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Diagnostic Accuracy of Doppler Twinkling Artifacts in Diagnosing Smaller than 5mm Urolithiasis

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ABSTRACT

Background: The Doppler twinkling effect has also become a promising adjunctive method to improve the ultrasound image of small urinary stones. The aim of the current research was to determine the diagnostic accuracy of the Doppler twinkling artifact in detecting urolithiasis with a diameter less than 5mm using non-contrast computed tomography of the kidneys, ureters, and bladder (CT-KUB) as the reference standard.

Methods: This cross-sectional validation study carried out at the Department of Radiology, Indus hospital and health network, Karachi, between the months of August 2025 and March 2026. The sample comprised 134 patients aged between 20 and 80 years old and whose chief complaint was acute flank pain, which was followed by sequential grayscale and color Doppler ultrasonography, then non-contrast CT-KUB. The twinkling artifact in the Doppler imaging was noted and its diagnostic capability evaluated. All the essential diagnostic accuracy parameters were evaluated and stratified analysis was done on the basis of age, gender and duration of onset of symptoms.

Results: Study was male dominant with 62.7% of male population and mean age of the total study population was 50.4±18.46 years. Urolithiasis was positive in 38.1% of enrolled subjects on non-contrast CT. Doppler twinkling artifact demonstrated a sensitivity of 86.3%, specificity of 92.8%, PPV of 88.0%, NPV of 91.7%, and overall diagnostic accuracy of 90.3%. The accuracy of the diagnosis had been found to be consistent across gender, age groups, and symptom duration with the overall accuracy ranging between 87.5% and 93.0%.

Conclusion: The Doppler twinkling artifact is a noninvasive, radiation-free, reliable imaging adjunct, which has high diagnostic accuracy in detecting urolithiasis less than 5mm. Its systemic integration with ultrasound assessments would make it less reliant on computed tomography particularly in resource-limited contexts.

Keywords: accuracy, computed tomography, doppler, twinkling artifact, ultrasound, urolithiasis.

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Introduction

Nephrolithiasis refers to kidney /renal stone formation. When these stones exit the kidney, they are located in renal pelvis or anywhere in the urinary tract such as ureter, it is referred to as urolithiasis. (1,2) Majority of stones are made of calcium oxalate and / or phosphate.

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Other types include struvite, uric acid and cysteine. (3) Poor oral fluid intake, high intake of animal proteins, high intake of oxalate containing foods and increased intake of salt are some of the factors for urolithiasis and nephrolithiasis. (4) The common locations of obstructing calculi include pelviureteric junction (PUJ) and ureterovesical junction (UVJ).The stones in ureter result in colicky pain because they result in increased luminal tension and release of prostaglandins. (5,6) Common presenting symptoms include acute right or left flank pain with or without hematuria. Abdominal examination is usually unremarkable. Due to the colicky in nature, the pain often waxes and wanes. (7) It has been reported that prevalence of urinary tract calculi is approximately 24.9% in Pakistani population. (8)

Ureteral stones under 5 mm should be prudently managed because their size appears to determine their passage. Urological referral is necessary for stones over 4 mm. Patients with stones larger than 5 mm and ureteral stones that have not passed after two to four weeks should see a urologist. Non-contrast computed tomography (NCCT) is the current gold standard to use in the evaluation of acute flank pain and has superseded intravenous urography (IVU). The initial, radiation-free imaging modality is ultrasound, though NCCT is reserved as a means to confirm diagnosis if needed, especially in younger patients, during pregnancy and for follow up (9,10) Moreover, by applying Doppler twinkling artifact, the accuracy can be improved. In calculi less than 5.0 mm, the application of Doppler twinkling artifact yields higher diagnostic accuracies (11).

