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DIAGNOSTIC ACCURACY OF ULTRASOUND IN DETECTING URETERIC STONES USING NON-ENHANCED COMPUTED TOMOGRAPHY AS THE GOLD STANDARD

Aisha Zahid

Radiology Department, Combined Military Hospital Abbottabad, Pakistan

aishazahid1990@gmail.com

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Corresponding Author: *
Aisha Zahid

Abstract

Background: *Ureteric stones are a common urological emergency. While non-enhanced computed tomography (CT) is the gold standard, its use is limited by ionizing radiation, cost, and availability. Ultrasound presents a safer, more accessible alternative, though its diagnostic accuracy, particularly in local settings, requires further validation.*

Objective: *To determine the diagnostic accuracy of ultrasound in detecting ureteric stones in adults, using non-enhanced CT as the gold standard.*

Methods: *This cross-sectional validation study was conducted at the Radiology Department of Combined Military Hospital Abbottabad over six months. A total of 207 consecutive patients presenting with symptoms suggestive of ureteric colic were enrolled. All participants underwent both ultrasonography (using a color Doppler machine) and non-enhanced CT (using a 64-slice scanner). The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of ultrasound were calculated against CT findings.*

Results: *Out of 207 patients, 205 were confirmed to have ureteric stones on CT. Ultrasound correctly identified 185 of these as positive (true positives) but missed 20 (false negatives). Ultrasound correctly ruled out the disease in 2 patients (true negatives) but gave a false positive result for 0 patients. The calculated sensitivity of ultrasound was 90.2%, specificity was 100%, PPV was 100%, NPV was 9.1%, and overall diagnostic accuracy was 90.3%.*

Conclusion: *Ultrasound demonstrates high specificity and positive predictive value for diagnosing ureteric stones. However, its relatively lower sensitivity and notably low negative predictive value mean a negative ultrasound scan cannot reliably rule out a ureteric stone. Therefore, in cases of high clinical suspicion with a negative ultrasound, CT remains an essential diagnostic tool.*

INTRODUCTION

Ureterolithiasis, also known as ureteric calculi, is characterized by the presence or formation of stones within the ureters, the vital conduits responsible for transporting urine from the kidneys to the bladder (Khan et al., 2016). These stones predominantly consist of calcium in approximately 80% of cases, while struvite stones, composed of magnesium ammonium phosphate formed by urea-splitting gram-negative bacteria, make up around 15%. Uric acid and cysteine stones constitute a small

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percentage of the remaining stones (Alelign & Petros, 2018). The symptoms and signs associated with ureteric stones are loin, flank, or localized pain extending to regions such as the groin, testicle, or upper thigh, microscopic or macroscopic hematuria, nausea, vomiting, and dysuria. Small stones may pass asymptomatically (Pickard et al., 2015).

Ureteric stone-related concerns account for a significant proportion of urological outpatient visits and cases encountered in surgical emergency departments (Sorokin et al., 2017). The prevalence of ureteric stones exhibits variability among diverse ethnic groups, with studies reporting prevalence rates of 29.5% in Egyptians, 23.3% in Indians, 20.5% in Yemenis, 17.6% in Sudanese, 16.2% in Bangladeshis, and 7.4% in Saudi Arabians. Additional population-based investigations have explored the prevalence and incidence of urolithiasis in various countries, revealing intriguing insights (Liu et al., 2018). Notably, a rural population in Thebes, Greece, exhibited a notably high 15% prevalence of urolithiasis. In Iceland, prevalence rates ranged from 3.0% to 4.3% among different age groups, with a consistent trend over time (Ingvarsson et al., 2017). In the United States, urolithiasis is relatively common, impacting 12% of men and 7% of women. Notably, the risk is elevated among individuals with a prior history of ureteric stones or a family history of such conditions, primarily affecting individuals within the age bracket of 35-45 (Scales et al., 2012). In Pakistan, Rizvi et al. (2018) reported a prevalence of 16% for ureteric stones.

