Asian Journal of Urology 10 (2023) 39–49

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Original Article

Diagnostic value ultrasound signs of stones less than or equal to 10 mm and clinico-radiological variants of ureteric colic

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Received 13 December 2021; received in revised form 13 February 2022; accepted 22 March 2022
Available online 13 November 2022

KEYWORDS
Ureteric colic;
Urolithiasis;
Ultrasound;
Twinkle artifact;
Non-contrast computed tomography

Abstract *Objective:* To determine the diagnostic value of ultrasound signs of urinary stones less than or equal to 10 mm and to determine clinico-radiological variants of ureteric colic.
Methods: A total of 455 ultrasound investigations were performed in patients referring to emergency department with urolithiasis and symptoms suspected of ureteric colic between January 2021 and May 2021. In addition to microscopic evaluation of urine sediment to detect different crystals and non-contrast spiral computed tomography to detect stones, B-mode and color Doppler sonography was performed to assess the presence of acoustic shadow (AS) and twinkle artifacts (TA) as possible signs of stone(s) in ureter.
Results: While the sensitivity and specificity of AS and TA were higher than 90% in patients with stones greater than 5 mm; positive prognostic values of these parameters were found to be extremely low for stones with sizes of 1–3 mm with specificity and sensitivity values not exceeding 53%. The sensitivity and specificity of AS and TA in the upper and lower ureters were higher for stones greater than or equal to 5 than for compared to those less than 5 mm. At the

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Peer review under responsibility of Tongji University.

https://doi.org/10.1016/j.ajur.2022.03.015

same time, the diagnostic values of TA and AS for middle ureter stones were very limited. The most prevalent clinico-radiological variants of ureteric colic were types I, III, and V being observed in 39%, 28% and 21% cases, respectively.
Conclusion: Our results demonstrate that TA and AS parameters seem to have a very low sensitivity and specificity in the diagnosis of urinary stones less than 5 mm. The diagnostic value of TA and AS increase significantly in stones greater than or equal to 5 mm. Therefore, clinicians need to be very careful for overestimating the diagnostic values of TA and AS for stones less than 5 mm and non-contrast spiral computed tomography must be the method of choice for patients presenting to emergency department with ureteric colic.

1. Introduction

Ureteric colic due to its obstruction caused by a stone is the most common type of abdominal pain presenting in emergency departments [1]. It has been estimated that 6% of women and 12% of men will have at least one episode of ureteric colic during their life [2,3]. Currently, non-contrast enhanced computed tomography (NCCT) is considered the gold standard imaging modality for prompt diagnosis of urinary stones with the highest sensitivity and specificity. The NCCT can also provide us valuable information about stone characteristics and anatomical details (stone density, inner structure of stone, pelvicalyceal anatomy, and skin-to-stone distance) with possible three-dimensional image reconstruction. Despite these well-established advantages, the NCCT possesses high risk of ionizing radiation limiting its use for long-term follow-up of patients with recurrent ureteric colic caused by urinary calculi. Therefore, the implementation of the NCCT in all patients may be difficult and the use of ultrasound (US) for repeated admissions in emergency departments remains of paramount importance [4,5]. The US imaging represents a non-invasive, cheap, practical, and most importantly radiation-free modality commonly used for the long-term follow-up of urinary stone disease [6]. However, the latter imaging modality is associated with lower sensitivity depending on operator skills, and different patient-related (body mass index and anatomical abnormalities) and stone-related (location and size) factors. In current literature, there is a large inter-study heterogeneity and absence of unified standardization regarding training, experience, and technique of US operator. Maximizing diagnostic efficiency of the US while keeping its accuracy at high levels remains a major issue [7,8]. Thus, in this study we aimed to determine the diagnostic value of two different US signs (acoustic shadow [AS] and twinkle artifact [TA]) of urinary stones less than or equal to 10 mm and to determine clinico-radiological variants of ureteral colic.

2. Patients and methods

2.1. Study design and examinations

From January 2021 to May 2021, a prospective evaluation of 455 patients who underwent both NCCT and US imaging on the same day in the emergency departments at three different centers was performed. The study was approved by the local Ethics Committee of Central District Hospital Kamenolomni (2021-D00290-50), and informed consents were obtained from all patients in accordance to the 1964 Declaration of Helsinki Convention. Indications for US

Table 1 The demographic characteristics and computer tomography imaging results.

Characteristic	Value
Age, mean±SD, year	32.7±17.9
Body mass index, mean±SD, kg/m^2	27.8±3.9
Gender, *n* (%)	
Male	278 (61.1)
Female	177 (38.9)
Comorbidity, *n* (%)	52 (100)
Type 2 diabetes mellitus	18 (34.6)
Obesity[a]	15 (28.8)
Osteoporosis	5 (9.6)
Arterial hypertension	7 (13.5)
Dyslipidemia	4 (7.7)
Gout	3 (5.8)
The side of ureteric colic, *n* (%)	
Right	207 (45.5)
Left	245 (53.8)
Bilateral	3 (0.7)
Stone localization, *n* (%)	
Upper ureter	171 (37.6)
Middle ureter	152 (33.4)
Lower ureter	112 (24.6)
Multifocal	20 (4.4)
Stone size, *n* (%)	
1 mm	16 (3.5)
2 mm	21 (4.6)
3 mm	33 (7.3)
4 mm	44 (9.7)
5 mm	60 (13.2)
6 mm	51 (11.2)
7 mm	57 (12.5)
8 mm	52 (11.4)
9 mm	62 (13.6)
10 mm	59 (13.0)

[a] Obesity was defined as body mass index $\geq$30 kg/m^2.

Table 2 Sensitivity (%), specificity (%), PPV (%), NPV (%), and accuracy (%) of ultrasound signs of urinary stone (acoustic shadow and twinkle artifact).

