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ORIGINAL ARTICLE

Diagnostic Value of Colour Doppler Twinkling Artefact in Detecting Nephrolithiasis

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ABSTRACT

Objectives: *To determine the sensitivity and specificity of adding colour Doppler ultrasonography, which demonstrates twinkling artefact in the presence of stones, to B-mode ultrasonography in the detection of nephrolithiasis.*

Methods: *This was a cross-sectional prospective study conducted in the Radiology Department from June 2016 to July 2017. Colour Doppler ultrasonography twinkling artefact assessment in addition to the conventional B-mode ultrasonography was performed on patients who were being investigated for nephrolithiasis with unenhanced computed tomography (CT). CT images were then correlated with sonographic findings. With CT as reference standard, the sensitivity and specificity of adding colour Doppler to B-mode ultrasonography were calculated.*

Results: *A total of 121 calculi were detected with CT in 47 of our 57 patients. Sensitivity of B-mode ultrasonography was 34.7% compared with 42.1% when additional colour Doppler ultrasonography was performed. The specificity was 72.2% and 62.9% respectively. Sensitivity and specificity differences of these two imaging approaches are statistically significant. Based on the size of the renal calculi, detection rate with merely B-mode ultrasonography alone was 18.8% for calculi <5 mm, 50.5% for calculi 5-9 mm, 100% for calculi 10-19 mm and 90.9% for calculi of ≥20 mm in measurement. The combined B-mode and colour Doppler ultrasonography had a corresponding sensitivity of 23.5%, 72.2%, 100% and 100%.*

Conclusion: *The use of colour Doppler in addition to the conventional B-mode ultrasonography slightly increases the sensitivity of nephrolithiasis detection with comparable specificity empirically. Although the overall sensitivity and specificity of ultrasonography are rather low, it remains as an important screening tool for renal calculus due to its availability, lower cost, non-invasive nature, and lack of ionising radiation.*

Key Words: *Calculi; Nephrolithiasis*

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中文摘要

彩色多普勒超聲閃爍偽影對檢測腎結石的診斷價值

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目的：檢視彩色多普勒超聲閃爍偽影添加到B超對檢測腎結石的敏感性和特異性。

方法：這項橫斷面前瞻性研究於2016年6月至2017年7月期間在我院的放射科進行。對平掃CT尿路成像診斷的腎結石患者作常規B超檢查外添加彩色多普勒超聲閃爍偽影評估。然後將CT圖像與超聲檢查結果相關聯。以CT為參考標準下，檢視將彩色多普勒超聲閃爍偽影添加到B超的敏感性和特異性。

結果：57名患者中，47例透過CT檢測共121粒結石。B超的敏感性為34.7%，添加彩色多普勒超聲閃爍偽影後的敏感性為42.1%；特異性分別為72.2%和62.9%。兩種檢查方法的敏感性及特異性均有明顯差異。單以B超檢查發現小於5毫米腎結石的檢出率為18.8%、5-9毫米腎結石50.5%、10-19毫米腎結石100%，20毫米或以上腎結石90.9%。結合B超和彩色多普勒超聲的相應敏感性為23.5%、72.2%、100%和100%。

結論：與常規B超檢查比較，結合彩色多普勒閃爍偽影檢查能稍微提高檢測腎結石的敏感度，特異性於實證上則相若。儘管超聲檢查的總體敏感性和特異性較低，但由於它的可用性、較低成本、非侵入性以及非電離輻射性質，它仍然是腎結石的重要篩查工具。

INTRODUCTION

Nephrolithiasis is a common condition in which calculi are formed in the kidneys. The epidemiology of nephrolithiasis differs according to geographical area in terms of prevalence and incidence, age and gender distribution, stone composition and stone location. Race, diet, socio-economic status and climate are thought to be the contributing factors of such differences.[1] The global prevalence of the condition has increased from 3.25% in the 1980s to 5.64% in the 1990s.[2] It has been predicted that its prevalence among people residing in susceptible regions would further increase from 40% in 2000 to 56% by 2050.[2]