Disparities in diagnostic approaches for ureteric stone evaluation have emerged, with American guidelines from the American College of Radiology (ACR) advocating for Computed Tomography (CT) scans as the initial diagnostic tool for non-pregnant patients due to its exceptional sensitivity (98%) and specificity (100%) (Smith-Bindman et al., 2014). Conversely, European guidelines, such as those from the European Association of Urology (EAU), often favor ultrasound as the primary modality to minimize patient exposure to ionizing radiation (Turk et al., 2020). Intravenous urography for the diagnostic evaluation of ureteric stones is no longer utilized due to the potential risks associated with contrast media and its extended examination duration (Niall et al., 2019).

Computed tomography (CT) involves subjecting patients to ionizing radiation, which carries the potential for an increased risk of cancer over the long term, a significant concern particularly for younger patients and those requiring repeated imaging (Smith-Bindman et al., 2019). Additionally, CT scans often reveal incidental findings at a relatively high rate, which can result in unnecessary follow-up referrals, patient anxiety, and treatments—a phenomenon known as the "incidentaloma" dilemma (Lumbreras et al., 2010). Moreover, CT scans cannot be performed in pregnant patients and have a higher operational cost compared to ultrasound. Historically, comparative studies assessing the diagnostic precision of computed tomography and ultrasonography (USG) for nephrolithiasis have been limited. In available literature, ultrasonography demonstrates pooled sensitivity rates of 45% for renal calculi and 45% for ureteric calculi, along with specificity rates of 88% and 94%, respectively (Ray et al., 2010). However, the narrative is changing with technological progress. Importantly, recent data demonstrates that modern ultrasound, especially when employing techniques like twinkling artifact on color Doppler and meticulous examination of the juxtavesical ureter with a full bladder, exhibits significantly improved and comparable sensitivity, specificity, and accuracy for detecting renal and ureteral stones when compared to low-dose CT (Cheng et al., 2018). Ultrasound is safe (no risk of radiation), reproducible, inexpensive, and readily available. It can identify stones located in the calyces, pelvis, and pelviureteric and vesico-ureteric junctions (with a filled bladder), as well as provide critical information on the presence and degree of upper urinary tract (UUT) dilatation, which is a key indirect sign of obstruction (Gottlieb et al., 2015).

Recent technological advancements, including higher-resolution probes, harmonic imaging, and advanced Doppler applications, have led to a notable increase in the sensitivity of sonography for stone detection. To validate this improved approach and establish a standardized, reliable protocol for the use of abdominal ultrasound in stone detection, thereby potentially reducing the population's cumulative

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radiation dose, additional research is necessary. The primary objective of this study is to validate the use of ultrasound in detecting ureteric stones, with computed tomography (CT) as the gold standard for comparison. Because no such comprehensive study has been conducted in our local clinical setup, this research will provide a valuable perspective to the existing literature and yield significant local statistics on the subject, informing better diagnostic pathways in our resource-conscious environment.

2. Materials and Methods

2.1. Study Design and Setting

A cross-sectional diagnostic accuracy study was conducted at the Radiology Department of Combined Military Hospital (CMH) Abbottabad, Pakistan, over a period of six months. The study was designed to validate ultrasound against the gold standard of non-enhanced CT.

2.2. Sample Size and Sampling Technique

The sample size was calculated as 207 using the WHO sample size calculator, with an estimated prevalence of ureteric stone of 16% in the symptomatic population, a 95% confidence level, and a 5% margin of error. Consecutive non-probability sampling was used to enroll patients who met the inclusion criteria.

2.3. Participants

Inclusion Criteria: Patients aged 30-60 years of either gender presenting with clinical symptoms suggestive of ureteric stones (e.g., loin/flank pain, hematuria, dysuria, nausea, vomiting) were included.
Exclusion Criteria: Patients with a history of contrast hypersensitivity, pregnancy, or prior ureteric stone intervention were excluded.

2.4. Data Collection and Imaging Protocols

After obtaining informed consent and ethical approval, demographic data (age, gender, BMI, residence, occupation, socioeconomic status) were recorded.