Characteristic	Stone size (mm)									
	1	2	3	4	5	6	7	8	9	10
Acoustic shadow										
Sensitivity	0.0 (0.0–84.2)	33.3 (0.8–90.6)	52.9 (27.8–77.0)	52.5 (44.9–59.9)	91.7 (87.4–94.9)	95.1 (91.5–97.5)	98.2 (95.5–99.5)	99.1 (96.8–99.9)	100.0 (98.4–100.0)	100.0 (98.4–100.0)
Specificity	49.8 (45.1–54.5)	49.9 (45.2–54.6)	50.1 (45.3–54.9)	51.7 (45.5–57.7)	92.4 (88.1–95.5)	94.3 (90.5–96.6)	97.8 (94.9–99.2)	98.7 (96.2–99.7)	98.7 (96.2–99.7)	100.0 (98.3–10.00)
PPV	0.0 (0.0–0.0)	0.4 (0.1–2.1)	3.9 (2.5–6.1)	5.4 (4.5–6.4)	92.5 (88.6–95.1)	94.3 (90.7–96.6)	97.8 (94.9–99.1)	98.7 (96.1–99.6)	98.7 (96.1–99.6)	99.5 (97.6–99.9)
NPV	99.1 (99.0–99.2)	99.1 (98.1–99.6)	96.5 (94.2–97.8)	95.4 (94.5–96.1)	91.6 (87.7–94.4)	95.2 (91.7–97.2)	98.2 (95.5–99.3)	99.1 (96.6–99.8)	100.0 (98.7–100.0)	100.0 (98.3–100.0)
Accuracy	49.6 (44.9–54.3)	49.8 (45.1–54.5)	50.2 (45.5–54.9)	51.7 (47.0–56.4)	92.0 (89.2–94.4)	94.7 (92.3–96.6)	98.0 (96.2–99.1)	98.9 (97.5–99.6)	99.3 (98.1–99.8)	99.7 (98.8–99.9)
Twinkle artifact										
Sensitivity	0.0 (0.0–97.5)	47.1 (22.9–72.2)	52.8 (35.5–69.6)	85.7 (80.0–90.2)	89.4 (84.6–93.1)	93.3 (89.2–96.2)	94.6 (90.8–97.2)	96.4 (93.1–98.5)	98.7 (96.2–99.7)	99.1 (96.9–99.9)
Specificity	49.9 (45.2–54.6)	49.9 (45.1–54.7)	51.1 (46.2–55.9)	77.1 (71.5–82.1)	89.0 (84.2–92.8)	91.8 (87.5–95.0)	92.7 (88.6–95.7)	95.6 (92.1–97.9)	98.2 (95.6–99.5)	99.5 (97.6–99.9)
PPV	0.0 (0.0–0.0)	3.5 (2.1–5.7)	8.4 (6.2–11.2)	74.0 (69.3–78.2)	88.9 (84.8–92.1)	91.6 (87.7–94.4)	92.5 (88.7–95.1)	95.6 (92.2–97.6)	98.2 (95.5–99.3)	99.5 (96.9–99.9)
NPV	99.6 (99.5–99.6)	96.0 (93.9–97.4)	92.7 (89.9–94.8)	87.6 (83.3–90.9)	89.4 (85.2–92.5)	93.4 (89.7–95.9)	94.7 (91.2–96.9)	96.5 (93.3–98.2)	98.7 (96.0–99.6)	99.1 (96.6–99.8)
Accuracy	49.8 (45.1–54.5)	49.8 (45.1–54.5)	51.2 (46.5–55.8)	80.8 (76.9–84.3)	89.2 (85.9–91.9)	92.5 (89.7–94.8)	93.6 (90.9–95.7)	96.0 (93.8–97.6)	98.5 (96.6–99.4)	99.3 (98.1–99.8)

PPV, positive prognostic value; NPV, negative prognostic value.

Note: values are expressed as median (95% confidence interval).

