

An investigation into the clinical accuracy of twinkling artifacts in patients with urolithiasis smaller than 5 mm in comparison with computed tomography scanning

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ABSTRACT

Background: Ultrasound (US) is a non-invasive method used for the diagnosis of urolithiasis. If the size of the stone is <5 mm, it may be difficult to diagnose. This study aimed to compare the accuracy of twinkling artifact (TA) of color Doppler US imaging with unenhanced computed tomography (CT) for detecting urolithiasis <5 mm. **Materials and Methods:** This prospective study was conducted on 100 patients with suspected renal calculus presented to the emergency room at the Imam Khomeini Hospital of Ahvaz in 2018. The US findings such as posterior acoustic shadowing and TA were examined for their ability to detect urinary stones (greatest diameter ≤ 5 mm) using CT findings as the gold standard. **Results:** The mean size of renal stone was 3.43 ± 0.80 mm in CT and 3.49 ± 0.82 mm in color Doppler US. There was no significant difference between CT and color Doppler US report in quantification of urolithiasis sizes ($P = 0.603$). TA on color Doppler US was detected in 94 (94%) patients while posterior acoustic shadow was detected in 83 (83%) patients ($P = 0.004$). A significant difference was found between the TA and size of stones ($P = 0.036$). The sensitivity, accuracy, and positive predictive values of TA for the detection of calculus were 94%, 94%, and 100%, respectively. **Conclusion:** The results demonstrated that TA on color Doppler US could be a good and safe alternative imaging modality with comparable results with non-contrast-enhanced computed tomography for the sensitive detection of urolithiasis <5 mm.

Keywords: Color Doppler ultrasound, twinkling artifact, unenhanced computed tomography, urolithiasis

Introduction

Renal calculus is one of the most common concerns of people referring to the emergency centers with a possible occurrence of 12% for men and 6% for women.^[1-3] Accordingly, the most common causes of renal calculus are kidney and urinary tract stones.^[2] Eurography, ultrasound and computed tomography (CT) scan are used as modalities to diagnose the disease.^[4] In addition, CT scan is used as a gold standard for the detection of urolithiasis,^[1-3,5] but due to the excessive use of this modality and the side effects and risks of using it, low-dose CT protocols are used which may reduce sensitivity in detecting small stones in the kidney and urinary tract.^[1]

There are also circumstances in which CT scan is not available, including pregnancy, children, and people who are scared of CT scan.^[4] Accordingly, many patients with a history of urolithiasis (kidney stones) need to keep track of their condition and repeated CT scans do not seem to be appropriate for these people.^[1] Therefore, it is necessary to look for an alternative method for CT scan. Ultrasound is one of these alternatives which, despite its limitations, has an acceptable sensitivity and specificity in detection of urolithiasis.^[2] However, in ultrasound, small stones may not be differentiated from normal kidney tissue or create acoustic shading. Moreover, the stones in the ureter's middle part may not be detected due to intestinal and lipid gases.^[3]

Today, technological advances and changes in ultrasound devices and probes have made them high quality and better

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devices which can be used to detect urolithiasis. Twinkling artifact, which is observed in color Doppler ultrasound, is characterized by rapid changes in the composition of blue and red colors of the ecologically stable structures such as calcification, bone, and stones.^[3,5,6] It was initially defined by Rahmouni *et al.* in 1996.^[3,7-9] Although the reason for the development of this artifact is not clear, many studies have investigated its use in increasing the diagnostic accuracy of ultrasound for kidney and urinary tract stones.^[1] It is used to detect calcifications in various tissues such as prostate, testicular, kidney, bladder, liver, bile duct, pancreas, breast, and ureter, as well as non-calcified bilirubin stones and irregular hard and reflexive surfaces.^[4,7,10] Studies suggest that this artifact can increase the sensitivity and specificity of ultrasound in diagnosis of kidney stones.^[11] It can also transform the management and treatment of kidney stones.^[9]

Many studies have tried to determine the factors influencing the advent of twinkling artifact. Although our knowledge in this area is still limited, the following factors seem to have contributed to the emergence of this artifact:^[9]

1. The features of the object being imaged, including its texture, surface, size, and chemical composition;
2. Setting of the ultrasound device;
3. Doppler angle; and
4. The type or generation of the Doppler system.

