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ORIGINAL ARTICLE

Limited sensitivity and size over measurements of ultrasound affect medical decisions for ureteral stone compared to non-contrasted computed tomography

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Abstract

Purpose To evaluate the limited sensitivity and size over measurements of ultrasound (US) for ureteral stone, and demonstrate how this influenced medical decisions.

Patients and methods Retrospectively, we analyzed the data of patients with ureterolithiasis estimated by US and non-contrasted computed tomography (NCCT) within 48 h at our institution from January 1st 2014 to June 1st 2017. Stone size was grouped by the longest axis diameter on NCCT: < 5, 5–10, and > 10 mm. Then, US and NCCT results were compared for the sensitivity and measurements.

Results A total of 614 cases of ureterolithiasis were visible on NCCT. The sensitivity of US for ureterolithiasis < 5, 5–10, and > 10 mm were 63.49, 79.06, and 84.67%, respectively ($P = 0.001$). US overestimated the size in 63.49 and 50.54% of patients with ureterolithiasis < 5 and 5–10 mm compared to NCCT, respectively ($P < 0.001$). Under the assumptions that patients with ureteral stone < 5, 5–10, and > 10 mm would be simply observed, received medical expulsive therapy (MET), and surgical interventions, 20.94 and 15.33% of patients with stone sized 5–10 and > 10 mm might be improperly observed due to negative US reports. Besides, 63.49 and 50.54% of cases with stone < 5 and 5–10 mm might receive more aggressive interventions ascribed to over measurements of US.

Conclusions Limited sensitivity and size over measurements of US might significantly influence medical decisions for ureteral stone. Inaccurate evaluation of US should be taken in consideration for appropriate counseling options.

Keywords Ultrasound · Non-contrast computed tomography · Ureteral stone · Over measurement · Medical decisions

Introduction

It was widely agreed that there was a significantly inverse correlation between ureteral stone size and the spontaneous stone passage rate [1, 2]. Thus, studies [3, 4] and European Association of Urology (EAU) guideline [5] recommended observation, medical expulsive therapy (MET), and surgical interventions for patients with ureterolithiasis < 5, 5–10, and > 10 mm, respectively. This meant that stone management was essentially depended on accurate measurements.

At present, non-contrasted computed tomography (NCCT) was the most reliable technique for urolithiasis estimation [6, 7]. For another, ultrasound (US) was becoming preferred imaging for patients with suspected urolithiasis due to non-radiation and inexpensiveness [5]. Therefore, US was more frequently applied to the initial assessment and follow-up in urinary stone diseases [8, 9].

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However, the studies [10, 11] found that US significantly overestimated the stone size. Under the stone diameter classification of < 5, 5–10, and > 10 mm, literatures [12–14] considered that limited sensitivity and size over measurements of US might impact counseling decisions for urinary stones. Notably, those studies [10–14] just focused on nephrolithiasis, and similar investigations on ureterolithiasis were deficient. To address this dilemma, we aimed to evaluate the limited sensitivity and size over measurements of US for ureteral stone, and demonstrate how this influenced clinical decisions.

Patients and methods

Patient selection

The data of patients who diagnosed with single ureteral stone via urinary US and abdominal NCCT within 48 h from January 1st 2014 to June 1st 2017 at our center were analyzed retrospectively. Subjects were limited to adult ≥ 18 years of age, and reviewed to confirm stone location alteration, spontaneous passage, and medical interventions which did not occur between these two imageological modalities. The exclusion criteria were both images obtained more than 48 h apart. Besides, patients with pregnancy or history of ipsilateral urological surgery, urinary diseases like nephrolithiasis, renal masses, renal cysts, and other anatomic abnormalities which may influence the ureteral stone identification on US were also excluded. Demographic characteristics [gender, age, and body mass index (BMI)] of patients were recorded.

Image review and stone evaluation

NCCT was performed using a 16-detector row CT scanner (Brilliance, Philips Medical Systems, Best, The Netherlands) with 2 mm of the section thickness and interval (120 kV, 244 mAs). Scanning was performed from the upper abdomen (including the adrenal glands and kidneys) to the pubis, with patient in the supine position. Three parameters were measured (length, width, and height) through axial, sagittal, and coronal sections, respectively. NCCT images were independently reviewed by the radiologists to determine stone location and maximum diameter.