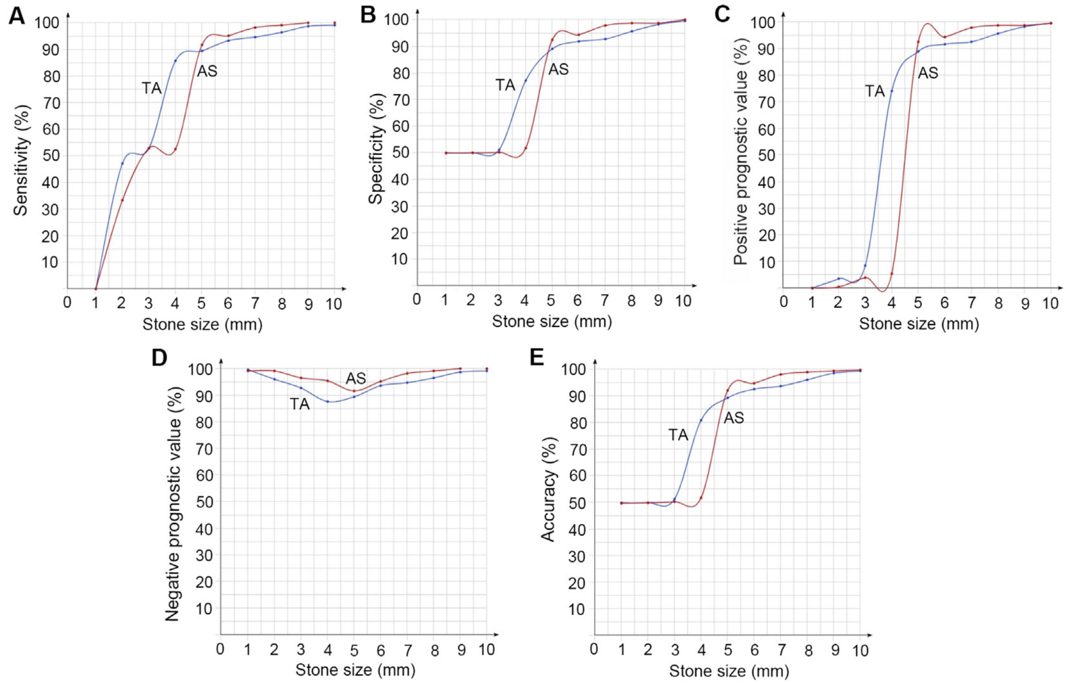

Figure 1 Graphical display of the dependence of the value (95% confidence interval) of TA and AS in percentage of the size of the stone. (A) Sensitivity; (B) Specificity; (C) Positive prognostic value; (D) Negative prognostic value; (E) Accuracy. TA, twinkle artifact; AS, acoustic shadow.

imaging included acute flank pain associated with macrohematuria and microhematuria. In case of absence of stones on US imaging, all patients with clinical symptoms of ureteric colic and dilation of pelvi-calyceal system were subjected to NCCT. Patients presenting with renal artery calcifications, any urinary stone greater than 10 mm, multiple stones in the ureter, ureteral colic after any type of active stone treatment, and patients with urinary diversion were excluded from study program.

The microscopic evaluation of urine sediment was done using brightfield microscope Levenhuk 320 series (Levenhuk Inc, Tampa, FL, USA) with an incorporated high-definition video camera to detect hematuria and the crystals of different salts. The NCCT was performed from the upper abdomen to the pelvis with images reconstructed at 1 mm or 2 mm intervals. The US evaluation was performed using B-mode and color Doppler regimen (Philips Lumify, Philips Ultrasound Inc., WA, USA) with a 2—5 MHz convex

Table 3 Multivariable logistic regression analysis for risk factors associated with maximal value of pain (VAS 8—10) and the degree of maximum extension of the renal pelvis.

Variable	VAS 8—10			Maximum extension of the renal pelvis		
	OR	95 % CI	*p*-Value	OR	95 % CI	*p*-Value
Twinkle artifact in US	1.018	0.966—1.073	0.032	0.024	0.002—0.259	0.021
Acoustic shadow in US	0.916	0.857—0.978	0.010	5.310	1.711—16.48	0.024
Kidney stone						
$\geq$5 mm	0.864	0.764—0.976	0.020	0.083	0.059—19.65	0.308
$<$5 mm	1.084	0.930—1.263	0.307	2.846	0.908—8.922	0.059
Ureter stone						
$<$5 mm	1.065	0.917—1.237	0.409	1.249	0.976—1.600	0.077
$\geq$5 mm	1.157	1.012—1.323	0.036	0.841	0.720—0.983	0.029
Microhematuria	0.973	0.930—1.018	0.237	1.497	1.212—1.850	0.014
Macrohematuria	1.000	0.996—1.004	0.972	0.975	0.952—0.998	0.043
Calcium oxalate dihydrate	0.859	0.754—0.978	0.023	0.913	0.730—1.141	0.041
Triple phosphate (NH_4MgPO_4) and calcium phosphates	0.949	0.824—1.092	0.463	1.412	0.288—6.932	0.647
Amorphous urates	1.185	1.029—1.365	0.020	0.586	0.341—1.005	0.069

CI, confidence interval; US, ultrasound; VAS, visual analogue scale; OR, odds ratio.

transducer. All US examinations were performed by four trained urologists (Krakhotkin DV, Chernylovskyi VA, Pikhovkin DN, and Iglovikov NY) with a skill competency level of 5 according to Miller's pyramid [9]. NCCT and US examinations were reviewed in a blind retrospective manner, and US images were reviewed without the reference of NCCT findings. Based on results of computer tomography (CT) imaging, US parameters (TA and AS) urine sediment study, the value of pain measured visual analogue scale (VAS), and the degree of extension of renal pelvis in US in whole study group, we determined five clinico-radiological variants of ureteric colic.

2.2. Study variables and statistical analysis

Patients' and stone characteristics including stone localization, stone size, previous urological surgery, body mass index, and side of ureteric colic were evaluated. The stones suspected with the ureteric colic were considered. Stone size was calculated using longest axis of the calculi detected

Table 4 Diagnostic value of ultrasound signs of stones (≤10 mm) in upper, middle, and lower ureter.

