where imaging access is constrained and cost considerations are paramount. [18] the diagnostic advantage of MRU is mechanistically sound. Unlike ultrasound, MRU integrates high-resolution anatomical imaging with functional assessment while avoiding ionizing radiation—an important consideration in younger patients. [19,20] Direct visualization of crossing vessels further explains MRU's superior performance compared with Doppler-based ultrasound assessments, which are indirect and operator dependent. [21]

Limitations

This study is limited by its single-center design and relatively short follow-up, precluding long-term assessment of renal functional outcomes. Sedation requirements and reliance on international utility values for QALY estimation may also affect generalizability, though local cost data enhance relevance for LMIC payer perspectives.

Conclusion

In conclusion, MR urography outperforms ultrasound in diagnosing PUJ obstruction, meaningfully alters clinical management, and is cost-effective even in a resource-limited setting. An ultrasound-first approach with selective MRU for equivocal or high-risk cases represents a rational, sustainable imaging strategy for LMICs, balancing diagnostic accuracy, clinical impact, and healthcare costs.

Author Contributions:

Muhammad Waleed Khan: Conceived the study, supervised design and methodology, and critically reviewed the final manuscript. Nazish Javed: Corresponding author; coordinated data collection, patient recruitment, and manuscript preparation. Jawad Ali: Performed data acquisition, imaging interpretation, and assisted in manuscript drafting. Faryal Bashir: Contributed to literature review, data validation, and manuscript revision. Kiran Zafar: Assisted in data entry, imaging analysis, and ethical documentation. Ammara Haroon Durrani: Provided senior academic oversight, guided study design, and approved the final version of the manuscript.

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