Urolithiasis (2017) 45:215–219
DOI 10.1007/s00240-016-0891-8

ORIGINAL PAPER

Can Doppler ultrasonography twinkling artifact be used as an alternative imaging modality to non-contrast-enhanced computed tomography in patients with ureteral stones? A prospective clinical study

Volkan Sen[1] · Cetin Imamoglu[2] · Ibrahim Kucukturkmen[1] · Tansu Degirmenci[1] · Ibrahim Halil Bozkurt[1] · Tarik Yonguc[1] · Ozgu Aydogdu[1] · Bulent Gunlusoy[1]

Received: 23 January 2016 / Accepted: 5 May 2016 / Published online: 12 May 2016

Abstract We aimed to evaluate the use of twinkling artifact (TA) on color Doppler ultrasonography (USG) as an alternative imaging modality to non-contrast-enhanced computed tomography (CT) in patients with ureteral stones in this prospective study. Totally, 106 consecutive patients who had been diagnosed with ureterolithiasis by CT were enrolled in this prospective study. A urinary system color Doppler ultrasonography was performed on the same day with CT by an experienced radiologist who was blinded to the CT scan. TA was graded as 0, 1 and 2. The overall specificity of TA was calculated according to the NCCT as a gold standard method. The size, side and localization of stone and the demographic characteristics of patients were compared with twinkling positivity. TA on color Doppler USG was detected in 92 (86.8 %) patients. Statistically significant difference was found between the TA and localization of ureteral stones ($p = 0.044$). When we sub-grouped the patients according to the TA grades as 0, 1 and 2, 14 patients were with TA grade 0, 55 with TA grade 1 and 37 with TA grade 2. The mean stone size of groups was significantly different ($p = 0.012$). Bigger and proximal ureteral stones tended to have more TA on color Doppler USG. TA on color Doppler USG could be a good and safe alternative imaging modality with comparable results between NCCT. It could be useful for the diagnosis and follow-up of patients with ureterolithiasis.

✉ Volkan Sen
sen_volkan@yahoo.com

[1] Department of Urology, Izmir Bozyaka Training and Research Hospital, Saim Cikrikci Str. No: 59 Bozyaka, Izmir, Turkey

[2] Department of Radiology, Izmir Bozyaka Training and Research Hospital, Izmir, Turkey

Keywords Twinkling artifact · Color Doppler ultrasonography · Computed tomography · Urolithiasis · Ureterolithiasis · Kidney–ureter–bladder radiography

Introduction

The prevalence rate of urolithiasis has been reported to be between 4 and 20 % in economically developed countries [1, 2]. The incidence of urolithiasis depends on geographical, climatic, ethnic, racial, dietary and genetic factors [3, 4]. Urolithiasis is an endemic disease in Turkey with a prevalence of 14.8 % [5].

Kidney–ureter–bladder (KUB) radiography, ultrasound (USG) and non-contrast-enhanced computed tomography (NCCT) are the most used imaging modalities in diagnosing urolithiasis. In consequence, NCCT has become a gold standard diagnostic method of urolithiasis and its use has increased in recent years [6]. Although CT is accurate for diagnosis, the ionizing radiation it uses is increasingly being recognized as a public health issue [7, 8]. Brenner et al. pointed that one-third of all CT scans (approximately, 20 million adults) are not justified by medical need in the USA [7]. To decrease the doses of ionizing radiation and unnecessary use of CT, alternative imaging modalities such as USG and MRI could be used when indicated. Based on this hypothesis, we wanted to evaluate the usability of twinkling artifact (TA) on color Doppler USG instead of CT scan in the diagnosis of ureteral stones. TA is described as a rapidly changing mixture of red and blue behind a stationary echogenic structure seen on color Doppler ultrasound. The TA was first studied by Rahmouni et al. in 1996 [9] and its use in the diagnosis of urolithiasis has been reported in recent years [10–12]. However, there are not enough prospective studies with larger cohorts. We aimed to evaluate

the use of twinkling artifact on color Doppler ultrasound as an alternative of NCCT in the diagnosis of ureteral calculi by a prospective clinical study.