Part of ureter	Diagnostic value of acoustic shadow	Diagnostic value of twinkle artifact
Upper ureter	- Sensitivity <5 mm: 0%—57.8%; ≥5 mm: 91.7%—99.7% - Specificity <5 mm: 48.9%—53.7%; ≥5 mm: 93.4%—99.8% - Positive prognostic value <5 mm: 0%—5.4%; ≥5 mm: 92.5%—99.8% - Negative prognostic value <5 mm: 98.1%—99.6%; ≥5 mm: 98.7%—99.7% - Accuracy <5 mm: 48.2%—52.9%; ≥5 mm: 92.9%—99.8%	- Sensitivity <5 mm: 0%—86.8%; ≥5 mm: 97.8%—99.9% - Specificity <5 mm: 45.4%—69.9%; ≥5 mm: 96.4%—99.8% - Positive prognostic value <5 mm: 0%—75.4%; ≥5 mm: 97.5%—99.9% - Negative prognostic value <5 mm: 98.7%—99.8%; ≥5 mm: 99.1%—99.9% - Accuracy <5 mm: 46.1%—72.9%; ≥5 mm: 97.9%—99.9%
Middle ureter	- Sensitivity <5 mm: 0%—37.8%; ≥5 mm: 45.6%—53.2% - Specificity <5 mm: 37.9%—48.7%; ≥5 mm: 41.4%—51.8% - Positive prognostic value <5 mm: 0%—4.8%; ≥5 mm: 43.5%—50.8% - Negative prognostic value <5 mm: 98.7%—99.8%; ≥5 mm: 99.1%—99.9% - Accuracy <5 mm: 0%—39.8%; ≥5 mm: 35.9—49.8%	- Sensitivity <5 mm: 0%—47.8%; ≥5 mm: 48.9%—65.7% - Specificity <5 mm: 48.9%—53.7%; ≥5 mm: 49.4%—59.8% - Positive prognostic value <5 mm: 0%—25.4%; ≥5 mm: 44.6%—62.4% - Negative prognostic value <5 mm: 99.2%—99.9%; ≥5 mm: 98.9%—99.9% - Accuracy <5 mm: 48.2%—60.9%; ≥5 mm: 50.9%—63.5%
Lower ureter	- Sensitivity <5 mm: 0%—53.8%; ≥5 mm: 95.6—99.9% - Specificity <5 mm: 45.8%—54.5%; ≥5 mm: 94.8%—99.9% - Positive prognostic value <5 mm: 0%—4.6%; ≥5 mm 96.5%—99.9% - Negative prognostic value <5 mm 98.7%—99.8%; ≥5 mm: 99.1%—99.8% - Accuracy <5 mm: 45.3%—50.8%; ≥5 mm: 95.4%—99.9%	- Sensitivity <5 mm: 0%—79.8%; ≥5 mm: 91.7%—99.7% - Specificity <5 mm: 44.9%—63.7%; ≥5 mm: 97.9%—99.9% - Positive prognostic value <5 mm: 0%—5.1%; ≥5 mm: 96.5%—99.9% - Negative prognostic value <5 mm: 99.3%—99.8%; ≥5 mm: 99.3%—99.9% - Accuracy <5 mm: 46.3%—59.8%; ≥5 mm: 96.9%—99.9%

on NCCT and US images. The sensitivity and specificity of TA and AS found on US imaging for stones less than or equal to 10 mm were calculated by examining the correlation of US and NCCT findings, having the NCCT as the gold standard. For the evaluation of US imaging reports, a blind revision by the author (Chernylovskyi VA) was performed. In all case, the intensity of pain was measured with VAS. The degree of maximum extension (cm) of the renal pelvis was measured as the long axis of the hypoechoic structure between the renal papilla and pyramid in US imaging.

Data were analyzed using SPSS 20.0 software (SPSS, Illinois, CA, USA). Descriptive analysis of continuous and categorical variables was performed using mean±standard deviation (SD) and percentages, respectively. A paired *t*-test was used to compare the differences between the groups. The diagnostic values of US sign of urinary stone (TA and AS) were analyzed by measuring their sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy with 95% confidence interval. A *p*-value below 0.05 was considered as statistically significant. Multivariable logistic regression analysis was used to evaluate for independent risk factors associated with maximum values of pain (VAS 8—10) and the degree of maximum extension (cm) of the renal pelvis. The multicollinearity test was performed where variance inflation factor was calculated for each variable.

3. Results

A total of 455 patients, 278 (61.1%) males and 177 (38.9%) females, were presented and evaluated for acute ureteral colic pain in emergency departments at three centers. The mean age of the patients was 32.7 (SD: 17.9) years and the mean body mass index was 27.8 (SD: 3.9) kg/m^2. In our study, 52 patients had following comorbidities: type 2 diabetes mellitus (34.6%), obesity (28.8%), osteoporosis (9.6%), arterial hypertension (13.5%), dyslipidemia (7.7%), and gout (5.8%). In all patients with suspected ureteric colic, the diagnosis of stone disease was made based on NCCT images, US data, and pathological findings of urine sediment (microscopic hematuria and pronounced crystalluria). Patients' characteristics and results of CT imaging are shown in Table 1.

The sensitivity and specificity of TA and AS in patients with stones greater than or equal to 5 mm were more than 89% and increased up to 100% for stones with 10 mm in diameter. Similarly, PPV, NPV, and accuracy of TA and AS parameters increased to 98%—100% in patients with stones 9—10 mm. A subgroup analysis of stones less than or equal to 3 mm found an extremely low PPV for TA and AS with a specificity and sensitivity of less than 53%. For 4 mm stones, the sensitivity and specificity of TA were 85.7% and 77.1%, respectively, whereas the sensitivity and specificity of AS