Despite numerous studies, many data have focused on determining the sensitivity and specificity of the twinkling artifact in the diagnosis of kidney and urinary tract stones. For example, Park *et al.* reported the diagnostic accuracy of this artifact for kidney stones as 86–96%,^[12] while Dillman *et al.* reported that the positive predictive value and sensitivity of twinkling artifact is 49% and 55%, respectively.^[11] Some have also reported that accuracy of the artifact depends on both the setting of the device and the shape of the stone. It has been argued that this artifact is also observed in many parts of the kidney where no stones exist.^[3] Therefore, the present study was conducted to evaluate the diagnostic accuracy of twinkling artifact, in comparison to non-contrast CT scans, for detecting (diagnosing) the kidney and urinary tract stones <5 mm.

Materials and Methods

The present study is an epidemiological analysis that was aimed at evaluating the accuracy of twinkling artifact compared to CT scan in the diagnosis of kidney stones <5 mm.

This study, approved under the ethical code IR.AJUMS.REC.1396.1049, was performed on 72 patients with renal calculus in the Ahwaz Imam Khomeini Hospital in 2018. After clinical examination, all of the patients were subjected to non-contrast CT scans and Doppler ultrasound to diagnose urolithiasis and urinary tract stones. After diagnosis of renal calculus was confirmed, they entered the study based on the inclusion and exclusion criteria. The sample size that was consisted of 100 subjects was determined using the following

formula. Sampling was done in a non-randomized sequential manner.

$$N = \frac{Z_{1-\alpha/2}^2 P (1 - P)}{d^2}$$

$$Z_{1-\alpha/2} = 1.96 \text{ confidence level (95\%)}$$

Sensitivity according to Reference^[13]

$$P = 0.93$$

$$d = 0.05$$

$$N = \frac{(1 / 96)^2 \times 0 / 93 \times 0 / 07}{(0 / 05)^2} = 100 \text{ the sample size}$$

Ultrasound imaging

At first, all of the patients were examined by a radiologist familiar with renal ultrasound and urinary tract. The radiologist did not have access to the medical history of the patients (using the Voluson E6, the USA). The technical parameters that were used included emission frequency (3.5 MHz), color frequency (2.5 MHz), gain (60, 70), filter (5), TIS (1.2), and MI (1.5). Color Doppler was used along with the red and blue color map and the power Doppler with the pink color map as well as the standard Doppler protocol to detect the twinkling artifact. The gain of color Doppler was set exactly below the color noise threshold. When a twinkling artifact was observed, Doppler spectra were used for arterial and venous flow. The ultrasound evaluation was continued to find twinkling artifacts. The presence of stone was defined as an echymosis with or without posterior acoustic shadow in the urinary tract [Figure 1]. All of the detected stones were measured at their greatest length. The twinkling artifact was classified as non-existent, mild, and strong artifact.

CT scan imaging

All of the patients underwent a non-contrast CT scanning with a routine protocol for renal calculus (64 × 0.625 mm collimation) on the CT machine (Siemens Emotion 16 slice, Germany). The CT parameters included 5 mm collimation, 120 kV, 200 mAs, and reconstruction at 3-mm intervals. The patients were advised to drink about 1 L of water about 60 min before examination. The images were investigated in the station [Figure 2]. All of the patients were examined by a radiologist who was familiar with renal ultrasound and urinary tract but was not aware of the study. Once the stone detection was confirmed, the size and location of the stones were reported, and the Hasfield number was calculated.

Data analysis

Statistical analyses were carried out by the Chi-square, Mann–Whitney, and Kruskal–Wallis tests using the SPSS 22 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05 for all statistical tests.