US scanners of Philips iU22, Antares, and GE Logic9 were used in this research. Abdominal US were conducted through multiple planes and found the maximum diameter. Parameters were saved at the discretion of the US technologists and applied to study comparison.

The results of US and NCCT were acquired from the official reports. According to the longest axis diameter on NCCT, ureterolithiasis was grouped into three categories based on clinical relevance in stone management: < 5, 5–10, and > 10 mm. Stone size was regarded concordant if both imagings' measurements were within the same diameter group. This kind of size classification was frequently applied to clinical practice and had been recommended in former articles [12, 13, 15].

Statistical analysis

The SPSS for Windows 23.0 software package (SPSS, Chicago, IL) was used for data analysis. The sensitivity of US and categorical variables was described with proportions and compared using the Chi-square test. The largest diameter measurements of US and NCCT were compared using two-sided *t* tests. The continuous data were evaluated using the independent-sample *t* test method. A P value < 0.05 was considered significant.

Results

Demographic characteristics

Herein, 1474 patients were diagnosed with ureterolithiasis during study period, and 614 patients were finally included after filtration. Of these subjects (females, $n = 279$, 45.44%; males, $n = 335$, 54.56%; left, $n = 326$, 53.09%; right, $n = 288$, 46.91%), all ureterolithiasis were visible on NCCT. The mean age was 51.50 ± 13.11 years with an average BMI of 24.23 ± 3.62 kg/m^2. According to the maximum stone diameter on NCCT, there were 63 (10.26%), 277 (45.11%), and 274 (44.63%) patients with ureterolithiasis sized < 5, 5–10, and > 10 mm, respectively.

Limited sensitivity of US for ureteral stone

The sensitivity of US for ureterolithiasis was 79.97% (491/614); for stone < 5, 5–10, and > 10 mm were 63.49% (40/63), 79.06% (219/277), and 84.67% (232/274), respectively ($P = 0.001$); for proximal, middle, and distal ureteral calculi were 84.81% (335/395), 76.24% (77/101), and 66.95% (79/118), respectively ($P < 0.001$) (Table 1). Refer

Table 1 Sensitivity of US for ureteral stone

	Stone size			*P*	Stone location			*P*
	< 5 mm	5–10 mm	> 10 mm		Proximal	Middle	Distal	
Sensitivity (%)	63.49	79.06	84.67	0.001	84.81	76.24	66.95	< 0.001

to the 123 (20.03%) patients with negative US results (< 5 mm, $n = 23$, 18.70%; 5–10 mm, $n = 58$, 47.15%; > 10 mm, $n = 42$, 34.15%), the mean diameter on NCCT was 9.59 ± 5.14 mm (Table 2).

Over measurements of US for ureteral stone size

For stone < 5 mm, US over measured 63.49% (40/63) of cases by an average of 4.85 ± 3.80 mm ($P < 0.001$). For stone sized 5–10 mm, US overestimation was found in 50.54% (140/277) of cases with a mean of 5.81 ± 4.01 mm ($P < 0.001$). For stone > 10 mm, size over measurements was not recorded by categorized groups but an average of 5.91 ± 5.07 mm in accurate value ($P < 0.001$) (Table 3).

Medical decision was affected by inaccurate estimation of US

To further assess the impact of US, we assumed that simple observation, MET, and surgical interventions would be recommended for patients with ureterolithiasis < 5, 5–10, and > 10 mm on NCCT, respectively. Under these assumptions, observation would have been suggested by NCCT, but the US results would recommend MET and surgical interventions in 52.38% (33/63) and 11.11% (7/63) of cases with stone < 5 mm, respectively. Besides, 50.54% (140/277) of cases with ureterolithiasis sized 5–10 mm might received urologic manipulations initially rather than MET. Furthermore, US was unable to recognized 20.94% (58/277) and 15.33% (42/274) of patients with stone sized 5–10 and > 10 mm, which should be required pharmaceutical and surgical interventions early (Table 4).