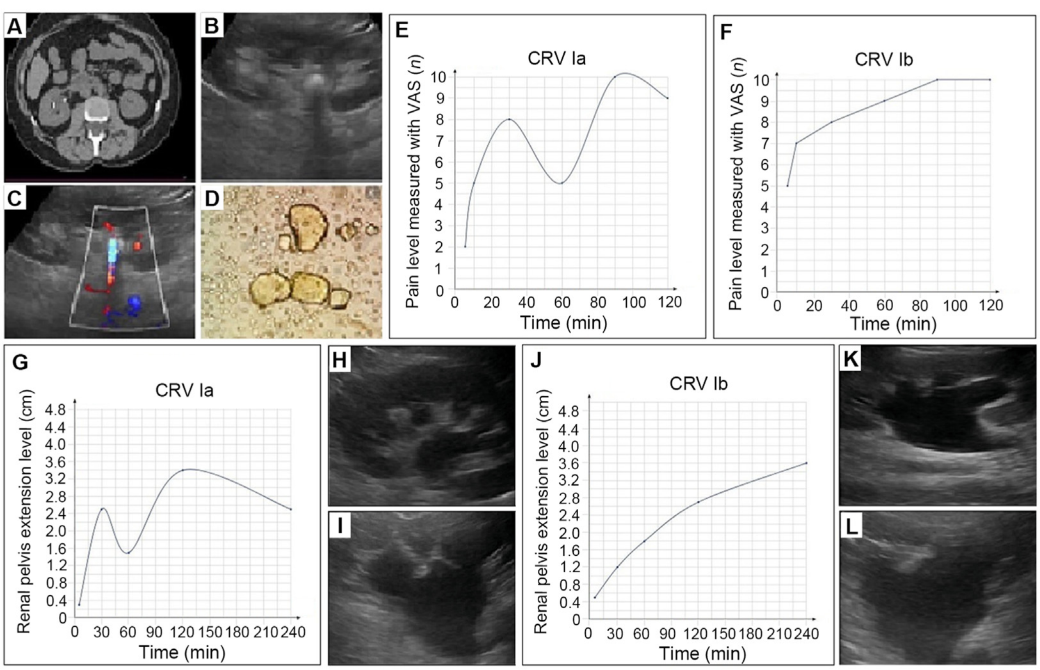

Figure 2 CRV I. (A) The presence of urinary stone in computer tomography scan in axial plane; (B) Ultrasound image of urinary stone with clear acoustic shadow; (C) Ultrasound image of urinary stone with clear twinkle artifact; (D) Microscopic image of crystals of different salts in urine sediment (magnification 400×); (E) Graphical display of the wavy dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (F) Graphical display of the rectilinear dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (G) Graphical display of the wavy dependence of renal pelvis extension level (cm) and duration of ureteric colic in minutes; (H) The maximum extension of the renal pelvis at 30 min of ureteric colic; (I) The maximum extension of the renal pelvis at 120 min of ureteric colic; (J) Graphical display of the rectilinear dependence of renal pelvis extension level (cm) and duration of ureteric colic in minutes; (K) The maximum extension of the renal pelvis at 60 min of ureteric colic; (L) The maximum extension of the renal pelvis at 240 min of ureteric colic. VAS, visual analogue scale; CRV, clinico-radiological variant of ureteric colic; CRV I, CRV type I; CRV Ia, CRV type Ia; CRV Ib, CRV type Ib.

were only 52.5% and 51.7%, respectively. As for 5 mm stones, the sensitivity and specificity values of TA and AS of up to 89.0%—92.4% were reported (Table 2). The graphical display of the dependence of the value of TA and AC in percentage of the size of the stone is depicted in Fig. 1.

The urine sediment study under high power magnification of bright field microscopy identified following types crystals: amorphous urates, calcium oxalate, triple phosphate (NH_4MgPO_4), and calcium phosphates ($CaHPO_4$ and/or $Ca[H_2PO_4]_2$).

The evaluation of the pain scores revealed that the maximum level of pain (VAS 8—10) was related to the following parameters: AS, TA, kidney and ureteral stone size greater than or equal to 5 mm in CT scan, calcium oxalate dihydrate, and amorphous urates crystals in urine sediment. The degree of maximum extension (cm) of the renal pelvis was associated to AS, TA, ureteral stone size greater than or equal to 5 mm, macrohematuria, microhematuria, and calcium oxalate dihydrate (Table 3). The sensitivity and specificity of AS for upper ureteral stones less than 5 mm ranged from 0%—57.8% and 48.9—53.7%, respectively. In the same group, the sensitivity and specificity of TA ranged from 0%—86.8% and 45.4%—69.9%, respectively. Stones located in the middle ureter regardless of the stones size showed very low sensitivity, specificity, PPV, and accuracy values of TA and AS. It is worth mentioning that the sensitivity and specificity of TA and AS for upper and ureteral stones greater than or equal to 5 were above 90%. The diagnostic values of US signs of stones located in the upper, middle, and lower ureters are shown in Table 4.

The most prevalent clinico-radiological variants of ureteric colic were types I, III, and V which were observed in 39%, 28%, and 21% cases, respectively. The types II and IV rarely occurred, comprising 5% and 7% of cases, respectively.

The patients with types I and V had two types of curves of dependence of pain values on the VAS scale and the degree of extension of the renal pelvis over time. In these patients, form of graph had both wavy character of the curve and parabolic view extending upward. At the same time, the graph of the dependence of pain values (VAS) and the degree of maximum extension (cm) of the renal pelvis in patients with types II, III, and IV consisted of an

