ORIGINAL ARTICLE

Accuracy of ultrasound versus computed tomography urogram in detecting urinary tract calculi

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ABSTRACT

Aim: To determine the (i) sensitivity and specificity of ultrasound (USG) in the detection of urinary tract calculi, (ii) size of renal calculi detected on USG, and (iii) size of renal calculi not seen on USG but detected on computed tomography urogram (CTU).

Methods: A total of 201 patients' USG and CTU were compared retrospectively for the presence of calculi. Sensitivity, specificity, accuracy, positive predictive value and negative predictive value of USG were calculated with CTU as the gold standard.

Results: From the 201 sets of data collected, 59 calculi were detected on both USG and CTU. The sensitivity and specificity of renal calculi detection on USG were 53% and 85% respectively. The mean size of the renal calculus detected on USG was 7.6 mm ± 4.1 mm and the mean size of the renal calculus not visualised on USG but detected on CTU was 4 mm ± 2.4 mm. The sensitivity and specificity of ureteric calculi detection on USG were 12% and 97% respectively. The sensitivity and specificity of urinary bladder calculi detection on USG were 20% and 100% respectively.

Conclusion: This study showed that the accuracy of US in detecting renal, ureteric and urinary bladder calculi were 67%, 80% and 98% respectively.

KEY WORDS:
Urinary tract calculi, ultrasound, computed tomography urogram, urolithiasis, nephrolithiasis

INTRODUCTION

Urolithiasis is a common finding in patients who present with acute flank pain and/or haematuria. In Malaysia, the incidence of urolithiasis was reported to have increased from 224 to 442 per 100,000 population over a period of 20 years (1962 – 1981).[1] The average global prevalence of urolithiasis was 3.25% in the 1980s and 5.64% in the 1990s, and is seen increasingly across sex, race and age.[2]

Radiological studies have an important role in the early diagnosis of urolithiasis. Ultrasound (USG) is the most appropriate and useful screening tool as it is easily available, radiation-free, reproducible, inexpensive and non-invasive.3 An USG that is negative for calculi may prompt the need for unenhanced computed tomography urogram (CTU).

CTU was shown to be highly sensitive and specific for ureteric stones.[3] Its significant advantages over other modalities in the detection of urolithiasis includes speed, accuracy, non-usage of intravenous contrast media, as well as the abilities to evaluate secondary effects of obstruction, delineate surgically relevant anatomy and detect other potential sources of pain.[4] However, patients are inevitably exposed to radiation. The sensitivity and specificity of CTU in detecting ureteric calculi has been reported to range 94 - 100% and 92 - 100%, respectively.[3]

There has been little direct comparison between USG and CTU in the detection of urolithiasis. Taking CTU as the gold standard, this study aims to determine the sensitivity of USG in detecting urinary tract calculi at our centre. In our centre, patients suspected of having renal tract calculi undergo a work-up that includes urinanalysis, KUB radiograph, and USG as first line investigations. A positive USG may or may not proceed to CTU. Invariably all negative USG will undergo CTU for further evaluation. But is it truly necessary for patients to be exposed to the radiation imposed by a CTU? In an attempt to answer this question, this study has set out to see how many negative USG proved to be positive on CTU.

MATERIALS AND METHODS

This study has been approved by the hospital technical and ethical committee. Patient informed consent was not obtained as this is a retrospective review.

Subjects

This is a retrospective study involving patients at our centre who had USG and CTU for suspected urinary tract calculi over a period of 14 months, from January 2010 to February 2011. A pilot study conducted in April 2010 showed that 25 patients had CTU during that particular month. Thus the estimated sample population was 350 patients. Based on 95% confidence level, 5% confidence interval and estimated sample population of 350, the calculated sample size was 183 patients.

Examination technique

CTU was performed in the Department of Radiology at our centre using Siemens CT Somatom Sensation 64 with a

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dedicated protocol. Patient with full urinary bladder was positioned supine on CT examination table and scanned from the upper abdomen to the symphysis pubis with image reconstructed at 5 mm intervals. No oral or intravenous contrast media was given. Calculus was defined as hyperdense focus in the kidney, ureter and/or bladder.