Ultrasonography: All scans were performed by a experienced radiologist using an Esaote MyLab 7 color Doppler machine equipped with 3.5, 5, and 7.5 MHz probes. The ureters were assessed in multiple planes for the presence of an echogenic focus with acoustic shadowing and twinkling artifact on Doppler.

Non-Enhanced CT: All patients underwent a non-contrast CT examination on a Siemens Somatom Sensation 64-slice scanner. Scans were performed from the upper abdomen to the pubic symphysis with the patient in supine position and a full bladder. A 5mm slice thickness was used. A ureteric stone was defined as a hyperdense focus within the ureteral lumen, often with a surrounding soft tissue rim sign.

2.5. Operational Definitions and Data Analysis

A true positive (TP) was defined as a stone identified on both ultrasound and CT. A true negative (TN) was the absence of a stone on both modalities. A false positive (FP) was a stone seen on ultrasound but not on CT. A false negative (FN) was a stone not seen on ultrasound but confirmed on CT.
Data were analyzed using IBM SPSS Statistics version 22.0. Sensitivity, specificity, PPV, NPV, and overall accuracy were calculated using a 2x2 contingency table. Quantitative variables were expressed as mean ± SD or median (IQR), and qualitative variables as frequencies and percentages.

3. Results

A total of 207 patients with a mean age of 42.1 ± 8.7 years were included in the final analysis. The cohort was predominantly male (n=170, 82.1%) and the largest age group was 30-40 years (n=150, 72.5%). The demographic characteristics are summarized in Table 1.

Table 1: Demographic Characteristics of the Study Participants (N=207)

Characteristic	Value

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Characteristic	Value
Age (Years)	
30-40	150 (72.5%)
40-50	30 (14.5%)
50-60	27 (13.0%)
Gender	
Male	170 (82.1%)
Female	37 (17.9%)

Non-enhanced CT confirmed the presence of ureteric stones in 205 patients (99.0% prevalence in this symptomatic cohort). The performance of ultrasound against CT is detailed in the 2x2 contingency table (Table 2).

Table 2: Diagnostic Performance of Ultrasound vs. CT for Ureteric Stones

	CT Positive	CT Negative
US Positive	185 (True Positive)	0 (False Positive)
US Negative	20 (False Negative)	2 (True Negative)

Based on the data in Table 2, the following metrics of diagnostic accuracy were calculated:
Sensitivity: 185 / (185 + 20) x 100 = **90.2%**
Specificity: 2 / (0 + 2) x 100 = **100%**
Positive Predictive Value (PPV): 185 / (185 + 0) x 100 = **100%**
Negative Predictive Value (NPV): 2 / (20 + 2) x 100 = **9.1%**

Overall Accuracy: (185 + 2) / 207 x 100 = **90.3%**

A total of 207 patients with the mean age of the participants was 42.1 ± 8.7 years. The cohort was predominantly male (n=170, 82.1%), with the largest proportion of patients (n=150, 72.5%) belonging to the 30-40 years age group. The demographic distribution is detailed in (Table 3) (Graph 1).

Table 3: Baseline Demographic Characteristics of the Study Cohort (N=207)

Characteristic	Category	Number (%)
Age Group (Years)	30-40	150 (72.5%)
	40-50	30 (14.5%)

