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Diagnostic Accuracy of Twinkling Artefact on Color Doppler Ultrasound to Diagnose Urinary Tract Stones taking Unenhanced CT-KUB as Gold Standard

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ABSTRACT

Background: The Unenhanced CT-KUB has remained the gold standard for diagnosing urolithiasis with high level of diagnostic accuracy. There are, however, concerns about radiation exposure and higher cost which arises the need for alternative imaging techniques. The twinkling artifact color Doppler ultrasound has gained attention as a potential technique in the diagnosis of urinary tract stones without these concerns. This study was therefore planned to determine the diagnostic accuracy of this technique in the diagnosis of urinary tract stones taking unenhanced CT-KUB as gold standard. **Material and methods:** This cross-sectional (validation) study was carried out at the Department of Diagnostic Radiology, CMH Multan, from July 2024 to December 2024. A total of 170 patients aged between 20 to 65 years, with complaints of flank pain, hematuria or dysuria for ≤ 7-days were added in this study. All the patients underwent twinkling artefact on color Doppler ultrasound and unenhanced CT-KUB for the diagnosis of urolithiasis. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of twinkling artefact on color Doppler ultrasound were determined taking unenhanced CT-KUB as Gold standard. **Results:** Age range of patients was 25-65 years with mean age of 43.2±10.4 years. Male comprised of 63% of total study population while females comprised of 37%. Twinkling artefact on color Doppler ultrasound diagnosed 148 (87%) patients while unenhanced CT-KUB diagnosed 143 (84%) of patients with urinary track kidney stones. Doppler twinkling artefact demonstrated sensitivity of 95%, specificity of 56%, positive predictive value 92%, negative predictive value 68% and diagnostic accuracy of 89% (p <0.0001). **Conclusion:** Twinkling artifact color Doppler ultrasound demonstrates high sensitivity and diagnostic accuracy for urinary track stones, offering a promising alternative to unenhanced CT-KUB.

INTRODUCTION

Flank pain is a common clinical symptom that often leads to emergency department visits, with urinary tract obstruction due to calculi being the most prevalent etiology of the condition. The global data indicate that approximately 10% of the population during their lifetime suffer from urinary tract stones (UTS), also known as urolithiasis.[1,2] This data also shows a steady increase in the disease over recent decades offering significant challenges to healthcare system. There is also a notable variability in stone disease prevalence in different regions of the world, pointing towards the involvement of dietary habits, metabolic disorders, hereditary and environmental factors.[3,4]

UTS are primarily composed of calcium oxalate, uric acid, struvite, or cystine and form due to supersaturation of urinary solutes. These stones can cause acute flank pain, hematuria, and urinary obstruction.[5] The diagnostic evaluation of UTS involves both clinical assessment and imaging techniques. The Unenhanced Computed Tomography of the kidneys, ureters, and bladder (KUB) also abbreviated as unenhanced CT-KUB has remained the gold standard for detecting UTS due to its high sensitivity (95–98%) and specificity (96–100%). There are, however, concerns about radiation exposure and higher cost which arises the need for alternative imaging techniques.[6]

Ultrasonography (USG) is a widely available imaging tool both as B-mode (grayscale) and color Doppler capabilities for evaluating urinary tract anatomy without ionizing radiations. As a safe and cost-effective option, it is particularly valuable in pregnancy, pediatrics, and cases requiring repeated imaging. While B-mode USG has traditionally served as the first-line diagnostic tool for urolithiasis, its effectiveness is limited by operator skill, patient body habitus, and stone characteristics which results in variable sensitivity (19-93%) in different

studies. Despite these limitations, USG remains a cornerstone in urinary tract evaluation due to its accessibility, affordability, and non-invasive nature.[7,8]

The twinkling artifact (TA), is a color Doppler phenomenon characterized by a rapidly alternating red and blue color signal behind highly reflective structures such as UTS. This specific artifact has gained attention as a potential tool to enhance the diagnostic accuracy of USG in urolithiasis. The physical basis of TA lies in the complex interaction between the USG beam and the rough surface of calculi, resulting in multiple reflections that are interpreted by the color Doppler as flow. By improving this contrast against surrounding tissues, the TA enhances stone detection, which serves as a valuable adjunct in USG evaluation.[8,9] With all the advantages offered by the technique, diagnostic accuracy of Doppler twinkling artifact (DTA) varies greatly among studies, depending on the size of stone, composition, and its location. The challenges also arises by the false positives results from vascular calcifications, bowel gas, and metallic objects, however, standardizing Doppler settings and refining ultrasound protocols could improve its clinical reliability and utility.[9]

As discussed above, the concerns about gold standard technique unenhanced CT-KUB related to radiation exposure make alternative imaging method a crucial research topic, especially for young patients. Urolithiasis is common disease in Pakistan and affects approximately 12% of the population.[10] With this high prevalence of the disease, there is a critical need for a safe, easily accessible, and affordable diagnostic method, especially in our limited healthcare facilities with budget constraints.