USG was performed using multiple new generation ultrasound scanners (Toshiba, Philips and GE Logic). Ultrasound included evaluation of the kidneys in multiple anatomic planes and maximum calculus measurement was recorded. Curved-phase array transducers were used with varied transducer frequency depending on the body habitus to optimise both patient penetration and image resolution. Calculus on ultrasound was characteristically demonstrated as highly echogenic focus with distinct posterior acoustic shadowing.

Data collection and statistical analysis
Data was collected from the hospital Integrated Radiology Information System (IRIS) and Picture Archiving and Communication System (PACS). Demographic data including age, sex and ethnicity were collected.

A review of the USG and CTU of each patient was done with documentation of the imaging findings including presence or absence of calculus, site (right or left urinary tract or both), location (kidney, ureter or bladder), and calculus size in millimeter.

With CTU as the gold standard, sensitivity, specificity, accuracy, positive predictive value and negative predictive value of USG for the detection of calculus at each of the three locations (kidney, ureter and bladder) were calculated. Statistical Package for Social Sciences (SPSS) version 20 was used for statistical analyses. P-value of <0.05 was taken as significant.

RESULTS

A total of 201 patients were included. The patients were predominantly in the late adulthood and elderly age groups, with 60 patients (33%) and 76 patients (42%) aged between 40-59 and 60-79 years old respectively. The mean age was 67 years old.

Ethnicity distribution had Malays, Chinese and Indians accounting for 61%, 32% and 7% respectively, while other races including foreigners accounted for 3% (6 patients).

Gender wise, there were 115 males and 86 females. In 45% of patients, the time interval between the USG and CTU was within 1 month. The interval was within 3 months for 24% and in the remaining 31%, it was more than 3 months.

The ultrasound studies were done mainly by radiology trainees (Master of Radiology) where 49% and 40% were performed by the senior and junior trainees respectively. The remaining 11% were performed by radiologists.

(i) Detection of renal calculi
From the 201 data collected, 59 renal calculi were detected on both USG and CTU (Table I). There were 13 false positive cases. The sensitivity and specificity of renal calculi detection on ultrasound were 53% and 85% respectively. The positive predictive value (PPV) was 82% and negative predictive value (NPV) was 59%. The accuracy of ultrasound in detecting renal calculi was 67%.

Of the 59 renal calculi detected on USG, 48 calculi were measured. The remaining 11 calculi not measured were too small and described as tiny or too large and described as staghorn calculi. The majority of calculi detected by USG measured 5.1-10 mm (Table II). The minimum, maximum and average size documented was 3 mm, 20 mm and 7.6 mm ± 4.1 mm respectively.

Fifty-three renal calculi were not detected on USG but positive on CTU (Figure 1) and 76 findings were true negative (Table I). Of the 53 calculi not detected on USG but detected on CTU, 10 were described as tiny and the other 43 were measured on CTU. The majority of calculi not detected by USG measured ≤ 5 mm (Table II). The minimum, maximum and average size of calculi that were not detected on USG was 1 mm, 12 mm and 4 mm ± 2.4 mm respectively.

There was no significant difference between the USG done by the trainees and the radiologists (P=0.727). The percentage errors of the junior and senior trainees were 46% and 45% respectively, and for specialist was 36% (Table III).

(ii) Detection of ureteric calculi
Ultrasound detected only 5 of the 41 ureteric calculi that were detected on CTU giving a low sensitivity of 12% (Table IV). However, it showed a high specificity of 97%. The accuracy of ultrasound in detecting ureteric calculi was 81%. The PPV and NPV were 63% and 81% respectively.

(iii) Detection of urinary bladder calculi
For the detection of urinary bladder calculi, ultrasound achieved 20% sensitivity and 100% specificity (Table V). The PPV was 100% with NPV of 98%. The accuracy was 98%.

DISCUSSION

This study showed that USG had limited value for the detection of renal calculi. The sensitivity and specificity of 53% and 85% respectively were lower compared to two previous studies that had reported 81% and 100%, and 76% and 100% for sensitivity and specificity respectively.[5,6] However, our sensitivity exceeded that of another study, which reported a sensitivity of 24%, but a slightly higher specificity of 90%.[7] The longer time interval between ultrasound and CTU (45% within 1 month, the rest 1 month or more) in this study could have contributed to this discrepancy, in contrast to 1 month or less in previous studies.

