COMPARATION OF DIAGNOSTIC VALUE B-MODE ULTRASOUND WITH COLOR DOPPLER TWINKLING ARTIFACT FOR DETECTING RESIDUAL STONE AFTER PCNL

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ABSTRACT

Objective: *To compare the accuracy of B-Mode US and color Doppler twinkling artifact for detecting residual stone after Percutaneous Nephrolithotomy (PCNL) with Non-contrast CT (NCCT) as the standard diagnostic.* ***Material & methods:*** *In this prospective study, 30 patients who underwent Percutaneous Nephrolithotomy (PCNL) were examined with US and NCCT. In US, echogenicity and posterior-shadow (PS) parameters were evaluated and compared with color-Doppler ultrasonography (CDUS) twinkling artifact and NCCT signs. The results then analyzed statistically with Kappa and McNemar tests.* ***Results:*** *More positive residual stone results with color Doppler twinkling artifact in 14 patients than B-Mode US in 11. NCCT detected 17 residual stone with the most location in inferior calyx. (n=10, 58.8%). The sensitivity, specificity and difference positive-negative likehood ratio of B-Mode US were 64.7%, 92.3% and 8.02, both Kappa test was significant (p=0.125) and McNemar tests was significant (p=0.002). The color Doppler twinkling artifact has 82.3%, 92.3%, and 10.5 for sensitivity, specificity and difference positive-negative likehood ratio, the Kappa test was significant (p=0.00), McNemar test was not significant (p=1.00).* ***Conclusion:*** *Color Doppler twinkling artifact was valid, highly sensitive and accuracy better than B-mode US in detecting residual stone after PCNL procedure.*

Keywords: *Percutaneous nephrolithotomy, residual stone, B-mode US, color Doppler US, twinkling artifact, non-contrast CT.*

ABSTRAK

Tujuan: *Membandingkan akurasi USG B-Mode dengan Color Doppler Twinkling Artifact pada deteksi residual stone setelah Percutaneous Nephrolithotomy (PCNL) dengan Non-contrast CT (NCCT) sebagai standar baku.* ***Bahan & cara:*** *Pada penelitian prospektif ini, 30 pasien yang telah menjalani PNL dilakukan pemeriksaan USG dan NCCT. Pada pemeriksaan USG, parameter ekogenesitas dan posterior shadow dievaluasi dan dibandingkan dengan gambaran ultrasonografi color Doppler Twinkling Artifact dan NCCT. Hasil penelitian dianalisa secara statistik dengan uji Kappa dan McNemar.* ***Hasil:*** *Hasil residual stone positif lebih banyak terdeteksi dengan color Doppler twinkling artifact sebanyak14 patients dibandingkan USG B-Mode US sebanyak 11 pasien. NCCT mendeteksi 17 residual stone dengan letak paling banyak di kalik inferior. (n=10, 58.8%). Sensitivitas, spesifisitas dan selisih rasio kemungkinan positif dan negatif sebesar 64.7%, 92.3% dan 8.02, baik uji Kappa (p=0.125) maupun uji McNemar (p=0.002) menunjukkan hasil signifikan. USG color Doppler Twinkling Artifact memiliki sensitivitas, spesifisitas dan selisisih rasio kemungkinan positif-negatif sebesar 82.3%, 92.3%, dan 10.5, uji Kappa menunjukkan hasil signifikan (p=0.00), sedangkan uji McNemar tidak signifikan (p=1.00).* ***Simpulan:*** *Color Doppler twinkling artifact cukup valid, lebih sensitif dan akurat dibandingkan USG B-mode pada deteksi residual stone paska PCNL.*

Kata kunci: *Percutaneous nephrolithotomy, residual stone, USG B-mode, USG color Doppler, twinkling artifact, non-contrast CT.*

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INTRODUCTION

Percutaneous Nephrolithotomy (PCNL) is minimal invasive procedure to extract kidney stone by percutaneous access with residual stone rate between 10–60%, depending on the size, number, composition, nature of the stone, and also surgeon's experience.[1] The residual stones may become

symptomatic with pain, infection, haematuria, and obstruction or act as a nidus become increase in size, pass spontaneously or remain silent with no growth.[2]

Post operative Kidney Ureter Bladder (KUB) photo and ultrasound examination as a routine diagnostic tool for residual stone has a low sensitivity. KUB image is affected by body size, gas in the intestines, and requires preparation of the patient prior to the exam. Detection of urinary stones on US may be problematic when the stones are obscured by ultrasonic beam-attenuating tissue, such as mesenteric fat, renal sinus fat, and bowel, or when their posterior acoustic shadowing is weak.[3]