The diagnostic value of the twinkling artifact with urinary calculi as a whole is known, but it is comparatively under investigated in patients having smaller calculi (<5 mm) and in patients in whom grayscale ultrasound fails most of the time. So, robust local data on this subgroup are scarce. The present study not only addresses this gap by isolating calculi measuring less than 5 mm but also benchmarks the twinkling artifact directly against NCCT, using the reference standard, and provides stratified diagnostic-performance data from a Pakistani populace extending previous accuracy studies, rather than duplicating them.

Methods

Following the approval of institutional review board of Indus Hospital & Health Network through letter number IHHN-IRB # IHHN_IRB_2025_12_003 issued on 1st January 2026 as well as prior approval of CPSP, this cross-sectional validation study was conducted from August 2025 to March 2026 in the Radiology Department. The study was designed and reported in accordance with the Standards for Reporting Diagnostic Accuracy Studies (STARD 2015) guidelines. Informed consent was obtained in writing with the help of all the participants prior to enrolment. Non-probability consecutive sampling was used to incorporate 134 patients; where, sample size was calculated using Dr. Lin Naing calculator and taking sensitivity as 94% (12), specificity as 94.68% (13), margin of error 3%, prevalence of urinary calculi as 24.9% (8) and confidence level as 95%. Eligible subjects were adult patients aged 20 -80 years who had an acute onset of severe flank pain (one or more episodes of 1 hour or longer) with stone size <5mm, and were referred to non-contrasted computed tomography (CT)- kidneys, ureters, urinary bladder (CT-KUB). Patients who have a history of urinary tract infection, previous diagnosis of nephrolithiasis with follow-up, renal malignancy, acute or chronic renal failure, or refused consent were not included. After detailed clinical analysis and physical examination, enrolled patients subjected to ultra-sonographic analysis of the kidneys, ureters, and urinary bladder with the help of Canon Xario 100 ultrasound machine using a 3.5 MHz transducer. Stone size was measured in mm with maximum diameter in any plane (sagittal, coronal or axial). A sonographer who had more than five years of experience co-registered grey-scale imaging and color Doppler examination and without knowledge of the CT results that would follow. The index test (Doppler twinkling artifact) was reported as positive when it was seen to contain a rapidly alternating color mosaic (red/blue/yellow). There was no quantitative cut-off that could be used. A blinded independent interpretation was conducted. False positives (n=6) were attributed to non-calcific twinkling or sub-CT-resolution fragment; false negatives (n=7) to composition of stone (uric acid), deep location, or very small size (<3mm).

Unenhanced helical CT-KUB was performed with 0.8mm slice thickness keeping 120kVp and smart mAs (50-250mAs) in axial, coronal and sagittal sections for the detection and characterization of urinary tract stones. A consultant radiologist with over eight years of experience interpreted the imaging and was blinded to the result of ultrasound. Urolithiasis was considered a hyper dense focus of any size located either in the kidneys, ureters or in the urinary bladder on CT. Analysis of the data was done in SPSS version 22. Mean and standard deviation were used to report quantities variables; frequencies and percentages were used to report qualitative variables. The diagnostic accuracy of the Doppler twinkling artifact was measured in terms of sensitivity, specificity, PPV, NPV, and overall accuracy with 95% confidence interval using a 2x2 contingency table with the gold standard of non-contrast CT. Stratified analyses were done to determine the possible effect modifiers such as age group, gender, and duration of symptoms in reference to diagnostic performance. ROC analysis wasn't performed due to the binary nature of the data.