The poor sensitivity and the high false negative rates (41%) of USG demonstrated in this study are related to multiple factors. Calculi may be missed at USG due to lack of acoustic shadowing of the calculus.[8] The other factors would be the

Table I: Detection of renal calculi on USG and CTU

USG	CTU		
	Normal	Abnormal	Total
Normal	76 (38%)	53 (26%)	129 (64%)
Abnormal	13 (6%)	59 (30%)	72 (36%)
Total	89 (44%)	112 (56%)	201 (100%)

Table II: Size of detected and undetected renal calculi on USG

Calculus size (mm)	Number Detected (%)	Number Undetected (%)
≤ 5	20 (34)	45 (85)
5.1 – 10	24 (41)	7 (13)
≥ 10.1	15 (25)	1 (2)
Total	59 (100)	53 (100)

* Calculi described as tiny have been classified as ≤ 5 mm.
* Calculi described as staghorn have been classified as ≥ 10.1 mm

Table III: Percentage error among the ultrasound operators

Findings	Ultrasound operator			
	Junior trainee	Senior trainee	Radiologist	Total
True positive (TP)	25	30	4	59
True negative (TN)	19	24	10	53
False positive (FP)	6	4	3	13
False negative (FN)	31	40	5	76
Total	81	98	22	201
Percentage error (FP+FN/Total)	46 %	45 %	36 %	44 %

P = 0.727

Table IV: Detection of ureteric calculi on USG and CTU

USG	CTU		
	Normal	Abnormal	Total
Normal	157	36	193
Abnormal	3	5	8
Total	160	41	201

Table V: Detection of urinary bladder calculi on USG and CTU

USG	CTU		
	Normal	Abnormal	Total
Normal	196	4	200
Abnormal	0	1	1
Total	196	5	201

body habitus,[6] the selection of the transducer power, and focal length.[8] The excellent contrast resolution of CTU allows discrimination of slight differences in attenuation, allowing better visualisation of stones. Furthermore, CTU has the ability to acquire a volume of data that includes the entire urinary system and not just the kidneys only. USG may miss stones within some parts of the urinary tract,[8] especially the ureters.

In this study, the false positive rate (FP) was 15% for USG and may have been due to renal vascular calcification.[8]

With regard to the size of renal calculi that were detected, this study showed that the mean size of the calculi detected on USG was 7.6 mm ± 4.1 mm, comparable to a study that reported a mean size of 7.1 mm ± 1.2 mm.[7] Of the 53 renal calculi not detected on USG, 85% measured ≤ 5 mm. A previous study showed that the mean size of calculus detected on CTU was 4.2 mm ± 0.4 mm.[7] Seventy-three percent of calculi not visualized on USG were 3 mm or less in size.[7]

The USG in which a 12 mm calculus had been missed but was detected later on CTU was performed by a junior trainee, and the time interval between USG and CTU was between 1 – 3 months. The presence of posterior acoustic shadowing depends on the size of the calculus. Therefore, the smaller the calculus, the more likely it could be missed.[4,8] However, the reason for a large calculi not being identified on USG is not clear. In this teaching centre, the majority of ultrasound scans were performed by Master in Radiology trainees. Although there was little difference in percentage error between USG done by the trainees and the radiologists, the trainees need closer supervision during their training to reduce the false negative and false positive findings. One way