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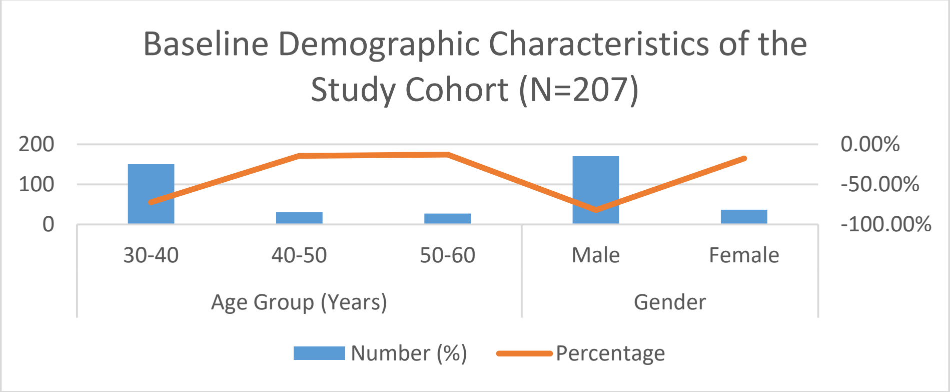
Characteristic	Category	Number (%)
	50-60	27 (13.0%)
Gender	Male	170 (82.1%)
	Female	37 (17.9%)

Graph 1: Baseline Demographic Characteristics of the Study Cohort (N=207)



Non-enhanced CT, serving as the gold standard, confirmed the presence of ureteric stones in 205 patients, yielding a disease prevalence of 99.0% in this symptomatic cohort. The overall diagnostic performance of ultrasound against CT is presented in Table 4.

Table 4: Overall Diagnostic Accuracy of Ultrasound vs. Non-Enhanced CT

	CT Positive (n=205)	CT Negative (n=2)
US Positive	185 (True Positives)	0 (False Positives)
US Negative	20 (False Negatives)	2 (True Negatives)

The metrics derived from this contingency table are as follows:
Sensitivity: 90.2% (95% CI: 85.3% - 93.6%)
Specificity: 100% (95% CI: 34.2% - 100%)
Positive Predictive Value (PPV): 100% (95% CI: 98.0% - 100%)
Negative Predictive Value (NPV): 9.1% (95% CI: 2.5% - 24.6%)
Overall Diagnostic Accuracy: 90.3% (95% CI: 85.5% - 93.7%)

3.1. Subgroup Analysis by Age

The diagnostic performance of ultrasound varied across different age groups. Sensitivity was highest in the youngest cohort (30-40 years) and showed a declining trend with increasing age. The results are summarized in Table 5.

Table 5: Diagnostic Performance of Ultrasound Stratified by Age Group

Age Group (Years)	Sensitivity (%)	False Negatives (n)	Specificity (%)

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Age Group (Years)	Sensitivity (%)	False Negatives (n)	Specificity (%)
30-40 (n=150)	92.6 (138/149)	11	100 (1/1)
40-50 (n=30)	86.2 (25/29)	4	100 (1/1)
50-60 (n=27)	81.5 (22/27)	5	N/A (0/0)

3.2. Subgroup Analysis by Gender
A higher sensitivity was observed in male patients compared to female patients. The distribution of false-negative results was also analyzed by gender.

Table 6: Diagnostic Performance of Ultrasound Stratified by Gender

Gender	Sensitivity (%)	False Negatives (n)	Specificity (%)
Male (n=170)	91.1 (155/170)	15	100 (0/0) *
Female (n=37)	85.7 (30/35)	5	100 (2/2)

3.3. Analysis of Stone Characteristics on CT
Among the 20 false-negative cases on ultrasound, CT provided further insight. The majority of missed stones (n=16, 80%) were located in the mid-ureter. Furthermore, the mean size of stones missed by ultrasound was significantly smaller (3.1 ± 1.2 mm) compared to the mean size of all stones detected on CT (5.8 ± 2.4 mm).

Table 7: Characteristics of Stones Missed by Ultrasound (False Negatives, n=20)

Characteristic	Value
Location	
Proximal Ureter	2 (10%)
Mid-Ureter	16 (80%)
Distal Ureter	2 (10%)
Mean Size (±SD)	3.1 mm (±1.2 mm)
Presence of Hydronephrosis	15 (75%)

4. Discussion
This study provides a comprehensive evaluation of ultrasound's diagnostic accuracy for ureteric stones in a high-prevalence symptomatic population. The overall findings confirm that ultrasound is an excellent tool for confirming the presence of a stone (high specificity and PPV of 100%) but is insufficient

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to rule it out due to a sensitivity of 90.2% and a critically low NPV of 9.1%.