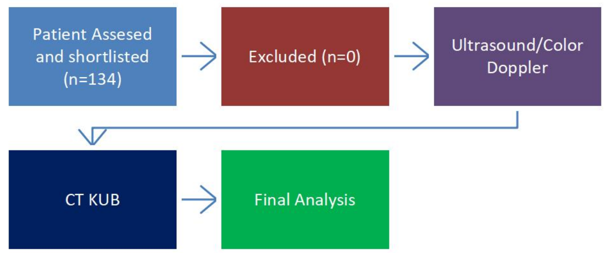

Figure 1: Graphical Presentation of study methodology

Results

Analysis of the collected data reflected that the mean age of the patients was 50.4±18.46 years and all the patients were further categorized in two age groups. Study population was male dominant with 62.7% of males and more than half of the patients belonged to age group of 20-50 years. Mean duration of flank pain was 24.84±12.67 hours. There was no much difference in the mean stone size measured by the CT and ultrasound which was 1.18±1.69mm for ultrasound and 1.19±1.67mm for CT. We further analyzed that more than 82% of the patients presented after 12 hours of onset of symptoms. Moreover, stones were identified in 38.1% of patients on grayscale ultrasound but twinkling artifact was observed in 37.3% of patients on doppler. Gold standard i.e. non-contrast CT confirmed stones in 38.1% patients. Detailed analysis of all the qualitative variables is shown in table 1 and locations of stones on CT and ultrasound is graphically presented in figure 1.

Upon cross tabulation we ruled out 44 patients were true positive and 77 were true negative. We further analyzed that twinkling artifact demonstrated a decent sensitivity (86.3%) as well as specificity (92.8%) for detection of ureteric stones <5mm keeping non-contrast CT as gold standard (table 2). Stratification analysis illuminated a high diagnostic yield of doppler twinkling artifact for detecting <5mm urolithiasis. However, sensitivity was higher in female gender 95% and specificity was higher in male gender 96.2% and overall diagnostic accuracy was nearly similar and around 90% in both subgroups. Sub-group analysis on the basis of age demonstrated higher sensitivity and specificity in age group less than or equal to 50 years. Similarly, the patients who presented ≥12 hours showed somewhat higher sensitivity and specificity. Detailed stratification analysis is shown in table 3.

The stratification based on localization of stones was not performed due to the fact that the small population of patients in each of the anatomical compartments could impair the statistical validity and reliability of estimations of diagnostic accuracy. As a result, a location stratified analysis was not carried out.

Table 1. Distribution of Qualitative Variables (n = 134)

Variable	Category	Frequency	Percentage (%)
Gender	**Male**	84	62.7
	Female	50	37.3
Age Group (years)	**20–50**	71	53.0
	51–80	63	47.0
Occupation	**Job**	79	59.0
	Business	31	23.1
	Unemployed/ None	24	17.9
Duration of Symptoms	**< 12 hours**	24	17.9
	≥ 12 hours	110	82.1
Stone on Grayscale Ultrasound	**Yes**	51	38.1
	No	83	61.9
Twinkling Artifact on Doppler	**Yes**	50	37.3
	No	84	62.7
Stone on Non-Contrast Computed Tomography	**Yes**	51	38.1
	No	83	61.9

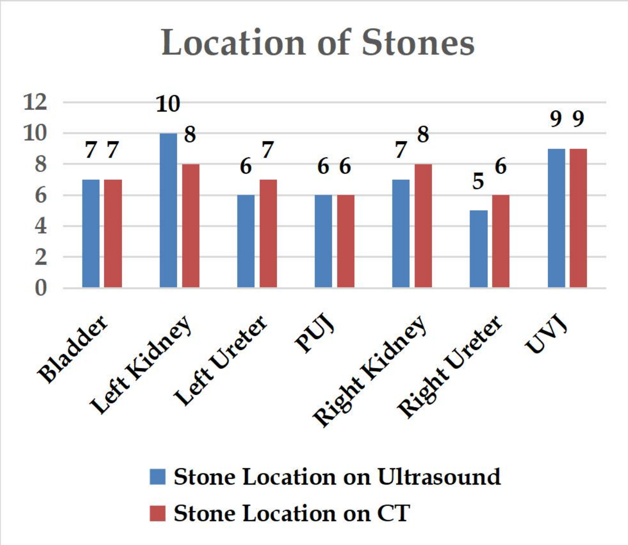

Figure 1. Frequency of stones at various locations on CT and ultrasound

Table 2: Diagnostic Performance of Doppler Twinkling Artifact Compared with CT (n = 134)