Materials and methods

This prospective study was approved by the hospital ethics committee and patients were included after giving oral and written informed consent. Between April 2015 and December 2015, totally 125 consecutive patients, who had been diagnosed with ureterolithiasis by CT and were older than 18 years, were included in this study. Patients with ureteral J stents, bilateral ureteral stones anf more than one stone in the same ureter were excluded from the study. All patients were prospectively underwent urinary system color Doppler ultrasonography by a single experienced ultrasonographer blinded to the CT scan results at the same day with CT.

Computed tomography technique

NCCT was performed using a Toshiba Aquilion 64 scanner Toshiba Medical Systems, Tokyo, Japan). It was performed as a volume scan (1.2 pitch, 120 kV, 225 mAs). Patients were scanned from the lower thorax to the pubic bone and images were reconstructed with 3 mm intervals.

Color Doppler ultrasonography technique

US examination was performed by an experienced sonographer using a scan model Toshiba Ablio 300 (Toshiba Medical Systems, Tokyo, Japan) equipped with a convex 2–5 MHz probe at kidney preset. The patient was examined in different positions including the supine and side position. The urinary tract was evaluated with both grayscale and color Doppler imaging. The sonographer filled out a standardized form indicating the renal size, presence or absence of hydronephrosis and any areas of high echogenicity with associated shadowing on grayscale images, the twinkling artifact on Doppler images, or both.

TA was graded as described by Chlefouh, Alan and Sharma et al. with absent twinkling considered as grade 0. Twinkling seen in only a portion of the acoustic shadowing was considered grade 1 (Fig. 1), and when the artifact occupied the entire acoustic shadowing, it was considered grade 2 (Fig. 2) [13–15]. The specificity of TA was calculated according to the NCCT as a gold standard method. The size, side and localization of the stone and the demographic characteristics of the patients were compared with twinkling positivity.

Statistical analyses were performed with SPSS version 21.0 (Chicago, IL) statistical software package. Kruskal–Wallis nonparametric test was performed to assess the comparison of twinkling grades with mean BMI and mean stone size. Chi-square test was performed to assess the comparison of TA and size subgroups and localization subgroups. Statistical significance was set at a p value of <0.05.

Results

A total of 125 consecutive patients with the diagnosis of urolithiasis were evaluated between April 2015 and December 2015 and 106 of them were included in the study. Patients who had ureteral J stent (6 patients), bilateral ureteral stones (4 patients) and more than one stone in the same ureter (9 patients) were excluded from the study. The mean age of the patients was 44.9 ± 15.1 (range 19–89) years and the mean BMI was 24.8 ± 1.8 (range 21–31) kg/m^2. Forty (37.7 %) patients were women, while 66 (62.3 %) were men. There were 45 (42.5 %) proximal,