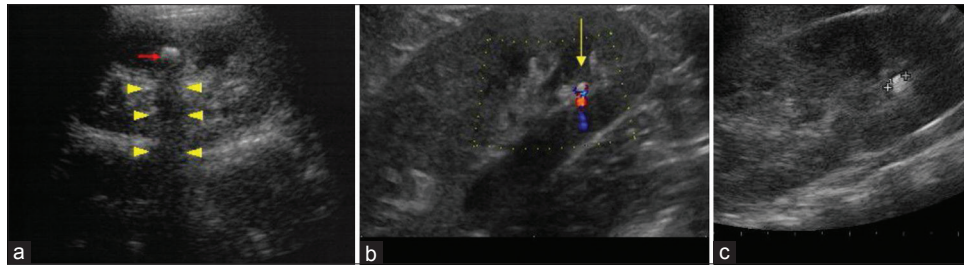


Figure 1: Kidney stone color Doppler ultrasound. (a) Between the two signs of +, related to the kidney stone in ultrasound; (b) the yellow arrow is related to the twinkling artifact of the same stone; (c) the red arrow shows the stone in the kidney and the tip of the yellow arrow represents posterior acoustic shadow for the ultrasound

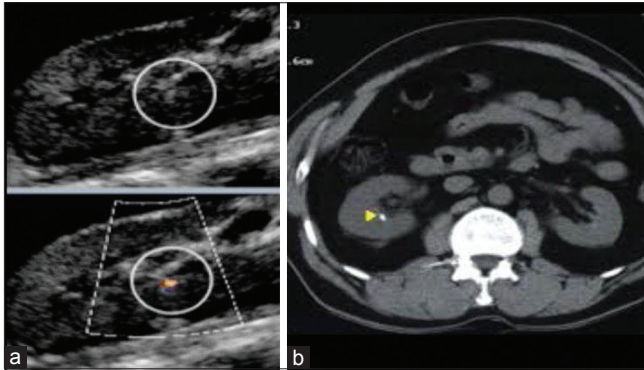


Figure 2: Non-contrast computed tomography and kidney color Doppler ultrasound. (a) The tip of the yellow arrow represents the kidney stone in the computed tomography scan; (b) the image of the stone in the ultrasound and its artifact

Results

Out of the 100 patients participated in the present study, 72 (72%) were male and 28 (28%) were female. The patients' age ranged from 12 to 91 years with a mean of 13.41 ± 42.39 years.

Table 1 shows the comparison of the sizes of the kidney stones detected using CT scanning and Doppler ultrasound. According to these results, there is no statistically significant difference between the size of the stones diagnosed through CT scanning and Doppler ultrasound ($P = 0.603$) [Table 1].

The results of the size of the kidney stones are presented in Tables 2 and 3. As observed, there was a significant difference between the twinkling artifact and size of the kidney stone, such that, larger stones created more artifacts in the ultrasound and vice versa [Table 2]. The results of color Doppler ultrasound for the diagnosis of urolithiasis compared to computed are showed in Table 4.

Discussion

The diagnosis of renal calculus and acute abdominal and back pain is still a subject of discussion which varies in different centers, cities, and countries. Important factors in choosing diagnostic methods depend on the prevalence of kidney stone diseases in the region, available medical equipment, relative costs in each system, and the characteristics and limitations of each diagnostic method.^[14]

Table 1: The comparison of the size of the kidney stones between computed tomography scanning and Doppler ultrasound

	Mean	Standard deviation	Minimum	Maximum
CT scanning	3.43	0.80	2.0	5.0
Ultrasound	3.49	0.82	1.8	5.0
P^*	0.603			

*Mann-Whitney test

Table 2: The size of the stone based on twinkling artifact grade

Twinkling grade	Size of the kidney stone (CT)		Size of the kidney stone (ultrasound)	
	Mean	Standard deviation	Mean	Standard deviation
Grade 0 (non-existent)	3.08	0.77	2.66	0.57
Grade 1 (mild)	3.33	0.81	3.29	0.85
Grade 2 (strong)	3.62	0.77	3.63	0.77
Total	3.43	0.80	0.49	0.82
P^*		0.024		0.036

*Kruskal-Wallis test

In the present study, there was no significant difference between the CT scanning and color Doppler ultrasound regarding the size of the detected stones. Yavuz *et al.*^[2] showed that there was no significant difference in the sizes of kidney stones detected through CT and Doppler ultrasound.^[2] The fact that there is no difference between the accuracy of the two methods in determining the size of the stone indicates the high reliability of these diagnostic methods.