Twinkling Artifact	Stone on CT Positive	Stone on CT Negative	Total
Positive	44 (True Positive)	6 (False Positive)	50
Negative	7 (False Negative)	77 (True Negative)	84
Total	51	83	134

- **Sensitivity**: 86.3% (95%CI: 74.9-93.1)
- **Specificity**: 92.8% (95%CI: 85.1-97.3)
- **Positive Predictive Value (PPV)**: 88.0% (95%CI: 75.7-94.8)
- **Negative Predictive Value (NPV)**: 91.7% (95%CI: 83.9-96.3)
- **Overall Diagnostic Accuracy**: 90.3% (95%CI: 84.0-94.7)

Table 3: Stratified Diagnostic Accuracy of Doppler Twinkling Artifact (Using CT as Reference Standard)

Effect Modifier	Category (n)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy (%)
Gender	**Female**	95.0	86.7	82.6	96.3	90.0
	Male	80.6	96.2	92.6	89.5	90.5
Age Group (years)	**20–50**	92.3	93.3	88.9	95.5	93.0
	51–80	80.0	92.1	87.0	87.5	87.3
Duration of Symptoms	**<12 hours**	83.3	91.7	90.9	84.6	87.5
	≥12 hours	87.2	93.0	87.2	93.0	90.9

NPV: Negative Predictive Value, PPV: Positive Predictive Value,

Discussion

This research shows that Doppler twinkling artifact is a very precise non-invasive imaging modality in detecting urolithiasis less than 5 mm with a high sensitivity value (86.3%), specificity (92.8%), and general diagnostic capability compared to non-contrast CT as the reference modality. The results of the study emphasize the diagnostic importance of the Doppler twinkling artifact in a regular ultrasound examination, especially when a patient comes with acute pain in his or her flank.

The diagnostic performance observed is similar to and in other parts corroborates other previously published studies. According to Hanafi et al. (12) twinkling artifact had a sensitivity of 94% in identifying urinary calculi less than 5 mm, and was as such more helpful in the detection of small stones where grayscale ultrasound could be at a disadvantage. On the same note, Adel et al. (13) also achieved high specificity (94.68%) of the twinkling artifact as a predictor of the urinary tract calculi. The sensitivity in this present study is a bit lower, but this difference can be linked to operator dependence, patient-related factors, stone composition and anatomical location which are known to affect the visibility of the twinkling artifact. The reported sensitivities vary between 71 - 99 % and specificities between 56 - 100 % across local and global literature which used non-contrast computed tomography as a reference standard (14,15,16,17,18). Studies that have looked into microlithiasis (<5mm) have demonstrated better detection using the twinkling artifact than using grayscale ultrasound (only) (14,18,19). The studies of Pakistani are also showing similar diagnostic accuracy, which supports the application of this technique in local conditions (15,16,17). The difference in specificity noted in certain studies can be explained by the fact that they used the twinkling artifact alone without the presence of the signs of complementary grayscale or shadowing as pointed out by Masch et al. (20). In general, the existing data supports the twinkling artifact to be used as a useful addition to ultrasound to avoid the use of computed tomography.

In the present study, twinkling artifact identified stones where grayscale ultrasound had failed and this supports the importance of twinkling artifact as a supplementary tool and not a substitute to the traditional ultrasound. On grayscale imaging alone, small stones especially those which do not have a distinct posterior acoustic shadowing can be easily overlooked. Color Doppler is added to enhance detection on the basis of exploiting the rough reflective surface of calculi, which generates the characteristic alternating color signal in short bursts (21,22). There were six false positive tests noted. The ones most likely were caused by twinkling due to vascular calcifications, parenchymal calcifications, crystalline deposits, or other highly reflective interfaces that caused Doppler signal fluctuations even in the absence of urinary stones. This is similar to what was observed in the past. There were seven cases of false negative following CT diagnosis of calculi. The extremely small size of stones (<3 mm), stones further from the kidney, poor acoustic windows, lack of surface irregularity, and stone type due to uric acid may have all contributed to the absence of the twinkling phenomenon in these cases.