Non-Contrast CT (NCTT) is currently considered as the optimal method of assessing the residual stone after an endourological intervention. NCCT has some advantages, such as quick and easy application, independence from various intravenously administered contrast agents, detection rate, and differential diagnosis of extraurologic diseases. Nevertheless, this method has some limitations: it is not available outside the hospital facilities and is not so cost effective. The amount of radiation in non-contrast-enhanced helical CT is ~10-fold that of plain radiography of the abdomen and pelvis.[4]

Brightness mode (B mode) is the basic mode that is usually used. The B mode gives a two dimensional (2D) black and white image that depends on the anatomical site of the slice. Since ultrasound waves cannot transmit through stones, a black acoustic shadow will be present behind them.[5]

Color Doppler ultrasound facilitates the detection of urinary stones. Specifically, the presence of a twinkling artifact is suggestive of the presence of urinary stones. Twinkling artifact is a color Doppler phenomenon that appears as a rapid change mixture of red and blue immediately behind a reflecting stationary object.[6]

OBJECTIVE

The aim of this study is to compare the accuracy of B-Mode US and color Doppler twinkling artifact (CDTA) with NCCT for detecting residual stone after PCNL.

MATERIAL & METHODS

A total of 30 patients (15 males and 15 females; mean age: 51.97 ± 7.83 years, range: 36-70 years) who underwent PCNL were enrolled in this study between June and October 2015. The Research Ethics Committee approved the study and informed consent was obtained from all patients prior to US studies.

The inclusion criteria: patient who underwent PCNL with age >18 year, transportable and stable post operative condition, also willing to be involved in the research. Exclusion criteria in this study there are uncooperative patient, renal cyst, nephrocalcinosis, dan obesity (BMI>27).

US and NCCT examination were done within 48 hours after PCNL procedure. All US studies were performed with the GE Voluson 730 pro V with a transmit frequency of 2.5 to 5MHz, 15 dB Pulse Repetitive Frequency (PRF) values of 0.9kHz, Color Write Priority (CWP) set to 120, gain 0, Wall Motion Filter (WMF) mid, ensemble number set to 10 and location of focal zone was set to below object.

B-Mode US criteria included visualization of a hyperechoic structure with posterior acoustic shadowing within the kidney. Color Doppler US was performed using a red and blue color map to detect the twinkling artifact. The color box size was adjusted to cover the whole renal sinus. Nephrostomy balloon catheter was deflated. Posterior acoustic shadow significance was classified as present (1) or absent (0) on B-mode US. The intensity of the color signal was recorded as 0 (= absent), 1 (= weak, present) and 2 (= strong, present). Furthermore, the length of the twinkling sign was classified and a length of >1 cm was defined as 2 (= strong present).

After US examination, all patients underwent an unenhanced helical CT examination using a multislice X-Ray CT Scanner Activion TM 16. In statistical analysis, McNemar and Kappa tests were used. Statistical Package for the Social Sciences (SPSS) 16.0 software was used to describe and analyze data, and $p<0.05$ was considered as statistically significant.

RESULTS

A total of 30 patients were examined in the present study including 15 (50%) males and 15 (50%) females. The mean age was 51.9 years and the age range was 36-70 years. Sample characteristic were noticed base on age, sex, stone size, stone number, stone location, stone side and obstruction sign (table 1).

More positive residual stone results with color Doppler twinkling artifact in 14 patients than

B-Mode US in 11. NCCT detected 17 residual stone (56.6%) with the most location in inferior calyx (n=10, 58.8%) (table 2). Based on NCCT, residual stone >5mm by B-mode US detected in 8 patients (72.7%), whereas residual stone ≤ 5 mm and >5mm by color Doppler Twinkling Artifact detected in 7 patients (50%), respectively (table 3). Six residual stone on B-mode US without acoustic shadow and echo difference showed 1 strong, 4 weak, and 1 no twinkling artifact. Eleven residual stone on B-mode with acoustic shadow showed 7 marked and 4 slight echo difference; 5 weak and 4 strong twinkling artifact intensity (table 4). The sensitivity, specificity and difference positive-negative likehood ratio of B-Mode US were 64.7%, 92.3% and 8.02, Kappa test was significant (p=0.125) and McNemar tests was not significant (p = 0.002). The sensitivity, specificity and difference positive-negative likehood ratio color Doppler twinkling artifact were 82.3%, 92.3% and 10.5, the Kappa test was significant (p = 0.000), McNemar test was not significant (p =0.625) (table 5).