The novel subgroup analyses offer deeper insights into the factors influencing ultrasound's performance. The observed decline in sensitivity with increasing age (from 92.6% in 30-40 years to 81.5% in 50-60 years) is a significant finding. This is likely attributable to age-related anatomical changes, such as a higher likelihood of overlapping bowel gas and decreased tissue clarity, which can obscure sonographic visualization of the ureters (Cheng et al., 2018). This suggests that a negative ultrasound in an older patient with colic should be interpreted with even greater caution.

The difference in sensitivity between genders (91.1% in males vs. 85.7% in females), while not drastic, is noteworthy. This may be influenced by body habitus, as a higher body mass index (BMI) can attenuate ultrasound beams and reduce image resolution. Although BMI was not individually analyzed in this subgroup, epidemiological trends could partly explain this variance.

The analysis of false-negative cases provides the most clinically relevant explanation for ultrasound's limitations. The fact that 80% of missed stones were located in the mid-ureter aligns perfectly with established literature; this segment is notoriously difficult to visualize due to overlying bowel loops and the iliac vessels (Ray et al., 2010). Furthermore, the significantly smaller size of missed stones (mean 3.1 mm vs. 5.8 mm) underscores a fundamental limitation of ultrasound in detecting very small calculi. Interestingly, 75% of these missed stones were associated with secondary hydronephrosis. This indicates that while hydronephrosis is a crucial indirect sign, its presence does not guarantee direct stone visualization and should not be solely relied upon to confirm a diagnosis, as the obstruction could be due to other causes.

In conclusion, while ultrasound remains a valuable first-line tool due to its safety and accessibility, its diagnostic efficacy is modulated by patient age, gender, and stone characteristics. Our results advocate for a nuanced imaging protocol: ultrasound is sufficient for positive findings, but in cases of high clinical suspicion with a negative scan especially in older patients, for small stones, or when pain localizes to the mid-ureter a low-dose non-enhanced CT is indispensable to prevent missed diagnoses and ensure appropriate patient management.

However, the sensitivity of 90.2%, while respectable, indicates that ultrasound failed to detect 20 out of 205 stones (9.8%). This false-negative rate is clinically significant. The negative predictive value (NPV) was critically low at 9.1%, meaning that a negative ultrasound result in this high-prevalence, symptomatic population is highly unreliable for ruling out a stone. This is likely due to technical limitations of ultrasound, such as obscuration by overlying bowel gas, patient body habitus, or the location of the stone (e.g., mid-ureteric stones are notoriously difficult to visualize sonographically) (Ray et al., 2010).

Our findings align with some previous studies but show a higher sensitivity than the often-cited pooled estimate of 45% (Ray et al., 2010). This discrepancy may be attributed to advancements in ultrasound technology (e.g., higher-resolution probes, twinkling artifact on Doppler), the expertise of the performing radiologist, and the specific study population. Our results are more in line with recent literature that suggests ultrasound can have good sensitivity, especially when performed by experienced operators (Cheng et al., 2018).

The clinical implication of our findings is clear: Ultrasound is an excellent rule-in tool. It can rapidly and safely confirm a suspected ureteric stone without exposing the patient to radiation. However, it is a poor rule-out tool. In a patient with a high clinical suspicion of ureteric colic but a negative or inconclusive ultrasound, proceeding to a non-enhanced CT scan is necessary to avoid missed diagnoses and potential complications like obstruction and infection.

5. Conclusion

In conclusion, this study provides valuable local evidence that ultrasound has high specificity and perfect positive predictive value for diagnosing ureteric stones, making it a reliable first-line imaging test for confirmation. However, its limitations in sensitivity and particularly its very low negative predictive value preclude its use as a standalone rule-out modality. A diagnostic algorithm that utilizes ultrasound initially, reserving CT for cases with high clinical suspicion and negative sonographic findings,

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represents a balanced approach that maximizes diagnostic accuracy while striving to minimize radiation exposure.

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