The main diagnostic modalities used for detection of urinary tract calculi include ultrasonography and non-contrast computed tomography (CT) of kidneys, ureters and bladder. Although CT has been shown to be highly sensitive (94%-100%) and specific (92%-100%), it involves radiation exposure.[3] Therefore, ultrasonography has been established as a screening tool in the early detection of renal calculi as it is readily available, inexpensive, and does not emit radiation.[4] However, the detection rate reduces when a calculus is smaller than 3 mm in size or when a stone is located within a non-dilated pelvicalyceal system, thus jeopardising its reliability as a useful diagnostic device.[5]

The twinkling artefact, or colour comet tail artefact, is a colour Doppler phenomenon that appears as a rapid interchange of colour behind a static object.[6,7] This artefact may also be demonstrated during power Doppler and spectral Doppler scans, giving rise to appearance of seemingly random vertical lines that form a heterogeneous spectral expansion.[6]

The twinkling artefact is believed to be a form of intrinsic noise fluctuation within the Doppler circuitry of the ultrasonography equipment.[6,8] Another theory suggests that this artefact is created by a strongly reflecting medium with a coarse and irregular surface, causing numerous internal reflections in the medium, resulting in prolonged pulse duration of the transmitted sound signal.[7]

The detection of certain medical conditions such as nephrolithiasis, nephrocalcinosis, calcified renal lesions and vascular calcifications has shown promising outcome with the application of this scintillation phenomenon.[6] Its presence in the setting of urinary tract calculi is associated with an improved contrast-to-noise ratio when compared with posterior acoustic shadowing.[9] The twinkle sign appears to be unaffected by frequency of the ultrasound beam.[9] It is, however dependent on several machine settings, which include location of the focal zone, colour filter, grey-scale gain, colour-white priority, and pulse repetition frequency (PRF).[10,11] It is possible that this phenomenon can be utilised to improve the sensitivity and specificity of ultrasonography in the diagnosis of nephrolithiasis.

This prospective study was designed to evaluate the benefit of adding colour Doppler to B-mode ultrasonography in the detection of nephrolithiasis, using CT as the reference standard. It was hoped that the improvement in the detection of urolithiasis can obviate the need for CT in some patients, thus reducing radiation dose and the expenses involved in investigation.

METHODS

This was a cross-sectional prospective study conducted in the Radiology Department from June 2016 to July 2017. Inclusion criteria were patients who presented with symptoms such as colicky loin pain, recurrent urinary tract infections, or haematuria, who were subsequently investigated for nephrolithiasis with CT as requested by clinicians, when colour Doppler ultrasonography was performed in addition to the conventional B-mode ultrasonography. Exclusion criteria included patients who were incapable of giving consent, patients who were critically ill, and those who were deemed unfit to undergo ultrasonography. Patients with known nephrocalcinosis and those who had >10 calculi on CT were also excluded.

CT was performed with Siemens CT Somatom-64 in which participants were required to have a full bladder prior to the scheduled examination. The scan was then performed with the patient positioned supine on the gantry, scanning from the upper abdomen to symphysis pubis. Parameters set for this examination include 5-mm collimation, 120 kV, 200 mAs and reconstruction at 3-mm intervals. Oral, intravenous, or rectal contrast were not administered.

Sonographic examination was done on the same day as CT for each patient by a registrar who has 3-year radiology experience, using multiple new generation ultrasound scanners (Toshiba TUS-X200 and Philips HD11 XE) with curved-phase array transducers. The examiner was blinded to the findings of CT scan. Grey-scale ultrasonography was first carried out to detect any abnormal foci of renal echogenicity with posterior acoustic shadowing. Emphasis was given on the site and size of these abnormalities. Subsequently, colour Doppler ultrasonography was performed by applying the colour window onto the area(s) of interest and adjacent tissue, with the PRF set just above the threshold for colour mapping of the renal vessels (>60 cm/s). The operator then assessed for a twinkling artefact with attention given to the location of the abnormal signal and whether it was associated with the presence of renal echogenicity or posterior shadowing.