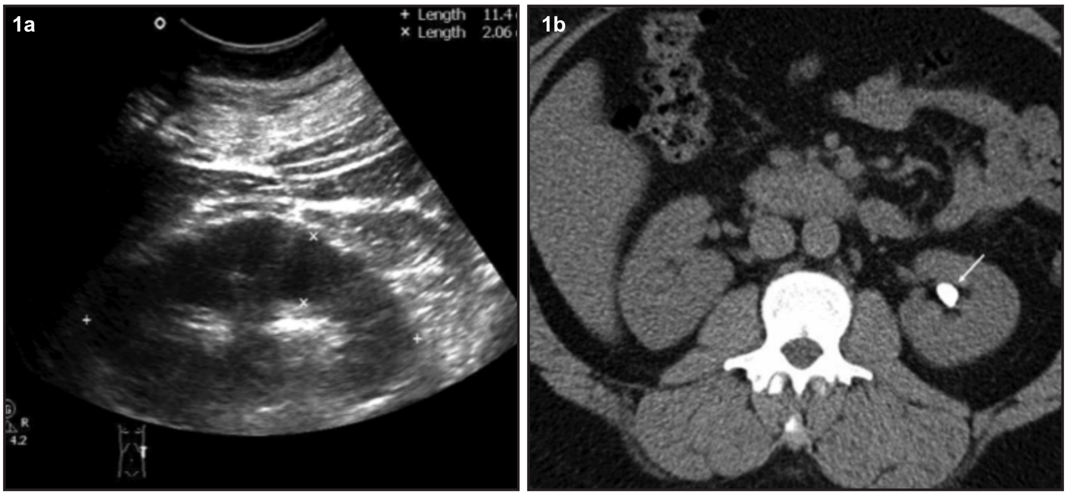

Fig. 1: An example of a false negative finding. (a) Ultrasound shows no obvious echogenicity with posterior shadowing. It was reported as no documented calculus. (b) Axial section CTU shows a large calculus (arrow) in the lower pole of the left kidney.

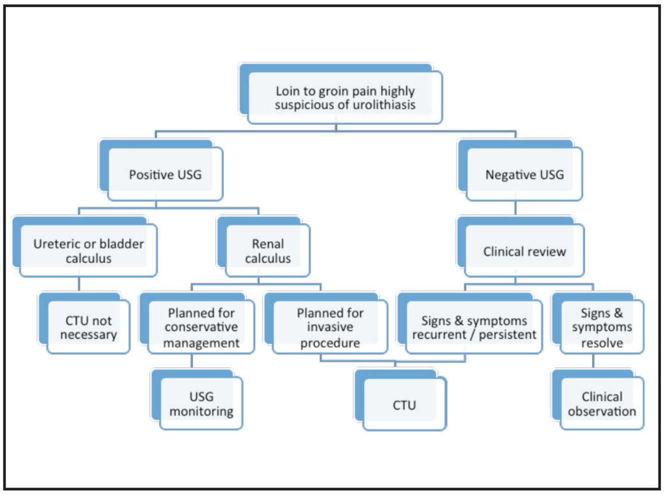

Fig. 2: Imaging algorithm for suspected urinary tract calculi.

to improve on USG skill is to repeat the USG whenever a false negative or false positive result is noted on CTU.

With regard to the detection of ureteric calculi, a prospective study in 1998 achieved a sensitivity of 19% and a specificity of 97%.[9] Another study in 2007 showed a slightly higher sensitivity of 23% and specificity of 100%.[10] In this study, almost similar results were achieved, with low sensitivity of 12% and high specificity of 97%. The low sensitivity is attributable to the presence of bowel gas, which commonly obscures the ureters, and a large body habitus with thick subcutaneous fat that reduces visibility.[6,11] The specificity of calculi detection on USG is greater in the ureter than in the kidneys. This is because the diagnosis of ureteric calculus is greatly aided by the presence of hydroureter.[4,10,12] In other words, USG lacks sensitivity for the detection of ureteric calculi. However, it is fairly specific when calculi are seen.

This study showed the accuracy of USG in detecting renal, ureteric and urinary bladder calculi was 67%, 80% and 98% respectively. USG is not equivalent to CTU in detecting urinary tract calculi. However, this does not mean that every patient suspected of having a urinary tract calculus should undergo a CTU. Based on the findings of this study, the following imaging algorithm is recommended (Figure 2).

A limitation of this study is the extended time interval between ultrasound and CTU. Approximately 55% of the patients had their ultrasound and CTU done at more than 1 month apart. Accuracy of ultrasound could be affected as calculi could have moved or changed in size during this period of time.

New ultrasound technique such as the use of Doppler ultrasound to detect "twinkling artefact" could potentially improve urolithiasis detection on sonography, and should certainly be looked into in future studies.[13]

CONCLUSION

The sensitivity and specificity of USG in detecting renal calculi was 53% and 85% respectively and the mean size of renal calculi not visualized on USG was 4 mm ± 2.4 mm. This study showed that the accuracy of USG in detecting renal, ureteric and urinary bladder calculi was 67%, 80% and 98% respectively.

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