After the twinkling artifact was discovered in the color Doppler ultrasound, it was expected that this artifact could improve detection of the stones by ultrasound. The sensitivity of ultrasound for detecting kidney stones increased from 48.66% in B-mode ultrasound to 99.55% in ultrasound with twinkling artifact.^[3,15]

Studies have also shown that color Doppler ultrasound twinkling artifact is very sensitive and can detect very small kidney stones.^[2,16] In this study, CT findings were used as a standard reference to evaluate the accuracy, sensitivity, and positive predictive value of the color Doppler ultrasound. Accordingly, the results showed that the accuracy and sensitivity of twinkling artifact in detecting kidney stones was 94% and its positive

Table 3: Mean and standard deviation of the size of kidney stone based on posterior shadow

Size of the kidney stone	Posterior acoustic shadow (83 cases)	No posterior acoustic shadow (17 cases)	P*
CT mean \pm (standard deviation)	3.48 \pm 0.80	3.15 \pm 0.56	0.070
Ultrasound mean \pm (standard deviation)	3.56 \pm 0.081	2.97 \pm 0.67	0.014

*Mann-Whitney test

Table 4: The results of color Doppler ultrasound for the diagnosis of urolithiasis compared to computed tomography

	Positive	Negative	CT (total)
Ultrasound			
Positive	93	7	100
Negative	0	0	0
Total	93	7	100

predictive value was 98.92%. Moreover, this artifact was not observed in 6% of the cases. Gliga *et al.*^[16] observed twinkling artifact in 92% of renal calculus patients. Besides, sensitivity, specificity, positive, and negative predictive value of twinkling artifact compared to non-contrast CT were 99.12%, 90.91%, 99.12%, and 91.90%, respectively.^[16]

In another study, Lee *et al.* found that 83% of kidney stones were detected by twinkling artifacts in the color Doppler ultrasound.^[17] Kielar *et al.*^[7] showed that the positive predictive value and sensitivity of twinkling artifact were 94% and 83%, respectively. This artifact also had 6 false positive (5.3%) and 22 false negative values (19.3%). As a result, twinkling artifact with a high positive predictive value can increase ultrasound diagnostic accuracy for kidney and urinary tract stones.^[7]

Overall, the results of the present study are in good agreement with those of the abovementioned studies and all showed a high sensitivity and positive predictive value for twinkling artifact in the diagnosis of kidney stones.

Abdel-Gawad *et al.*^[14] reported false negative values in four cases (0.4%). In those four cases, twinkling artifact was not observed and the Doppler ultrasound could not detect kidney stones. This was seen in overweight and obese people with a body mass index (BMI) higher than 35.^[14] The fact that the artifact was not seen in six cases (false negative) in the present study may also be attributed to the patients' height, weight, and BMI; however, these cases were not evaluated.

In addition, in a retrospective study, Dillman *et al.* compared the overall sensitivity of twinkling artifact with CT scanning for diagnosing urolithiasis and showed that the overall sensitivity of the former was 55%. They showed that the positive predictive value of twinkling artifact in detecting kidney stones was 78%. The true and false positive twinkling values of CT were 49% and 51%, respectively. These findings indicate that this artifact has a high false positive value, while it has low sensitivity. Accordingly, it is not very sensitive to be used in routine evaluation of urolithiasis.^[11] These results are not in line with those of the

present study whose results showed a higher positive predictive value for this artifact. This difference in results can be attributed to the slender thickness of the CT images which detects smaller stones in the form of noise. As a result, false positive results are observed in twinkling artifacts.