Table 2 Negative ureteral stone on US

Category	< 5 mm	5–10 mm	> 10 mm	*n*
Proximal	10	24	26	60
Middle	3	12	9	24
Distal	10	22	7	39
n	23	58	42	123

Table 4 Concordance by stone size categorical groups

Size on NCCT	Size on US				
	No stone	< 5 mm	5–10 mm	> 10 mm	*n*
Proximal, < 5 mm	10	0	16	3	29
Middle, < 5 mm	3	0	3	2	8
Distal, < 5 mm	10	0	14	2	26
Proximal, 5–10 mm	24	0	40	95	159
Middle, 5–10 mm	12	0	18	21	51
Distal, 5–10 mm	22	1	20	24	67
Proximal, > 10 mm	26	0	13	168	207
Middle, > 10 mm	9	1	7	25	42
Distal, > 10 mm	7	0	2	16	25

Discussion

Therapeutic strategy for ureterolithiasis was primarily based on stone size, which determined the type of management [1, 16]. In general, the spontaneous stone passage rates within 20 weeks were 98% in 0–3 mm and 81% in 4 mm [2]. Therefore, simple observation would be usually recommended for ureteral stone < 5 mm [1, 5]. With evidence of prospective studies [3, 4], MET was suggested as an effective expectant treatment for ureterolithiasis sized 5–10 mm [5]. Extracorporeal shock wave lithotripsy (SWL) and retrograde ureteroscopy (URS) were still regarded as available interventions for stone > 10 mm or larger [5]. Thus, appropriate management for ureteral calculi is essentially depended on accurate stone measurements.

Since promoted by Smith [17], NCCT has become the standard image for diagnosing urolithiasis with excellent sensitivity and precise measurements [6, 7]. However, radiological hazard was a problem that could not be ignored [18, 19]. To reduce radiation exposure, US was gradually regarded as ideal imageological modality to recognize patients with suspected urolithiasis [5]. Besides, higher accessibility and less costs also introduced more frequent US application to the initial assessment and follow-up of patients [8, 9]. Hence, it is necessary to evaluate its diagnostic precision for stone estimation.

Table 3 Categorical size parameter analysis based on US compared to NCCT

Stone diameter	Size on NCCT (mm)	Size on US (mm)	Size overestimation on US (mm)	Overestimation on US (%)
< 5 mm	3.71 ± 0.58	8.65 ± 3.80	4.85 ± 3.80 ($P < 0.001$)	63.49
5–10 mm	8.30 ± 1.79	12.84 ± 4.78	5.81 ± 4.01 ($P < 0.001$)	50.54
> 10 mm	15.97 ± 4.60	17.43 ± 6.78	5.91 ± 5.07 ($P < 0.001$)	/

For stone > 10 mm, size over measurements was not recorded by categorical groups

With the expanding usage of US, the studies [10–14] found the inaccuracy of this technique for urolithiasis evaluation, including limited sensitivity and size over measurements, which might directly influence the counseling decisions. Regrettably, those investigations just focused on nephrolithiasis and lacked of similar researches on ureterolithiasis. Meanwhile, we considered that stone classification of < 5, 5–10, and > 10 mm was more suitable for ureteral calculi research rather than nephrolithiasis study in the previous articles [10–14].

To further evaluate the impact of US, we assumed that observation, MET, and surgical interventions were recommended for patients with ureterolithiasis < 5, 5–10, and > 10 mm on NCCT, respectively. Under these assumptions, the sensitivity and stone diameter on both images would be made into comparison, and demonstrated how this influenced clinical decisions.

Actually, the sensitivity of US for ureteral stones was provided with a polarization [20–24]. Hamm [20] investigated that the poor sensitivity value of US was 11% for ureterolithiasis, while Patlas [21] reported 93% for same type patients. Most literatures [22–24] concluded that US presented the limited sensitivity of 60–79% for ureterolithiasis. Studies [25, 26] considered that those discrepancies were associated with multi-factors, including stone size, location, pyeloureterectasis, US equipments, and technicians' skills.

Similar to other studies [22–24], the total sensitivity of US in our text also presented a limited value of 79.96%, and we further demonstrated the results by grouping stone size and location in Table 1. As expected, the sensitivity value showed a growth with longer stone diameter ($P = 0.001$), and this was in line with prior data [12]. Besides, it also declined with lower stone position ($P < 0.001$); Saita [27] and Mos [9] considered that the deep location of lower segment and the intestinal gas anterior to middle–distal ureter were the major causes for this phenomenon.