CT images were reviewed by two observers (radiologists) separately. In cases of disagreement, a consensus agreement on the radiological findings was reached. Sonographic findings were then correlated with CT, which was used as the gold standard. The sensitivity and specificity of adding colour Doppler to B-mode ultrasonography were calculated.

RESULTS

A total of 70 individuals were enrolled in the study. Thirteen of them with >10 calculi and nephrocalcinosis were excluded. The final patient cohort consisted of 57 patients (31 males and 26 females). Their age ranged between 25 and 78 years, with a mean of 55.3 years. Ethnically, there were 45 (78.9%) Malay, nine (15.8%) Chinese and three (5.3%) Indian patients.

Out of the 57 patients, 121 stones were detected in 47 of them on non-contrast CT. Nephrolithiasis was correctly diagnosed in 29 patients (61.7%) with conventional B-mode ultrasonography and 31 patients (66%) with the application of both B-mode and Doppler ultrasonography. Using only grey-scale ultrasonography, the sensitivity of calculus detection was 34.7% (42 calculi) with 72.2% specificity. The sensitivity increased to 42.1% (51 calculi) by using both B-mode and Doppler ultrasonography, with specificity of 62.9% (Table 1). Figures 1 and 2 show twinkling artefacts with calculi measuring 8 mm and 3 mm, respectively.

Table 1. Diagnostic indices of nephrolithiasis, using only conventional grey-scale ultrasonography and grey-scale plus colour Doppler ultrasonography with twinkling artefact assessment.

Diagnostic index	Ultrasonographic assessment	
	Grey-scale ultrasound (%)	Grey-scale and colour Doppler (%)
Sensitivity	34.7%	42.1%
Specificity	72.2%	62.9%
PPV	73.7%	68.9%
NPV	33.1%	35.8%
Accuracy	46.3%	49.2%

Abbreviations: NPV = negative predictive values; PPV = positive predictive values.

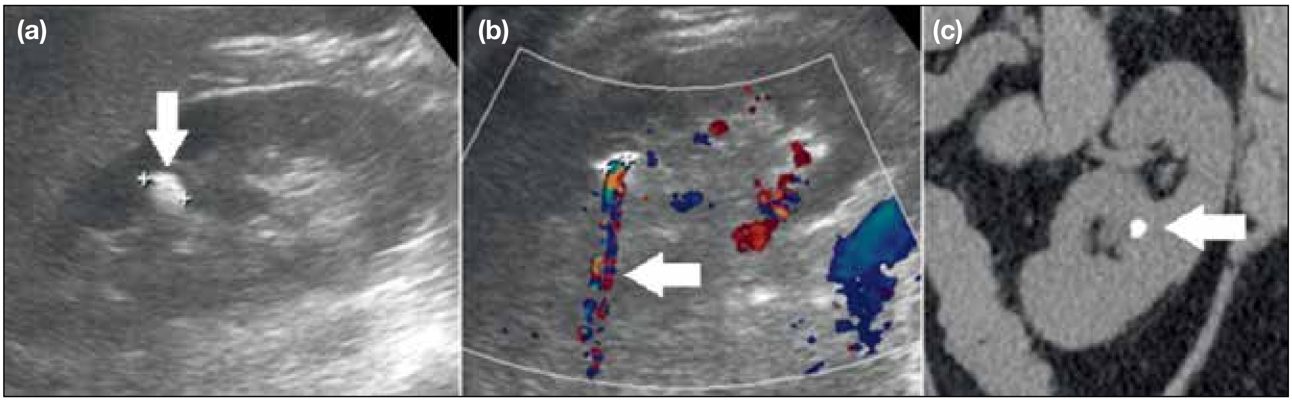

Figure 1. A 66-year-old woman with left flank pain. (a) Ultrasonograph showing echogenic focus (8 mm) with posterior acoustic shadowing (arrow) in the left kidney. (b) Colour Doppler ultrasonograph showing corresponding twinkling artefact (arrow). (c) Diagnosis of left nephrolithiasis was confirmed by computed tomography (arrow).