Despite the high efficiency of twinkling artifact in detecting kidney stones, it is unclear why this artifact does not exist in some stones, while it is present in some kidneys without stones. Currently, it is not clear what causes these false positives and in particular false negatives, but it may be related to the chemical composition of the stones, fine microlithiasis stones, ultrasound device settings, or the age/generation of the ultrasound device.^[5,18,19]

The appearance of the twinkling artifact depends on the hardness of the stone. The harder the stone, the larger the artifact will be.^[20] This attribute can explain why artifact was not present in six patients in the present study, which may be attributed to the smooth surface of the stones. Gliga *et al.*^[16] also attributed the lack of artifacts in 10 cases to the smooth surface of the stone.

According to the present reports, twinkling artifact depends on the device settings, the biochemical composition of the stone, and the level of calcification. Most quantitative studies have focused on small-size kidney stones and consisted of a small number of patients.^[21] The radiologist's experience can also be effective in this regard. Therefore, by knowing this artifact, it will be possible to improve the process of detection of stones, especially in the kidneys.

Since this artifact depends on the parameters of the device and the frequency of the ultrasound emission,^[22] in this study, the settings and parameters of the device were similar in all of the patients. In the present study, there was a significant positive relationship between twinkling artifact and the size of kidney stone.

Sen *et al.*^[23] showed that there was a significant difference between the size and location of the stone and the twinkling artifact.^[23] In another study, Abdel-Gawad *et al.*^[11] investigated the diagnostic accuracy of the twinkling artifact for diagnosing kidney stones and showed that the results of color Doppler ultrasound and the observation of twinkling artifact were significantly affected by the size of kidney stones.^[11]

Abdel-Gawad *et al.*^[14] reported that there was no relationship between the twinkling artifact and kidney stone size.^[14] These results are not in good agreement with those of the present study, which can be attributed to the fact that Abdel-Gawad *et al.*^[14] included small to large stones (3–26 mm) in their study, while only stones <5 mm were investigated in the present study.

In the present study, posterior acoustic shadow was present in 83% of cases, while artifact was seen in 94% of cases. There was also a significant positive relationship between twinkling artifact and posterior acoustic shadow. Mitterberger *et al.*^[15] showed that posterior acoustic shadow was observed in 76% of kidney stones, while twinkling artifact was observed in 97% of cases. Ahmad and Abdallah^[24] emphasized that there was a significant relationship between twinkling artifact and posterior acoustic shadow. They also reported that twinkling artifact in the Doppler ultrasound, compared to posterior acoustic shadow, can improve the diagnosis of kidney stones (95.8% vs. 87.3%).^[24]

In another study, Shabana *et al.* compared the ability of posterior acoustic shadow and color Doppler twinkling artifact in an *in vitro* environment and observed that the twinkling artifact outperformed posterior acoustic shadow on detecting the pattern of color variations. Accordingly, twinkling artifact is more resistant against barriers such as out-of-focus scans caused by beam aberration resulting from patient body structure.^[18]

Finally, it should be pointed out that the twinkling artifact ultrasound has a high clinical potential to improve the diagnosis of kidney stones. In addition, ultrasound is a safe way even for pregnant women and children. It has no ionizing radiation and costs less than CT. Improving the accuracy and sensitivity of ultrasound in detecting and determining the size of stones can increase its routine applicability. However, the general purpose of existing ultrasound systems is to detect inhomogenesis of soft tissues and blood flow, instead of hard structures such as stones. Meanwhile, it is possible to improve the accuracy of the ultrasound in detection and measurement of kidney stones by recognizing and harnessing the differences between soft tissue and stones and creating a new commercial ultrasound mode for kidney stones.

Study limitations

The main limitations of this study included the small number of patients and neglecting the external kidney stones and biochemical composition of stones. Moreover, the type and the shape of kidney stones were not taken into consideration.

Conclusion

The results showed that color ultrasound twinkling artifact has a high sensitivity and high positive predictive value for detecting the kidney stones <5 mm. This artifact can also be used as a good and safe alternative method for non-contrast CT scanning.

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Conflicts of interest

There are no conflicts of interest.

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