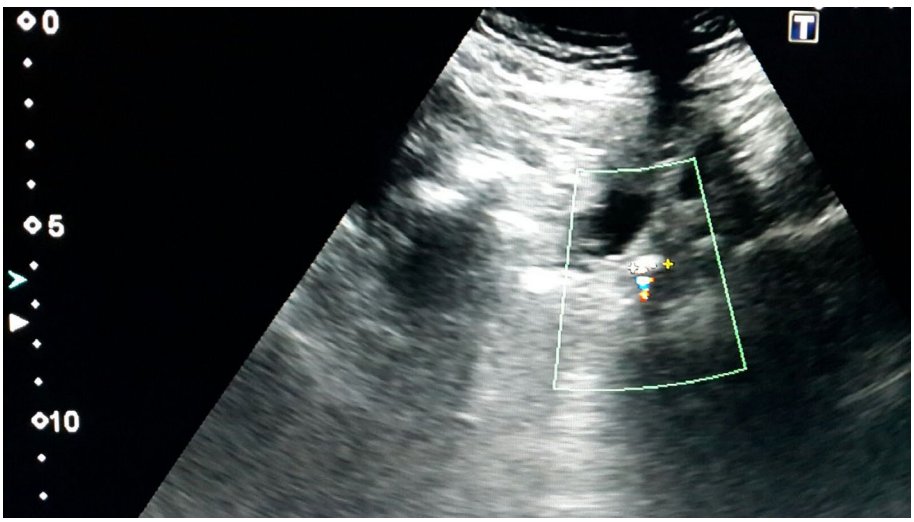

Fig. 1 Twinkling grade 1, only a portion of the acoustic shadowing

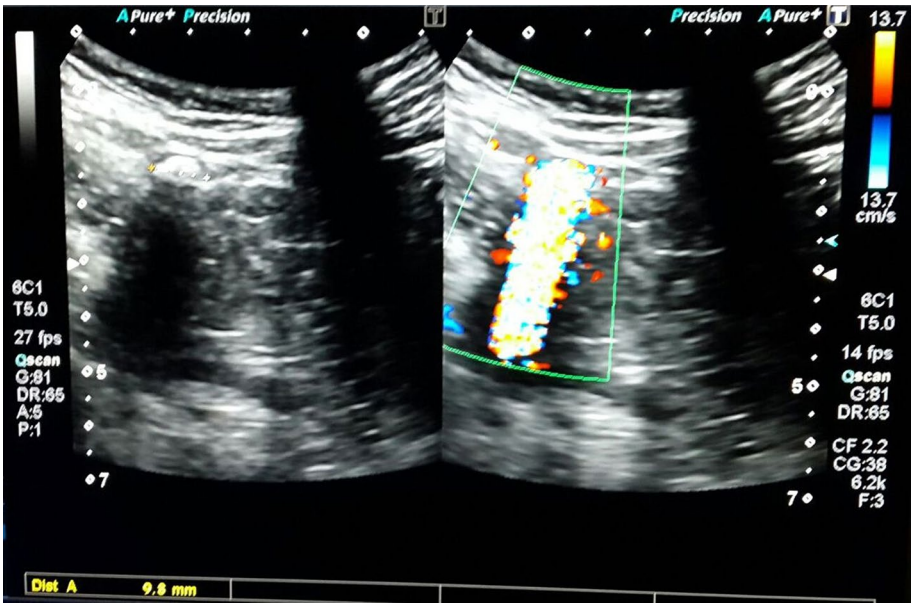

Fig. 2 Twinkling grade 2, the artifact occupied the entire acoustic shadowing

Table 1 Demographic characteristics of the patients and the localizations of ureter stones

Age (years), mean ± SD	44.9 ± 15.1
Gender	
Female	40 (37.7 %)
Male	66 (62.3 %)
BMI (kg/m^2), mean ± SD	24.8 ± 1.8 (range 21–31)
Localization of ureter stone	
Left	44 (41.5 %)
Right	62 (58.5 %)
Proximal	45 (42.5 %)
Middle	21 (19.8 %)
Distal	40 (37.7 %)
Size (mm), mean ± SD	10.6 ± 4.1

SD standard deviation

Table 2 Frequency of TA compared with the size and localization of ureteral stones

	Total (*n*, %)	Twinkling (+) (*n*, %)	Twinkling (−) (*n*, %)	*p*
Size (mm)				
<5	6 (100 %)	4 (66.7 %)	2 (33.3 %)	0.215*
>5 ≤ 10	61 (100 %)	51 (83.6 %)	10 (16.4 %)	
>10	39 (100 %)	37 (94.9 %)	2 (5.1 %)	
Total	106 (100 %)	92 (86.8 %)	14 (13.2 %)	
Localization				
Proximal	45 (100 %)	43 (95.6 %)	2 (4.4 %)	0.044*
Middle	21 (100 %)	16 (76.2 %)	5 (23.8 %)	
Distal	40 (100 %)	33 (82.5 %)	7 (17.5 %)	
Total	106 (100 %)	92 (86.8 %)	14 (13.2 %)	