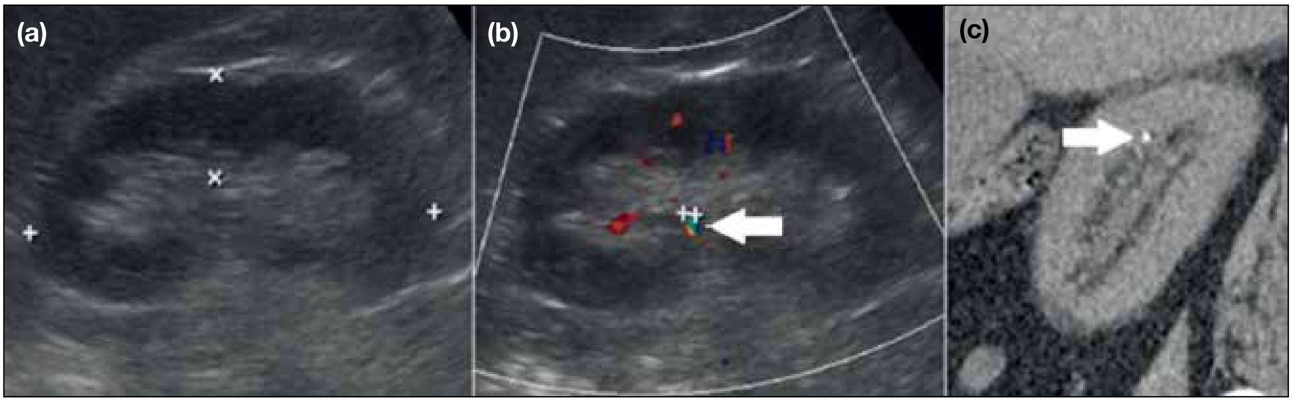

Figure 2. A 67-year-old woman who presented with microscopic haematuria. (a) Grey-scale ultrasonograph. (b) Colour Doppler ultrasonograph showing twinkling (arrow) in the right kidney corresponding to a stone (3 mm) that could not be distinguished from the renal sinus fat on the grey-scale ultrasonograph. (c) Computed tomography image confirmed that the twinkling sign was indicative of a stone (arrow).

The detection rate of nephrolithiasis varied based on size of the calculus. With conventional B-mode sonography alone, sensitivity of detection was 18.8% for calculi of 1-4 mm, 50.5% for calculi of 5-9 mm, 100% for calculi of 10-19 mm and 90.9% for calculi of ≥20 mm in diameter. The corresponding specificity was 91%, 39.1%, 100% and 100% (Table 2).

When complimentary colour Doppler was added to the examination, 23.5% of 1-4 mm calculi, 72.2% of 5-9 mm calculi, 100% of 10-19 mm calculi and 100% of calculi ≥20 mm in size were detected. The specificity was 55.6%, 37.5%, 100% and 100%, respectively (Table 2).

Table 2. Sensitivity and specificity of grey-scale ultrasonography and grey-scale plus colour Doppler ultrasonography with twinkling artefact assessment, based on the size of the renal calculi.

Size of renal calculi	Ultrasonographic assessment	
	Grey-scale only	Grey-scale and colour Doppler
<5 mm		
Sensitivity	18.8%	23.5%
Specificity	91.0%	55.6%
5-9 mm		
Sensitivity	50.5%	72.2%
Specificity	39.1%	37.5%
10-19 mm		
Sensitivity	100%	100%
Specificity	100%	100%
≥20 mm		
Sensitivity	90.9%	100%
Specificity	100%	100%

DISCUSSION

Non-contrast spiral CT remains the gold standard for diagnosing urinary calculi with promising sensitivity and specificity.[3,12] Nevertheless, exposure to ionising radiation following a CT examination is one of the main limiting factors of its clinical implementation, especially when children and young adults are involved.[8] Thus, ultrasonography, which is more readily available, inexpensive, and devoid of ionising radiation,[4] became another convenient alternative.