Table 1. Preoperative sample characteristic.

Parameter		Description
Age (year old)		51.97±7.83
Sex	Male	15 (50%)
	Female	15 (50%)
Stone size	≤ 10 mm	2 (6.7%)
	10-20 mm	11 (36.7%)
	> 20 mm	17 (56.7%)
BMI (Kgm^2)		24.77±1.77
Stone number	Single	14 (46.7%)
	Multiple	16 (53.3%)
Stone location	Calyx	5 (26.7%)
	Pyelum	9 (33.3%)
	Pyelum&calyx	16 (40%)
Stone side	Right	14 (46.7%)
	Left	16 (53.3%)
Obstruction Sign	Hidronefrosis (-)	7 (23.3%)
	HN grade I-II	12 (40%)
	HN grade III-IV	11 (36.7%)

Table 2. Comparation of residual stone detection with B-mode US and color Doppler twinkling artifact.

		NCCT	
		Residual Stone	No Residual Stone
B Mode US	Positive	11	1
	Negative	6	12
CDTA US	Positive	14	1
	Negative	3	12

Table 3. Residual stone size and location based on US B-mode and color Doppler twinkling artifact after PCNL.

Size	Location			B Mode US		CDTA US	
	Upper calyx	Mid calyx	Lower calyx	Positive	Negative	Positive	Negative
≤ 5 mm	1	2	5	3	5	7	1
> 5 mm	1	3	5	8	1	7	2
Total	2	5	10	11	6	14	3
Chi Square		0.932		0.05		1	

Table 4. Comparation of residual stone image intensity with B-mode US and color Doppler Twinkling artifact.

	Residual stone					
Acoustic Shadow		Absent (6)			Present (11)	
Echo Difference	Indistinct (6)	Slight (0)	Marked (0)	Indistinct (0)	Slight (7)	Marked (4)
Twinkling Artifact	Absent (1)	Weak (4)	Strong (1)	Absent (2)	Weak (5)	Strong (4)
Size (mean ± SD)		4.4 mm ± 1.4			7.6 mm ± 3	

Table 5. Diagnostic value B-mode US and color Doppler twinkling artifact US for detecting residual stone after PCNL.

Diagnostic Value	B mode US	Color Doppler US
Sensitivity	64.7%	82.35%
Specificity	92.3%	92.3%
Positive predictive value	91.6%	93.3%
Negative predictive value	66.7%	80%
Accuracy	76.6%	86.67%
Positive likehood ratio	8.4	10.7
Negative likehood ratio	0.38	0.19
Statistic test		
Mc Nemar	0.125	0.625
Kappa	0.002	0.000

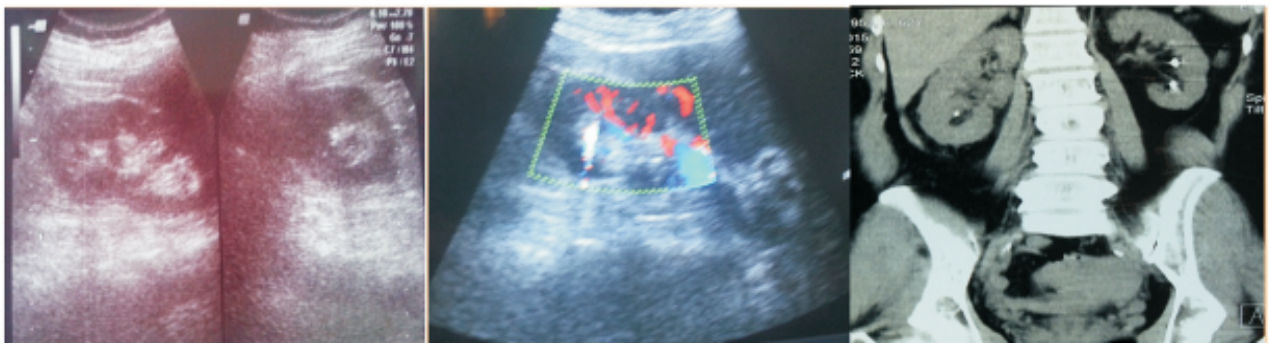

Fig.1. Fifty four year-old female patient after right PCNL with 3 mm residual stone. A). US does not shows clearly posterior acoustic shadow B). Color Doppler sonogram shows twinkling artifact. C). Corresponding unenhanced computed tomography with clearly visible stone in right kidney lower pole.