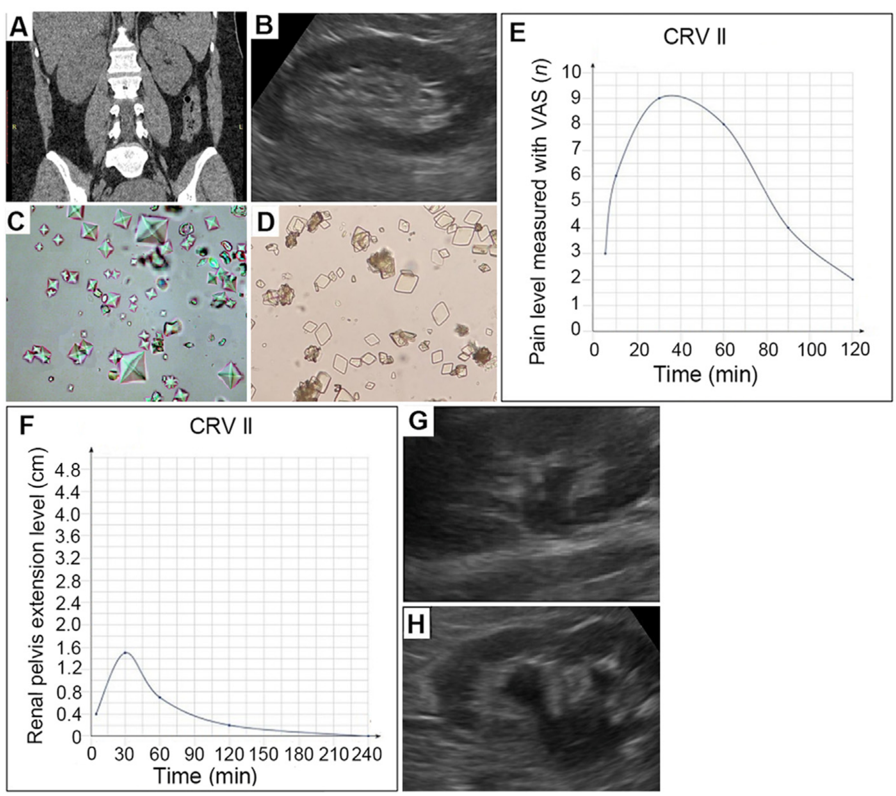

Figure 3 CRV II. (A) The absence of urinary stone in computer tomography scan; (B) Ultrasound image of urinary stone without acoustic shadow and twinkle artifact; (C, D) Microscopic images of crystals of different salts in urine sediment (magnification 400×); (E) Graphical display of the dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (F) Graphical display of the dependence of the maximum extension of the renal pelvis and duration of ureteric colic in minutes; (G) The maximum extension of the renal pelvis at 15 min of ureteric colic; (H) The maximum extension of the renal pelvis at 30 min of ureteric colic. VAS, visual analogue scale; CRV II, clinico-radiological variant of ureteric colic type II.

ascending part, a plateau, and a descending part. The maximum values of VAS and the degree of maximum extension (cm) of the renal pelvis, which correspond to the plateau, were mainly in period time from 30—60 min (Figs. 2—6). A very important finding of our study was the spontaneous passage rates of stones during 6-week follow-up period which were 99.9% in 0—3 mm, 91.5% in 4 mm, 82.0% in 5 mm, and 11.0% greater than 6 mm, respectively.

4. Discussion

Radiologic imaging with appropriate modalities is highly important both in the diagnosis and follow-up for urolithiasis. Currently the US is the primary diagnostic, reproducible, radiation-free imaging tool which should be used in patients referring to emergency departments with ureteric colic due to urinary stones [10]. In clinical practice, the patients presenting with ureteric colic have worse depiction of echogenicity of ureteric stones, TA and AS, compared with renal ones. Data reported so far in the literature suggest that TA has high sensitivity and specificity values in the accurate diagnosis of urinary stones less than 5 mm. The TA is a complex phenomenon which occurs as a focus of alternating colors on Doppler signal behind a reflective object such as a urinary stone [11,12]. Related with the radiological use of this parameter, Korkmaz et al. [13] demonstrated that the sensitivity of TA for stones less than 5 mm was 93.4% while US without color Doppler regimen was able to detect the urinary stones only in 19.7% cases. A prospective study by Gliga et al. [14] reported that the sensitivity and specificity of TA in detecting urinary stones less than 5 mm was 99.12% and 90.91%, respectively. The advantage of our study was that all cases of urinary stones were confirmed with NCCT. Unlike those findings, our data demonstrated that the TA and AS have a very low sensitivity and specificity values for diagnosis of urinary stones less than 4 mm in patients with ureteric colic when compared with the NCCT being accepted as the reference standard.

Abdel-Gawad et al. [15] reported that the TA was generated in 702 (97.1%) patients with sensitivity and specificity of 97.2% and 99%, respectively. Most of the stones (511 [70.7%] stones) were sized between 5 mm and 10 mm; only 172 (23.8%) of the stones had a size less than