Literature on ultrasonography as a diagnostic tool for renal calculi is diverse. Vijayakumar et al[5] stated that complementing standard grey-scale sonogram with twinkling artefact assessment improves detection of urolithiasis. Likewise, Lee et al[13] reported that comet-tail artefact on colour Doppler had a sensitivity of 75% for calculi between 5 mm and 9 mm and 100% for stone <5 mm or >10 mm. Kielar et al[14] noticed that by adding Doppler evaluation, the sensitivity and positive predictive value for stones ranging from 1 mm to 9 mm in size improved from 80.2% to 83% and 64.9% to 94%, respectively. In a study by Shabana et al,[9] the twinkling sign increased the contrast-to-noise ratio when compared with posterior acoustic shadowing. Turrin et al[15] concluded that patients with urinary calculi are more likely to have twinkling phenomenon on their colour Doppler ultrasonography (95.5%) than were those without urinary calculi (9.0%). Studies by Korkmaz et al,[16] Yavuz et al,[17] and Aytaç and Ozcan[18] found that the Doppler phenomenon produced satisfactory results in detecting small calculi (≤5 mm), especially in the setting of equivocal findings on B-mode scanning.

The pattern of our results is similar to outcomes of the abovementioned studies, where the sensitivity was slightly higher when both B-mode and Doppler techniques were utilised together (42.1%), compared with sole grey-scale scanning (34.7%).

Ultrasonography gives a wide range of sensitivities in different studies, due to patient population, body habitus, technical variations, reference standards, location, and size of the calculus.[19] The overall detection rates in our study were low for both grey-scale and colour Doppler ultrasonography. This could be partly due to the larger numbers of calculi present in the studied population, where 121 calculi were found in 47 of our 57 participants (2.6 calculi/patient). A prospective study by Ahmad and Abdallah[7] concluded that sonographic examination with adjunct colour Doppler ultrasonography has a higher sensitivity (68%) in detecting urinary calculi than does posterior acoustic shadowing (62%) or echogenic focus on greyscale (58%); however, those authors found only 100 calculi in a sample size of 71 patients (1.4 calculi/person). A similar study design by Dillman et al[8] with sample cohort of 49 and confirmed urinary calculi of 132 from CT (2.7 calculi/person), came to a conclusion that twinkling artefact is relatively insensitive (55%) in routine practice with a high false-positive rate (51%). It could be technically challenging to identify and segregate each calculus with ultrasonography, especially when they are small and close to one another.

Other studies with similar results include Ulusan et al[20] and Fowler et al,[21] who considered ultrasonography a limited tool in the detection of nephrolithiasis. Sorensen et al[22] reported that B-mode is more sensitive than colour Doppler ultrasonography when each of them is applied separately. Hence, colour Doppler ultrasonography should always be viewed as an extra tool to enhance grey-scale ultrasonographic findings, rather than as an isolated assessment.

According to Brisbane et al,[19] calculi of <3 mm may not produce acoustic shadowing and thus could be frequently missed on ultrasonography. In our study, the incidence of correctly identifying a stone decreased with decreasing calculus size. The sensitivity of identifying a calculus <5 mm was 18.8% with grey-scale and 23.5% with both techniques.

The specificities of calculus detection with grey-scale sonography as well as the combined grey-scale and colour Doppler methods were comparable (72.2% and 62.9% respectively). As our patients were all referred for radiological assessment owing to clinical suspicion of nephrolithiasis, there were only 10 (17.5%) of 57 patients in whom no renal calculi were identified. Selection bias with an insufficient control population may be one of the causes of its low specificity.