DISCUSSION

Residual stone fragments are generally defined as stone fragments remaining in the urinary system after the completion of an intervention procedure. The main reasons for failure of complete stone clearance are inability to access the calyces containing stone fragments, poor visualization due to bleeding, technical problems and stone composition.[7]

Variable that affected stone-free rates after PCNL were Body Mass Index (BMI), stone number and size, location in calyx, staghorn calculus, and moderate to severe hydronephrosis.[8,9] Post operative KUB or ultrasound was used to determine the stone-free status.

NCCT is not routinely suggested because of high cost and high radiation doses, disadvantage of this application warrant the need for alternative methods with similar reliability. US is an excellent imaging modality for detecting urinary tract stones because it is readily available, inexpensive and does not emit radiation. However, ultrasound detection of urinary stones obscured by renal sinus fat, mesenteric fat and bowel gas is sometimes problematic.[10,11]

In 1996, Raumani et al. defined "twinkling artifact" as a color Doppler artifact generated by strongly reflecting medium, which represents a substantial improvement for the sonographic detection of urolithiasis.[6] Recent studies have reported that the twinkling sign may be useful for detection of urinary stones.[12-15]

In our study, the sensitivity, accuracy and positive-negative likehood ratio difference of B-mode US for detecting residual stone were 64.7%, 76.6% and 8.02 respectively. These figures were lower than CDTA with 82.3%, 86.6% and 10.5 for sensitivity, specificity, accuracy and difference positive-negative likehood ratio. Both examination, McNemar test is not significant ($p>0.05$) there is no difference between US and NCCT for detecting residual stone and Kappa test is significant ($p<0.05$) or showed association US and NCCT as the gold standart for detecting residual stone. Based on this statistic analysis showed that study result has high validity.

Recent studies concluded that range of sensitivity of B-mode US in determining residual stone was 20-50%.[10,11,16] Winkel et al. reported that sensitivity of 48% and spesificity 99% on B-mode US. More than half of the stones detected by US (61%) were ≤ 3mm and, most likely, were noted as stones because they often presented a CDTA as well (72%).[15]

Aytac¸ et al. comparing old and new generation colour Doppler systems, the use of the new generation system also produced a CDTA in 96% of the urinary tract stones diagnosed on B-mode US. Aytaç and Ozcan concluded that this artifact can help differentiate a very small stone from other small echogenic structures.[17]

Lee et al. reported that they prospectively looked at 36 urinary stones and found that 83% showed a CDTA. They classified the number of urinary stones and frequency of CDTAs according to size of the stone and found that stones <5mm and stones >10mm all presented the CDTA whereas only 75% of stones sized 5–10mm revealed the artefact.[12] Winkle et al. also reported that no significant difference between small and middle-sized stones. All large stones (>10 mm) presented a CDTA, however, only three stones in this category.[15] In this study find no significant difference according to size of the stone that presented a CDTA.

Park et al.,who studied 318 patients, reported sensitivity and specificity rates for CDTA of 98% and 100%, respectively.[18] Korkmaz et al. who evaluated a total of 76 calculi < 5mm detected in 60 patients reported almost all stones (93%, 71 of 76) exhibited TA, which has potential place in clinical practice, especially to confirm the presence of stones with indistinct echogenicity difference and indistinct Posterior Shadow. US and CDTA detection rates were 19.7 and 93.4%, respectively.[19]

Lee et al. further reported that the location of focal zone can influence the occurrence and intensity of the sign. Our study standardized protocol placed the focal zone slightly below the area of interest. Using this focal position we found a twinkling sign in almost all stones (14 of 17).[12]

Echogenic foci with color signs can be seen in the area of the renal sinus and do not always suggest stones. Renal artery calcification should be considered in the differential diagnosis, especially in patients with long-standing diabetes, hypertension, or other systemic diseases associated with atherosclerotic vascular disease. Real-time scanning can help differentiate arterial calcifications from renal calculi because arterial calcifications are seen to pulsate. However, twinkling sign may also develop from calcifications of renal tumor, renal cyst, and renal parenchyma.[13]

Yavuz et al. compared the effectiveness of B-Mode and color-Doppler ultrasound imaging features, including twinkling-artifact with unenhanced CT for detecting millimetrical nephrolithiasis (≤5mm) in 397 patient suspected urolithiasis. Based on CT, detected 219 millimetric calculies in 164 cases with increasing sensitivity of 86% and PPV of 88.3%. They concluded that twinkling artifact based color-Doppler US is preferable for the sensitive detection of millimetrical nephrolithiasis; however, the high false-positive value can lead to an overestimation of the stone number, has to be considered.[20]