Stratified analysis also revealed that diagnostic accuracy of twinkling artifact was consistently good in various subgroups. The difference between genders in terms of sensitivity was more common among female patients; however, the difference in specificity was more prominent among male patients; the overall accuracy between the genders was similar. Equally, the diagnostic performance was minimally higher in younger patients and in patients with the longest period of onset, perhaps because of greater obstruction-related changes or higher stone conspicuity with age. Such results indicate that twinkling artifact has a good level of reliability when applied within a broad clinical range and is not strongly affected by low-level demographic variables.

Clinically, this study is of special interest to resource-constrained practices, including those found in Pakistan, in which CT access might be limited and radiation exposure an issue. Considering the large incidence of urolithiasis among the local population and the many patients presenting with acute flank pain, Doppler ultrasound with twinkling artifact evaluation is an inexpensive, radiation-free, and an easily accessible form of diagnosis, particularly in the initial examination and screening. It is a low cost, exposure-free, and accessible first line tool in resource constrained settings like Pakistan where access to CT may be compromised and radiation exposure could be a concern. A positive twinkling artifact in the right clinical situation could be used to help prioritize patients, where ultrasound is uncertain, if there is persistent clinical suspicion, or if complications like obstruction or infection are suspected, and could allow a reduction in the need for CT, rather than replacement of it.

The clear methodology, employment of the non-contrast CT as the gold standard, case of only small (less than 5 mm) stones, and the strong stratified analysis of diagnostic performance are among the main strengths of this study. The results provide meaningful local information, which fills a significant gap in the Pakistani literature on the diagnostic usefulness of the Doppler twinkling artifact.

However, there are several reasons why these findings should be interpreted with caution. The twinkling artifact is operator- and equipment-dependent and is influenced by Doppler parameters (such as pulse repetition frequency, colour gain, and the placement of the focal-zone), the type of transducer used, and patient body habitus. Artifacts can be confused with other echogenic or crystalline signals, such as vascular calcification, intrarenal calcifications, and Randall plaques. The effect depends on having a roughened, irregular reflecting surface, and false-negative results occur more often with very small, deep, and anterior stone locations; when the patient has large body habitus; and when the stone surface has a low reflectiveness, as seen with the low reflectability of the stones of the Durocher group. It is critical to be aware of these mechanisms when using the technique. In short, the standardized acquisition protocols and proper operator training will be important for the reproducibility between different institutions.

However, in spite of these strong points, there are some limitations to be taken into consideration. First, it was a single-center study, which does not allow one to generalize the results. Second, ultrasound is operator dependent and even though the examinations were conducted by trained sonographers interobserver variability was not evaluated. Third, the small number of cases in each anatomical site made stratification by location of stone anatomically insignificant, making location-specific inferences difficult. Also, the stone composition was not assessed, which could affect the existence and the strength of the twinkling artifact. The findings of these studies should be viewed in context of multicenter, prospective studies with interobserver assessment and stone-composition analysis to confirm the reproducibility and external validity of these findings.

Conclusion

Compared to non-contrast computed tomography, the color Doppler twinkling artifact provides high sensitivity, specificity and overall diagnostic accuracy in detecting urolithiasis less than 5mm. The method is also consistent across various age cohorts, genders and symptom duration, which further strengthens its soundness as a diagnostic instrument. Considering that it is non-invasive, does not involve ionizing radiations and is commonly available in the market, integration of color Doppler evaluation in the standard practice of ultrasonography can greatly improve early detection of small stone in the urinary tract. Non-contrast CT is still the gold standard but the use of Doppler twinkling assessment may add to the confidence of ultrasound diagnosis and help to make clinical decisions, especially when immediate CT scanning is not available. The results have to be confirmed in larger multicenter studies before wide-spread use in clinical guidelines.

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