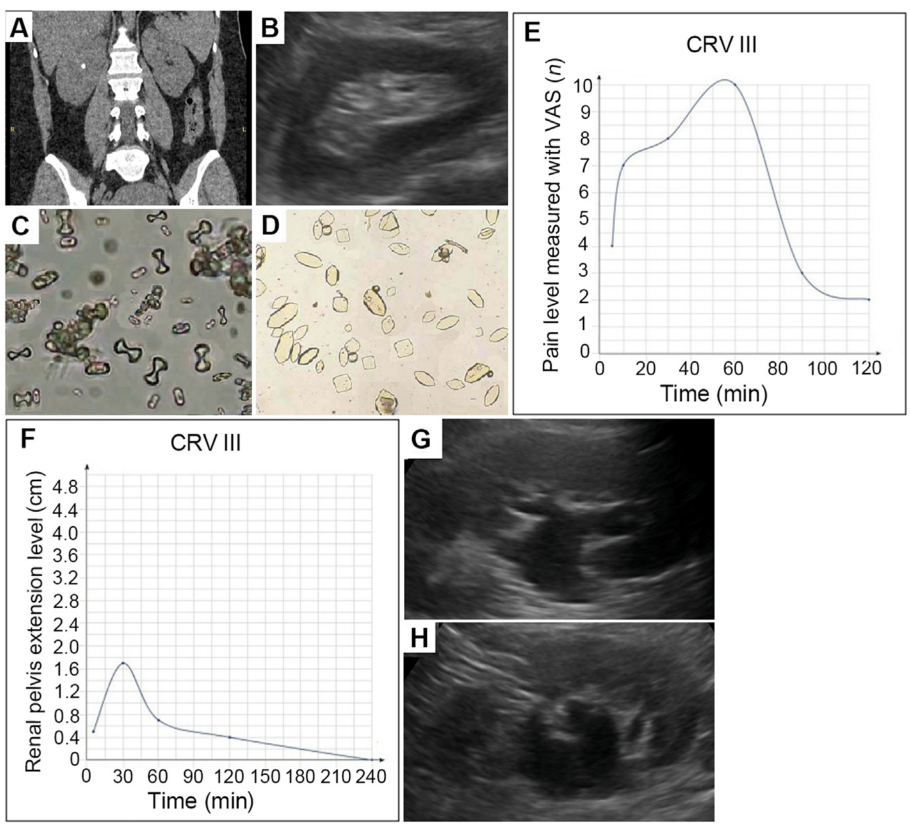

Figure 4 CRV III. (A) The presence of urinary stone in computer tomography scan in frontal plane; (B) Ultrasound image of urinary stone without acoustic shadow and twinkle artifact; (C, D) Microscopic images of crystals of different salts in urine sediment (magnification 400×); (E) Graphical display of the dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (F) Graphical display of the dependence of the maximum extension of the renal pelvis and duration of ureteric colic in minutes; (G) The maximum extension of the renal pelvis at 5 min of ureteric colic; (H) The maximum extension of the renal pelvis at 30 min of ureteric colic. VAS, visual analogue scale; CRV III, clinico-radiological variant of ureteric colic type III.

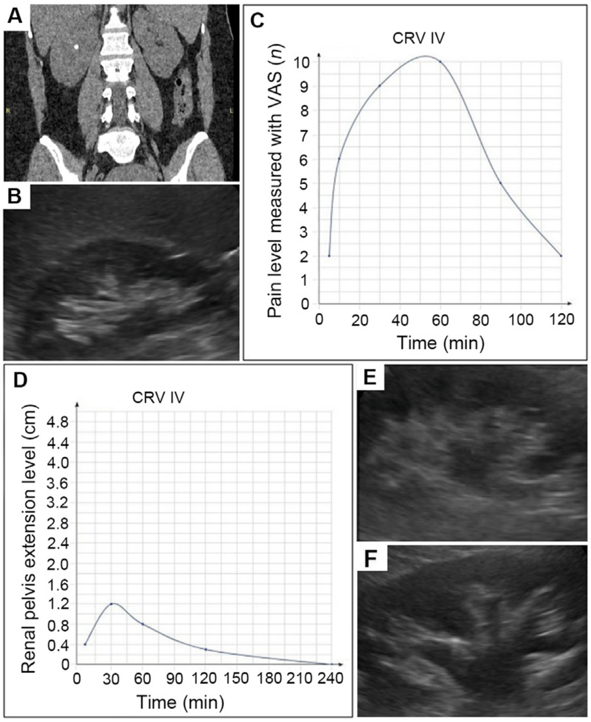

Figure 5 CRV IV. (A) The presence of urinary stone in computer tomography scan in frontal plane; (B) Ultrasound image of urinary stone without acoustic shadow and twinkle artifact; (C) Graphical display of the dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (D) Graphical display of the maximum extension of the renal pelvis and duration of ureteric colic in minutes; (E) The maximum extension of the renal pelvis at 5 min of ureteric colic; (F) The maximum extension of the renal pelvis at 30 min of ureteric colic. VAS, visual analogue scale; CRV IV, clinico-radiological variant of ureteric colic type IV.

5 mm (range 3–5 mm). A prospective study by Masch et al. [16] showed that isolated TA has a high false-positive rate (60%) for the diagnosis of renal calculus in patients without urolithiasis history. The sensitivity, specificity, PPV, and NPV of TA for stones with a mean size of 5 mm (range 1.5–10.0 mm) were also described by Puttmann et al. [17] with 83%, 78%, 74%, and 86%, respectively. During the statistical processing of our data, it was shown that the sensitivity values of AS and TA did not exceed 52.5 % and 85.7%, respectively. However, the sensitivity, specificity, PPV, NPV of TA and AS significantly increased in the detection of urinary stones greater than or equal to 5 mm. Our analysis showed that the sensitivity and specificity of AS and TA in the upper and lower ureters were higher for stones greater than or equal to 5 mm compared to stones less than 5 mm, whereas stones in the middle ureter had very low sensitivity and specificity due to the significant difficulties for imaging related to bowel interposition. A possible explanation of the discrepancies in the results could be associated with the overestimation of the stone size on US for small stones less than 5 mm. Dai et al. [18] demonstrated that US may overestimate stone size by 1.0±1.4 mm based on shadow width and 3.8±2.4 mm based on stone width. It is worth noting that renal stone-like bright specks less than 5 mm may appear on US due to vascular and nonvascular reflectors within renal sinus. Some medical conditions such as acute tubular necrosis, chronic glomerulonephritis, and chronic neoplastic hypercalcemia may be the cause of hyperechoic focus of nonvascular origin [19].

In this present study, based on correlation between urine microscopy sediment findings and that of NCCT as well as US imaging modalities, we determined five clinico-radiological variants of ureteric colic. Type I was the most prevalent (39%), which is characterized by stone size greater than 5 mm on CT and US, and type I had a clearer AS and TA in US. At the same time, type II (5%) was rarer clinico-radiological variant of ureteric colic without any CT and US image of urinary stone, but characterized with large amount of crystal of different salts during microscopy of urine sediment. So far, limited data are available reporting about the relationship between crystalluria and clinical symptoms. Fazil Marickar et al. [20] found that among 238 patients with clinical symptoms, 176 had significant urinary deposits. These authors also demonstrated that presence of a calcium oxalate dihydrate stone is significantly higher in symptomatic patients and produces an injury of urothelium when compared with calcium oxalate monohydrate stones without symptoms. In one study, Fan and Chandhoke [21] demonstrated that predominant crystal type in fresh urines of both normal individuals and recurrent calcium stone formers appears to be calcium phosphate.