* Chi-square test

21 (19.8 %) middle and 40 (37.7 %) distal ureteral stones. The demographic characteristics of the patients and localization of stones are given in Table 1. Twinkling artifact on color Doppler USG was detected in 92 (86.8 %) patients. This rate reached up to 94.9 % in patients who had ureteral stone bigger than 10 mm (Table 2). The mean age of TA (+) and TA (−) patients were similar (44.2 ± 13.9 and 49 ± 21.2 years, respectively; $p = 0.723$). The mean size of ureteral stones was significantly higher in TA (+) patients (10.9 ± 4.1 vs 7.8 ± 2.1; $p = 0.005$). Statistically significant difference was found between the TA and localization of ureteral stones ($p = 0.044$) (Table 2). Binary comparison of ureteral stone localizations showed that higher TA rates were found in the proximal ureteral stones than in the middle one ($p = 0.029$). Although proximal ureteral stones had better rates of TA than distal ones, this difference was not statistically significant ($p = 0.077$). When we sub-grouped the patients according to the TA grades as 0, 1 and 2, 16 patients were with TA grade 0, 55 with TA grade 1 and 37 with TA grade 2. The BMI of patients was similar between the groups ($p = 0.334$); however, the mean stone size of groups was significantly different ($p = 0.012$) (Table 3). This difference was especially related to the comparison of the mean stone size of patients with TA grade 0 with TA grade 1, and TA grade 0 with TA grade 2 ($p = 0.008$ and $p = 0.018$).

Table 3 The comparison of twinkling grades with mean BMI and mean stone size

	Mean BMI (kg/m^2)	Mean stone size (mm)
Twinkling grade 0 ($n = 14$)	25.2 ± 1.6	7.8 ± 2.1
Twinkling grade 1 ($n = 55$)	24.8 ± 1.7	11 ± 3.7
Twinkling grade 2 ($n = 37$)	24.6 ± 2.0	10.7 ± 4.8
p	0.334*	0.012*

* Kruskal–Wallis test

Discussion

Urolithiasis is a common and serious health problem worldwide with a prevalence of 4–20 % [1, 2]. According to the data of the National Hospital Ambulatory Medical Care Survey of the USA, approximately 1,100,000 emergency department visits for renal colic were done in the year 2000 [16]. Pearle et al. pointed that the cost of urolithiasis exceeded $2 billion per year in the USA [17]. A large part of costs consisted of imaging modalities including KUB, NCCT and USG. KUB radiography had been used for many years in diagnosing urolithiasis. The sensitivity and specificity of KUB radiography was reported as 44–77 and 80–87 %, respectively [18]. While the NCCT has become the gold standard for diagnosing acute flank pain, the use of KUB radiography has decreased in the initial diagnosis; however, it is still helpful in the follow-up of radiopaque stones.

NCCT has very high sensitivity (96–98 %) and specificity (96–100 %) in diagnosing urolithiasis [19, 20]. NCCT can detect radiolucent stones (uric acid and xanthine), but not indinavir stones. The advantage of NCCT must be balanced against the loss of information on renal function and urinary collecting system anatomy, as well as higher radiation dose. CT dose index (CTDI) is used to calculate the radiation exposure. The mean dose for the total examined volume is defined as CTDIvol and dose length product (DLP) is obtained by multiplying CTDIvol and the total length of the dose during the procedure. The CTDIvol value that the patient is exposed for a procedure ranges between 1.5 and 15 mGy and the DLP value ranges between 100 and 1000 mGy-cm [21]. A new CT technique (low-dose CT) has been used to decrease this higher dose of radiation, but its sensitivity was reported as 86 % in patients with body mass index (BMI <30) and <3 mm ureteral stones [22]. USG could be used as an alternative method instead of NCCT to reduce the cost and radiation dose. It can be useful to identify stones and pelvicaliectasis due to the obstruction of the urinary tract; however, its sensitivity and specificity were reported to be 45 and 94 % for ureteral stones, and 45 and 88 % fpr renal stones, respectively [6, 23]. Although grayscale US has limited value in diagnosing urolithiasis especially in ureteral stones, it could be used safely in children and pregnant women. The use of TA on color Doppler USG has been started to improve the sensitivity and specificity of USG in diagnosing urolithiasis [9, 24, 25].