When colour Doppler ultrasonography is applied, renal vascularity and high attenuating conditions such as medullary calcinosis, vascular calcification, surgical clips, and stents may sometimes mimic the appearance of twinkling artefact, as seen in Figure 3. Therefore, a slightly higher false positive value was seen with the combined technique (n = 18) as opposed to grey-scale ultrasonography alone (n = 16). A 51% false-positive rate was recorded by Dillman et al.[8]

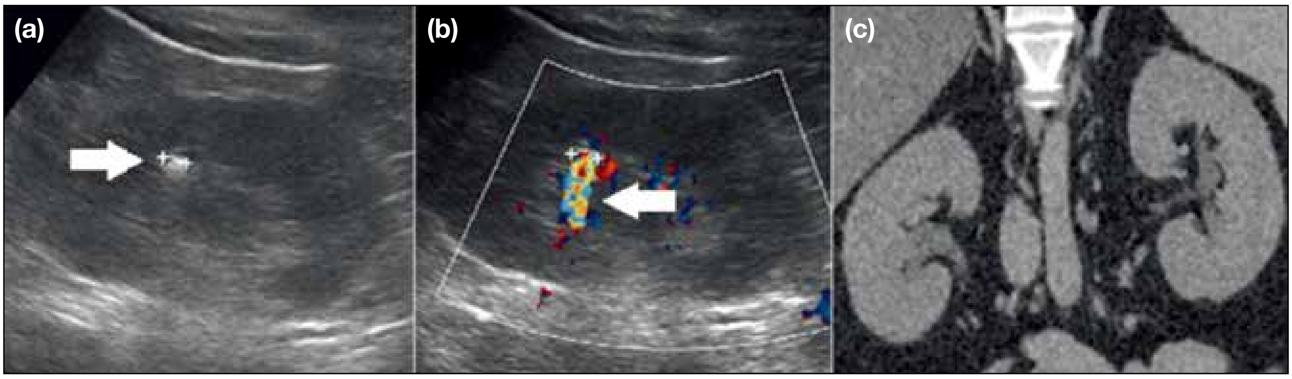

Figure 3. A 39-year-old woman with suspected urinary tract stone. (a) Grey-scale ultrasonograph (arrow) and (b) colour Doppler ultrasonograph (arrow) indicate presence of a calculus in left kidney. (c) Unenhanced computed tomography images obtained at the same level reveal no corresponding calculus.

Our study has several limitations. First, it had a relatively small sample size of 57 patients. Second, two different models of ultrasound machines were used for the study. Although the PRF was adjusted for each patient to the recommended threshold, the intrinsic setting and performance of each machine may still differ from each another and thus interfere with the interpretation and end results.[10,11]

Apart from renal vascularity, the presence of high attenuating structures and machine settings, other factors which influence the intensity and appearance of twinkling effect include motion, surface roughness, and components of the calculus.[10] As genetic and environmental factors such as dietary practices and regional climate may affect the prevalence of stone disease,[2] data collected from our centre might not mimic the results of studies conducted in other regions. Another purported pitfall of ultrasonography is its lack of reliability in detecting ureteric calculi.[14] The overlying bowel gas hinders the usefulness of sonography, affecting twinkling assessment to an even greater extent.

For further strengthening of this research, a study with a larger sample size and longer duration may be necessary. Proper optimisation of ultrasound machines in terms of its gain, depth and alternate modes (such as flash and stone modes) may enhance the process of data collection and thus obtaining a larger patient cohort.[5]

Regardless of the low sensitivity of ultrasonography in the detection of urinary calculi, adding colour Doppler ultrasonography can improve its sensitivity compared with grey-scale alone. This would increase clinicians' diagnostic confidence in the diagnosis of small stones, especially in patients with symptoms of nephrolithiasis who do not require CT or surgical intervention. Nonetheless, radiologists should be acquainted with the higher false-positive ratio when both techniques are employed simultaneously.

CONCLUSION

The use of colour Doppler ultrasonography in addition to the conventional B-mode ultrasonography slightly increases the sensitivity of nephrolithiasis detection with comparable specificity. Even though the overall sensitivity and specificity of ultrasonography are rather low, it remains as an important screening tool for renal calculi due to its availability, lower cost, non-invasive nature and lack of ionising radiation.

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