This study was therefore planned to determine the diagnostic accuracy of DTA in the diagnosis of UTS taking unenhanced CT-KUB as gold standard. The findings of this study will help to establish the DTA as a preferred first-line imaging modality, potentially reducing reliance on CT-KUB. This shift can provide a cost-effective, widely accessible, and non-invasive diagnostic alternative with minimized radiation exposure for our local health care settings.

METHODOLOGY

This cross-sectional (validation) study was conducted at the Department of Diagnostic Radiology, CMH Multan, from July 2024 to December 2024 over a period of 6 months after getting approval from ethical committee of the hospital.

Sample size was estimated as per following details:

Prevalence of urolithiasis = 57.5%, sensitivity of DTA = 54.33%, specificity of DTA=94.68%, desired precision=10% and confidence interval=95%,

The estimated sample size (n) =166.[11]

A total of 170 patients aged between 20 to 65 years, belonging to either gender and suspected with renal/ureteric colic for ≤ 7-days (Flank pain, hematuria or dysuria) were included in this study through consecutive sampling.

Exclusion Criteria

was set as, patients with a history of surgery due to urolithiasis, having BMI ≥ 30 kg/m2 and pregnancy.

- A consent form was obtained from each patient prior to their inclusion in the study.
- All the related demographics and clinical history was taken from each patient.
- All the patients underwent DTA of KUB and unenhanced CT-KUB for the diagnosis of urolithiasis.

Color Doppler Ultrasound with a high-frequency transducer and protocol-based configurations and optimized settings was used to maximize the detection of TA. Pulse repetition frequency and gain were adjusted to minimize aliasing and enhance artifact visibility while reducing background noise. Simultaneous gray-scale and color Doppler imaging was done to enable the cross-referencing of anatomical structures with TA. A positive TA was documented when a dynamic multicolor signal variation was detected at an echogenic focus, which confirmed a UTS. All imaging procedures utilized a Toshiba 160-slice CT scanner without administering oral or intravenous contrast agents, incorporating automatic tube current modulation technology. Standard imaging parameters were adopted including a tube voltage of 120 kVp, a tube current range of 270-350 mAs, a slice thickness of 5 mm, and a reconstruction thickness of 1.25 mm.

Two consultant radiologists with ≥ 5-year post fellowship experience separately reported the findings of DTA KUB and unenhanced CT-KUB. The radiologist reported the presence of calculi (yes/no), location (renal, pelvis, ureter), size (in mm), and number of all calculi present.

All the obtained data was be noted on proforma designed for the study.

The data obtained were analyzed through SPSS version 26. Age, BMI, number and size of calculi were presented as mean and standard deviation. Gender, presence of obesity, presence of calculi and location of calculi were presented as frequency and percentages. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy for DTA were determined taking unenhanced CT-KUB as Gold standard. Chi-square test was applied with 95% confidence interval and taking a p-value <0.05 as statistically significant for the analyses.

Results:

Age range of patients in this study was 25-65 years with mean age of 43.2±10.4 years. The demographic details, clinical and sonographic findings are shared in Table-I.

Table I

Demographics, clinical and sonographic findings (n=170)

Demographics		
Age (Mean±SD) years		43.2±10.4
Gender	Male n (%)	107 (63)
	Female n (%)	63 (37)
Presenting symptoms	Flank pain n (%)	93 (55)
	Hematuria n (%)	16 (9)
	Dysuria n (%)	3 (2)
	≥2 symptoms n (%)	58 (34)
Location of stones (as per diagnosed with DTA*)	Kidney n (%)	101 (59)
	Upper ureter n (%)	28 (17)
	Mid ureter n (%)	22 (13)
	Lower ureter n (%)	19 (11)

Doppler twinkling artefact*

The DTA technique diagnosed 87% of patients with UTS while unenhanced CT-KUB diagnosed 84% patients with UTS as shown in Table-II.

Table II

Results of DTA and unenhanced CT-KUB in the diagnosis of UTS (n=170)

UTS*	DTA**	CT-KUB***
Positive n (%)	148 (87)	143 (84)
Negative n (%)	22 (13)	27 (16)
Total n (%)	170 (100)	170 (100)

Urinary tract stones*, Doppler twinkling artefact**, Unenhanced Computed Tomography of kidneys, ureters & bladder***

DTA showed good overall performance when compared with the gold standard method of CT-KUB for diagnosis of UTS. DTA demonstrated a sensitivity of 95.12% and specificity of 55.56%, indicating its strong ability to identify positive cases and also good at ruling out negative ones. The test showed PPV of 91.9% and NPV of 68.2%, suggesting reliability of the method in both positive and negative test results. The overall diagnostic accuracy was 89% (p <0.0001) as presented in Table-III.

Table-III

DTA sensitivity, specificity and predictive values (n=170)

DTA*	Results
Sensitivity	95 %
Specificity	56 %
PPV	92 %
NPV	68 %
Diagnostic accuracy	89 %

Doppler twinkling artefact*

In direct comparison with CT-KUB, TDA demonstrated utility as a diagnostic tool for UTS as shown in Table-IV.