Nevertheless, a few articles concerned the actual size of negative stones on US. Sternberg [14] reported that 37.4% of renal stones were invisible on US and the average diameter was 4.5 mm on NCCT, but the detailed data had not been recorded. Ganesan [13] retrospectively analyzed 552 cases of nephrolithiasis, and found that US unidentified 82, 43, and 13 cases of stone sized 0–4, 5–10, and > 10 mm, respectively. Depressingly, correlative investigations on ureterolithiasis were currently deficient.

In our series, US unrecognized 123 (20.03%) cases with an average stone diameter of 9.59 ± 5.14 mm, which included 23, 58, and 42 patients with ureterolithiasis < 5, 5–10, and > 10 mm, respectively. This meant that 58 and 42 patients who NCCT suggested pharmaceutical and surgical interventions might lose the opportunity for appropriate counseling advice if assessed by US initially. In addition, 23 patients with stone < 5 mm might be terminated follow-up due to negative US reports.

Progressively, the ability of US for accurate stone measurements also came into questions. Fowler [10] compared NCCT and US estimation in 24 cases of nephrolithiasis and found that stone size concordance was 79%. Kanno [11] concluded that stone diameter on NCCT and US was concordant in 72% via a large retrospective study.

With the headway, studies [12–14] considered this in concordance between both images mainly caused by the overestimation of US. Ray [12] reported that, in 71 cases of upper urinary stone sized 0–5, 5.1–10, and > 10 mm, the mean stone diameter on NCCT/US was 3.8 ± 0.9/5.7 ± 1.3 mm, 6.8 ± 1.3/8.4 ± 1.7 mm, and 14.2 ± 3.8/16.4 ± 3.6 mm, respectively. It presented a magnification effect on calculi when using US for assessment.

Ganesan [13] reported that, in 552 cases of nephrolithiasis, the mean stone diameter were 3 (2–4)/6 (4–8) mm and 7 (6–9)/8 (6–12) mm on NCCT/US in 0–4 and 5–10 mm groups, respectively. Sternberg [14] reported that, in 79 patients with renal stone < 5, 5.1–10 and > 10 mm on NCCT, US overestimated the diameter in 82.1, 52.6, and 38.5% of the cases by an average of 3.3, 1.9, and 0.4 mm, respectively. Both studies considered the systematic over measurements of stone size could result in inappropriately counseling by relying on the US technique alone.

Our results also supported the previous findings of size overestimation on stones with the use of US. In our study, stone diameter concordance was just 46.74% on both images. Based on preceding assumptions, 52.38 and 11.11% of patients with stone < 5 mm would be improperly suggested receiving MET and surgical manipulations by US, respectively. This finding was similar to studies [13, 14] which considered that small stones might warrant a period of observation before more active interventions. In addition, 50.54% of patients with stone sized 5–10 mm on NCCT would be recommended urologic interventions rather than MET initially, and this also highlighted that overestimation of US would lead to unbefitting management.

Indeed, the reason for stone overestimations of US was unclear. Kampa [16] thought stone edge was often ill defined on US image, and technicians might chronically report larger diameter in records and introduced magnification error. Besides, questionnaire [16] demonstrated a portion of US technicians would measure urolithiasis by naked eyes rather than electronic measurement. It was possible that some US technicians did not appreciate how much size influenced stone management.

This analysis presented a large sample study of comparing US and NCCT for ureterothiasis estimations, but included other limitations in addition to the retrospective nature. First, our study design was based on the ideal assumption that stone < 5, 5–10, and > 10 mm should receive observation,

MET, and surgical interventions, respectively. Actually, we fully appreciated that management to stones also depended on various clinical factors. Second, US is a highly subjective diagnostic technique for urolithiasis assessment. As multiple US technicians involved in the research, experiences discrepancy among different individuals might generate intra-observer variability, which directly influenced sensitivity and measurements. However, this reflected real-world clinical setting and the data with which treatment decisions were made.

Conclusions

Limited sensitivity and size over measurements of US might significantly influence clinical decisions for ureteral stone compared to NCCT. Inaccurate evaluation of US should be taken in consideration for appropriate medical options.

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Compliance with ethical standards

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

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