Mitterberger et al. compared the sensitivity of grayscale sonography and color Doppler sonography in the diagnosis of urinary stones. Totally, 41 patients with 77 urinary stones were evaluated. The sensitivity of grayscale US and Doppler sonography using the twinkling sign were detected as 66 and 97 %, respectively. They showed the improvement in the detection of urinary stones using color Doppler US with twinkling sign [25].

Ripollès et al. first investigated the value of TA in the diagnosis of ureteral stones in patients with renal colic in the emergency setting by a prospective study [26]. Color Doppler US with TA and CT was performed on 100 patients with suspected renal colic. Urolithiasis was detected in 84 patients and color Doppler US with TA was positive in 59 of them (78 %). They reported that the color Doppler TA had more success in the middle ureter (88 %). In our study, the specificity of TA was calculated as 86.8 % and its success was better in proximal ureteral stones (95.6 %).

Winkel et al. reported the first prospective study comparing US to low-dose NCCT in detecting urolithiasis when including the color-Doppler twinkling artifact as an additional diagnostic US feature [27]. They concluded that TA on color Doppler US could be helpful, especially in patients who had contraindications for CT and in monitoring stones left to pass without intervention.

Some of the studies reported that higher BMI values decreased the sensitivity of USG and color Doppler USG in the diagnosis [28, 29]. However, we did not find any correlation between BMI and TA similar to recent studies [27, 30] and could be related to the small number of patients with BMI >30 kg/m^2.

The role of stone size in the detection of TA was evaluated in several studies. Mitterberger et al. [25] and Winkel et al. [27] could not find any correlation between the stone size and presence of TA; however, Sorensen et al. reported that when the stone size increased, the sensitivity of TA on color Doppler USG also increased [12]. In our study; the mean size of ureteral stones was significantly higher in TA (+) patients.

The present study has some limitations. First, color Doppler ultrasound examination is strongly dependent on the skill of the examiner. All of the TAs on color Doppler US were investigated by only an experienced radiologist (CI) in our study. This was a single-blinded study (the radiologist was blinded to the NCCT results), and further double-blinded investigations could be designed for evaluating TA

on color Doppler US. By these future studies, color Doppler USG might be preferred instead of NCCT.

While the NCCT has become the gold standard imaging method in diagnosing urolithiasis, the use of ionizing radiation has also increased. TA on color Doppler USG could be a good and safe alternative imaging modality with comparable results to NCCT. It could be useful in the diagnosis and follow-up of patients with ureterolithiasis.