Table IV

DTA versus unenhanced CT-KUB for diagnosis of UTS (n=170)

DTA*	Unenhanced CT-KUB**		Total
	Positive	Negative	
Positive	136 (TP)	12 (FP)	148
Negative	7 (FN)	15 (TN)	22
Total	143	27	170

Doppler twinkling artefact*, Unenhanced Computed Tomography of kidneys, ureters & bladder**

TP =True positive, **FP** = False positive, **FN** = False negative, **TN** = True negative

DISCUSSION

Age range of patients in our study was 25-65 years with mean age of 43.2±10.4 years. Male comprised of 63% of total study population while females comprised of 37%. Twinkling artefact on color Doppler ultrasound diagnosed 148 (87%) patients while unenhanced CT-KUB diagnosed 143 (84%) of patients with urinary track kidney stones. DTA demonstrated sensitivity of 95%, specificity of 56%, PPV 92%, NPV 68% and diagnostic accuracy of 89% (p <0.0001).

Arshad S et al. assessed the diagnostic accuracy of TA in detecting nephrolithiasis, using CT-KUB as the gold standard and showed that the DTA had a sensitivity of 75.6%, specificity of 46.1%, PPV of 80% and NPV of 40%, with an overall diagnostic accuracy of 68%. These findings suggested that while the TA is useful for screening and detecting renal stones with its relatively high sensitivity and PPV, its lower specificity and NPV indicate a likelihood of false positives results.[12] Similar findings were reported by Rashid A et al. where DTA, combined with gray-scale USG, achieved a diagnostic accuracy of 85.3% for ureteric stones, with high sensitivity (90.4%), moderate specificity (73.9%), a PPV of 88.7%, and a NPV of 77.2%. While highly effective in detecting stones, Doppler artifact may generate false positives, necessitating CT confirmation in uncertain cases.[13]

Studies examining specifically smaller stones have also demonstrated the value of DTA. The study by Letafati M assessed the accuracy of the DTA in detecting renal stones smaller than 4 mm, using non-contrast CT as the gold standard. DTA showed a sensitivity of 76.8%, specificity of 100%, PPV of 100%, and NPV of 32.4%**.** The study also concluded that DTA is a reliable indicator for detecting small renal stones. However, its diagnostic sensitivity improves when it is combined with grayscale USG findings.[14]

Adel H et al conducted a study in patients presenting with the symptoms of urolithiasis to find the diagnostic accuracy of DTA keeping non-contrast CT as gold standard. DTA demonstrated a sensitivity of 54.33%, high specificity of 94.68%, and an overall diagnostic accuracy of 71.49% for detecting urinary tract calculi. The PPV and NPV were reported to be 93.24% respectively. While the study offered a strong specificity, its lower sensitivity limited its standalone use.[11]

Bacha R et al. compared the diagnostic accuracy of gray-scale USG and DTA as diagnostic tool for UTS. The results showed that although gray scale US had a high sensitivity (96.1%) but low specificity (57.9%) while the DTA demonstrated both perfect sensitivity (100%) and high specificity (97.4%), making it a highly reliable diagnostic tool, especially in cases with small UTS of <5mm size.[15]

Abid A et al evaluated DTA's diagnostic accuracy for renal and ureteric calculi against CT-KUB. Results showed sensitivity 91.2%, specificity 95.7%, PPV 98.7%, NPV 75.2%, and diagnostic accuracy 92.2%. These strong metrics proved DTA as a reliable method for urinary calculi detection, making it a viable alternative where CT is unavailable.[16] Similar findings were shared by Hanafi MQ et al. where accuracy of DTA was evaluated, using unenhanced CT as the gold standard. The mean stone size measured by CT (3.43 ± 0.80 mm) and US (3.49 ± 0.82 mm) showed no significant difference (p= 0.603). DTA demonstrated 94% sensitivity, 94% accuracy, and 100% PPV for detecting small urinary stones and found that DTA is a highly sensitive and reliable alternative to CT-KUB for detecting urolithiasis ≤5 mm.[17]

While individual studies show varying results, a meta-analyses by Nabheerong P et al. comprised of 16 studies with 4,572 patients provided a more comprehensive view of twinkling artifact's diagnostic utility. The meta-analysis revealed a sensitivity of 86% (95% CI: 72-94%) and specificity of 92% (95% CI: 75-98%). There was a positive likelihood ratio of 11.3, and the negative likelihood ratio of 0.2. The overall diagnostic accuracy is reflected in the impressive diagnostic odds ratio of 75.5, indicating strong discriminatory power. These metrics confirm that the DTA is a valuable aid in urolithiasis diagnosis, reducing the

need for additional imaging while ensuring high diagnostic confidence in clinical use.[18]

The results of our study and the studies discussed above confirm DTA as a valuable tool for urolithiasis, maintaining diagnostic confidence for the clinicians.

Our study was a single center study and involved a relatively small sample size, hence the results can't be generalized to diverse patient populations. Future studies with a multi-center design and larger sample size will add up in this data regarding use of DTA in the diagnosis of UTS.

CONCLUSION

DTA demonstrates high sensitivity and diagnostic accuracy for detecting UTS. This technique offers a promising, non-invasive alternative to unenhanced CT-KUB, potentially reducing radiation exposure and associated costs while maintaining reliable diagnostic performance in the detection of urolithiasis.

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