Shabana et al. compared the renal stone detecting ability of gray-scale acoustic shadow and CD "twinkling" sign in vitro. They demonstrated that the color flutter pattern of twinkling artifact was

more determinable than classical "acoustic shadowing" and that the twinkling sign was more resistant to obstacles, such as out-of-focus scans caused by beam aberration effects due to patient body habitus.[21]

Chelfouh et al. performed an in vitro study to determine whether the presence or the absence of the twinkling artifact behind renal calculi is correlated with their chemical composition, with the smoothness of their surface, or with changes in the primary sonography machine settings. They declared that an in vitro relationship exists between the twinkling artifact and the morphology of the urinary stones. By looking at a small number of stones, they showed that calcium oxalate monohydrate calculi are usually not associated with a twinkling artifact but that calcium oxalate dihydrate calculi mostly are. Indeed, monohydrate stones are usually smooth or mottled, whereas dihydrate stones are rough or crystalline. Dihydrate stones meet Rahmouni's definition of a rough reflective surface and are inclined to cause a TA. Smooth monohydrate stones are not. Color-flow sonography could play a role in detecting dense calcium oxalate monohydrate calculi, which in turn may help predict fragmentability.[6,22]

Alan et al. determine whether the presence or absence of the twinkling artifact is correlated with the chemical composition of the stones in sixty kidney stone patients ≥0.5cm who performed ESWL and PCNL. Artifact was detected nearly in all of the calcium oxalate dihydrate and calcium phosphate stones, whereas the artifact was detected in more than half of the calcium oxalate monohydrate and uric acid stones. In ESWL group it was observed that as the grade of the twinkling artifact increases, the number of required ESWL sessions decreases ($p<0.001$). In PCNL group twinkling artifact was found in all the patients (100%) with roughly surfaced stones.They declared that the roughness of stone surface is the most important factor in terms of formation of the twinkling artifact in kidney stones.[23]

In other study, Hassani et al. evaluated the value of combining noncontrast helical computerized tomography (NCCT) and color Doppler ultrasound in the assessment of the composition of urinary stones. They concluded that the mean HU value derived from NCCT measurement in vitro can be used to predict stone composition (calcium oxalate vs. calcium phosphate vs. uric acid vs. cystine). However, NCCT is unable to discriminate calcium oxalate stones (i.e.,monohydrate vs. dihydrate), which account for about 70% of all urinary stones. This is a shortcoming, since the dihydrate form is easily breakable with urologic fragmentation methods (such as shock wave lithotripsy) but the monohydrate form is refractory to these treatments. If a calcium oxalate stone (previously recognized by NCCT) lacks a CDTA in color Doppler, it is more likely to be a monohydrate stone. Thus, in an in vitro setting, a combination of NCCT and color Doppler can be used to assess the five main mineral types of stone composition.[24]

The mechanism of the CDTA is still unknown. Some studies have shed some light towards developing an understanding of the mechanism of the CDTA on kidney stones. So far, there are two main hypotheses on the origin of the CDTA. The variability that is responsible for the appearance of the CDTA comes from 1) the acoustic field or 2) the imperfection of the machine. Some investigators believe that the variability responding to the presence of the CDTA comes from the acoustic field. Rahmouni et al. explained that the CDTA is a result of random scattering of the ultrasound beam at multiple reflectors associated with the rough interface typical for the stones.[6] Chelfouh et al. considered the intensity character of the CDTA might depend on the morphologic and biochemical content of stones. They found that the artifact is always present for calcium phosphate and dehydrated calcium oxalate stones, but absent for urate stones and calcifications that contain more than 93% monohydrate calcium oxalate.[22]

Other investigators support the idea that the appearance of the CDTA is determined by the ultrasound machine or machine settings. For example, Aytac et al. published results comparing two ultrasound scanners (analog and digital) that were used to image kidney stones. They discovered that the presence and intensity of the CDTA depends on the scanner type; the digital scanner showed twinkling on 96% of stones while the analog scanner only showed twinkling on 39% of stones.[17] Kamaya et al. hypothesized that the cause for the artifact is narrow-band internal noise due to “phase jitter” and the irregular stone surface is only secondary and serves for broadening the spectrum.[25]

CONCLUSION

Color Doppler twinkling artifact was valid, highly sensitive and accuracy better than B-mode US in detecting residual stone after PCNL procedure.

Can be suggested as a routine procedure for monitoring after PCNL. Further and more comprehensive studies may be required.

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