Lastly, in our study, we were able to demonstrate a significant association between the maximum value of pain measured with VAS (range 8–10) and TA, AS values in US. Moreover, the maximum value of pain had a significant association with presence of kidney and ureteral stone with size greater than or equal to 5 mm in CT scan; crystals were composed of oxalate dehydrate and amorphous urates in the urine sediment. At the same time, the degree of maximum extension (cm) of the renal pelvis had a significant association with TA, AS values in US, ureteral stone with size greater than or equal to 5 mm in CT scan, microhematuria and macrohematuria, and calcium oxalate dehydrate in urine sediment.

Therefore, the present study demonstrated that any physician should not overestimate the values of TA and AS in the diagnosis of urinary stone less than 5 mm. Currently, European Association of Urology guidelines recommend that NCCT valuation should be performed for the confirmation of urinary stone(s) after an initial ultrasonography examination. From our point of view, microscopy of urine sediment needs to be performed to detect the presence and the type of crystals which may show a close association with clinical symptoms and ease further clinical decision making. Tamošaitytė et al. [22] reported that the presence urinary deposits of uric acid in urine sediment was observed for 71% of urate kidney stone patients.

The main limitation of our study was the absence of unified standardization of reporting US images between the operators, which might have impacted our outcomes.

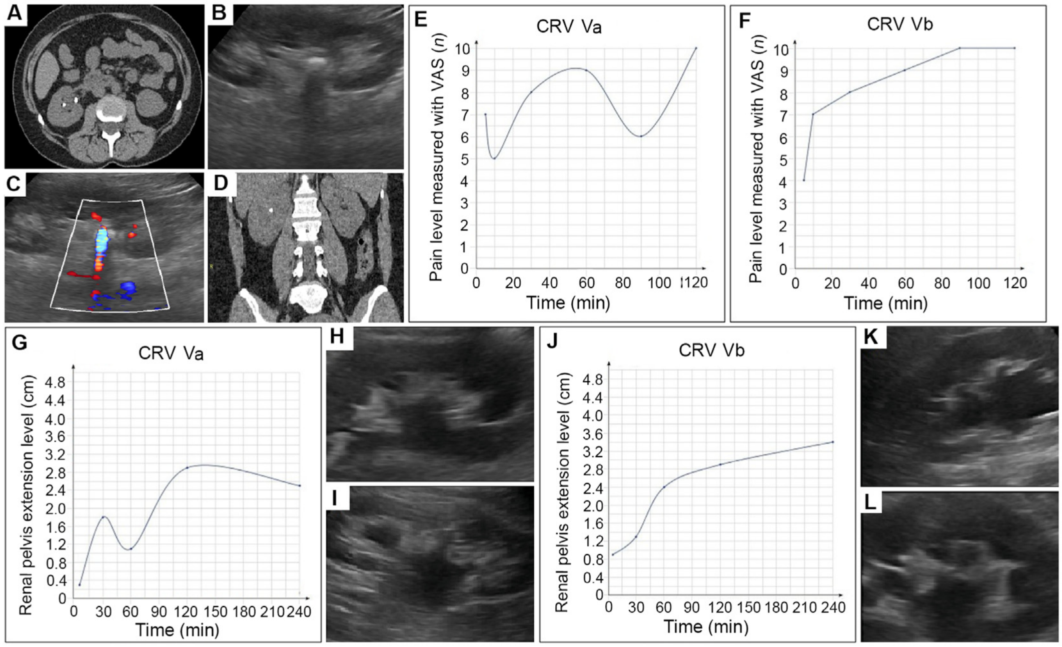

Figure 6 CRV V. (A) The presence of urinary stone in computer tomography scan in axial plane; (B) Ultrasound image of urinary stone with clear acoustic shadow; (C) Ultrasound image of urinary stone with clear twinkle artifact; (D) The computer tomography scan of urinary stone in frontal plane; (E) Graphical display of the wavy dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (F) Graphical display of the rectilinear dependence of the pain level measured with VAS and duration of ureteric colic in minutes; (G) Graphical display of the wavy dependence of renal pelvis extension level (cm) and duration of ureteric colic in minutes; (H) The maximum extension of the renal pelvis at 120 min of ureteric colic; (I) The maximum extension of the renal pelvis at 30 min of ureteric colic; (J) Graphical display of the rectilinear dependence of renal pelvis extension level (cm) and duration of ureteric colic in minutes; (K) The maximum extension of the renal pelvis at 60 min of ureteric colic; (L) The maximum extension of the renal pelvis at 120 min of ureteric colic. VAS, visual analogue scale; CRV, clinico-radiological variant of ureteric colic; CRV V, CRV type V; CRV Va, CRV type Va; CRV Vb, CRV type Vb.

However, in trained urologists, the sensitivity of US imaging may achieve 99.7% including detection hydronephrosis due to urinary stone [23]. Moreover, reporting the US data of different operators may reduce the bias associated with a single operator expertise.

5. Conclusion

Our results demonstrated that TA and AS parameters assessed during color flow Doppler sonographic examination may have a very low sensitivity, specificity, positive prognostic value, negative prognostic value, and accuracy for diagnosis of stones less than 5 mm. However, the diagnostic values of TA and AS increase significantly in stones greater than or equal to 5 mm. At the same time, the sensitivity and specificity of TA and AS for stones of any size in the mid-ureter were very low, whereas for stones in the upper and lower ureters, they exceeded 90% for stones greater than or equal to 5 mm. Therefore, clinicians need to be very careful for overestimating the diagnostic values of TA and AS for stones less than 5 mm and NCCT must be the method of choice for an accurate confirmation of such stones in patients presenting to emergency departments with ureteric colic. It should be noted that outcomes of the US imaging are highly dependent on US-operator, and to develop sufficient US operator skills a specific training may be required.

Author contributions

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Conflicts of interest

The authors declare no conflict of interest.

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