Compliance with ethical standards

Conflict of interest None declared.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Trinchieri A (1996) Epidemiology of urolithiasis. Arch Ital Urol Androl 68:203–250
2. Kim HH, Jo MK, Kwak C et al (2002) Prevalence and epidemiologic characteristics of urolithiasis in Seoul, Korea. Urology 59:517–521
3. Soueidan M, Bartlett SJ, Noureldin YA et al (2015) Leisure time physical activity, smoking and risk of recent symptomatic urolithiasis: survey of stone clinic patients. Can Urol Assoc J 9:257–262
4. Ordon M, Urbach D, Mamdani M et al (2015) A population based study of the changing demographics of patients undergoing definitive treatment for kidney stone disease. J Urol 193:869–874
5. Akıncı M, Esen T, Tellaloğlu S (1991) Urinary stone disease in Turkey: an updated epidemiological study. Eur Urol 20:200–203
6. Türk CK, Knoll T, Petrik A et al (2015) Guidelines on urolithiasis. European Association of Urology. http://uroweb.org/wpcontent/uploads/22-Urolithiasis_LR_full.pdf. Accessed 20 Jan 2016
7. Brenner DJ, Hall EJ (2007) Computed tomography—an increasing source of radiation exposure. N Engl J Med 357:2277–2284
8. Moore CL, Daniels B, Ghita M et al (2015) Accuracy of reduced-dose computed tomography for ureteral stones in emergency department patients. Ann Emerg Med 65:189–198
9. Rahmouni A, Bargoin R, Herment A et al (1996) Color Doppler twinkling artifact in hyperechoic regions. Radiology 1991:269–271
10. Hassani H, Raynal G, Spie R et al (2012) Imaging-based assessment of the mineral composition of urinary stones: an in vitro study of the combination of hounsfield unit measurement in noncontrast helical computerized tomography and the twinkling artifact in color Doppler ultrasound. Ultrasound Med Biol 38:803–810
11. Gao J, Hentel K, Rubin JM (2012) Correlation between twinkling artifact and color Doppler carrier frequency: preliminary observations in renal calculi. Ultrasound Med Biol 38:1534–1539
12. Sorensen MD, Harper JD, Hsi RS et al (2013) B-mode ultrasound versus color Doppler twinkling artifact in detecting kidney stones. J Endourol 27:149–153
13. Chelfouh N, Grenier N, Higueret D et al (1998) Characterization of urinary calculi: in vitro study of twinkling artifact revealed by color flow sonography. AJR Am J Roentgenol 171:1055
14. Alan C, Hocoglu H, Hosar S et al (2011) Role of twinkling artifact in characterization of urinary calculi. Actas Urol Esp 35:396
15. Sharma G, Sharma A (2013) Clinical implications and applications of the twinkling sign in ureteral calculus: a preliminary study. J Urol 189:2132–2135
16. Brown J (2006) Diagnostic and treatment patterns for renal colic in US emergency departments. Int Urol Nephrol 38:87–92
17. Pearle MS, Calhoun EA, Curhan GC (2005) Urologic diseases in America project: urolithiasis. J Urol 173:848–857
18. Heidenreich A, Desgrandschamps F, Terrier F (2002) Modern approach of diagnosis and management of acute flank pain: review of all imaging modalities. Eur Urol 41:351–362
19. Tiselius H-G (2003) Epidemiology and medical management of stone disease. BJU Int 91:758–767
20. Chowdhury FU, Kotwal S, Raghunathan G et al (2007) Unenhanced multidetector CT (CT KUB) in the initial imaging of suspected acute renal colic: evaluating a new service. Clin Radiol 62:970–977
21. Tack D, Kalra MK, Gevenois PA (2012) Radiation dose from multidetector CT. Springer, Berlin
22. Poletti PA, Platon A, Rutschmann OT et al (2007) Low-dose versus standard-dose CT protocol in patients with clinically suspected renal colic. AJR Am J Roentgenol 188:927–933
23. Ray AA, Ghiculete D, Pace KT et al (2010) Limitations to ultrasound in the detection and measurement of urinary tract calculi. Urology 76:295–300
24. Shabana W, Bude RO, Rubin JM (2009) Comparison between color Doppler twinkling artifact and acoustic shadowing for renal calculus detection: an invitro study. Ultrasound Med 35:339–350
25. Mitterberger M, Aigner F, Pallwein L et al (2009) Sonographic detection of renal and ureteral stones. Value of the twinkling sign. Int Braz J Urol. 35:532–539
26. Ripollés T, Martínez-Pérez MJ, Vizuete J et al (2013) Sonographic diagnosis of symptomatic ureteral calculi: usefulness of the twinkling artifact. Abdom Imaging 38:863–869
27. Winkel RR, Kalhauge A, Fredfeldt KE (2012) The usefulness of ultrasound colour-Doppler twinkling artefact for detecting urolithiasis compared with low dose nonenhanced computerized tomography. Ultrasound Med Biol 38:1180–1187
28. Asbeutah AM, Bakir YY, Swamy N et al (2013) Subject body mass index affects Doppler wave form in celiac artery by duplex ultrasound. Open Cardiovasc Med J 7:40–45
29. Abo A, Shannon M, Taylor G et al (2011) The influence of body mass index on the accuracy of ultrasound and computed tomography in diagnosing appendicitis in children. Pediatr Emerg Care 27:731–736
30. Kielar AZ, Shabana W, Vakili M et al (2012) Prospective evaluation of Doppler sonography to detect the twinkling artifact versus unenhanced computed tomography for identifying urinary tract calculi. J Ultrasound Med 31:1619–1625