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Dr. Md. Atik Ahmed
Associate Professor, Al Ameen
Medical College, Vijayapur,
Karnataka, India

Toufik Ahemad
Junior Resident, Navodaya
Medical College, Raichur,
Karnataka, India

Mustak Ahmed
Junior Resident, Al Ameen
Medical College, Vijayapur
Raichur, Karnataka, India

Corresponding Author:
Dr. Md. Atik Ahmed
Associate Professor, Al Ameen
Medical College, Vijayapur,
Karnataka, India

Comparative study of ultrasound and computerized tomography for nephrolithiasis detection

Dr. Md. Atik Ahmed, Toufik Ahemad and Mustak Ahmed

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Abstract

Background: There is a lack of consensus about whether the initial imaging method for patients with suspected nephrolithiasis should be computed tomography (CT) or ultrasonography.

Material and Methods: A total of 130 patients' USG and CTU were compared 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 150 sets of data collected, 45 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 6.8 mm \pm 3.8 mm and the mean size of the renal calculus not visualized on USG but detected on CTU was 3.5 mm \pm 2.7 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 68%, 80% And 99% Respectively.

Keywords: Nephrolithiasis, ultrasound, computed tomography

Introduction

Kidney stones or Nephrolithiasis are mainly lodged in the kidney(s). Mankind has been afflicted by urinary stones since centuries dating back to 4000 B.C., and it is the most common disease of the urinary tract. The prevention of renal stone recurrence remains to be a serious problem in human health ^[1]. The prevention of stone recurrence requires better understanding of the mechanisms involved in stone formation. Kidney stones have been associated with an increased risk of chronic kidney diseases, end-stage renal failure, cardiovascular diseases, diabetes, and hypertension ^[2]. It has been suggested that kidney stone may be a systemic disorder linked to the metabolic syndrome. Nephrolithiasis is responsible for 2 to 3% of end-stage renal cases if it is associated with nephrocalcinosis ^[3].

The symptoms of kidney stone are related to their location whether it is in the kidney, ureter, or urinary bladder ^[4]. Initially, stone formation does not cause any symptom. Later, signs and symptoms of the stone disease consist of renal colic (intense cramping pain), flank pain (pain in the back side), hematuria (bloody urine), obstructive uropathy (urinary tract disease), urinary tract infections, blockage of urine flow, and hydronephrosis (dilation of the kidney). These conditions may result in nausea and vomiting with associated suffering from the stone event ^[5]. Globally, kidney stone disease prevalence and recurrence rates are increasing, with limited options of effective drugs. Urolithiasis affects about 12% of the world population at some stage in their lifetime ^[6]. It affects all ages, sexes, and races but occurs more frequently in men than in women within the age of 20–49 years ^[7]. If patients do not apply metaphylaxis, the relapsing rate of secondary stone formations is estimated to be 10–23% per year, 50% in 5–10 years, and 75% in 20 years of the patient ^[8]. However, lifetime recurrence rate is higher in males, although the incidence of nephrolithiasis is growing among females ^[9]. Therefore, prophylactic management is of great importance to manage urolithiasis.

Recent studies have reported that the prevalence of urolithiasis has been increasing in the past decades in both developed and developing countries. This growing trend is believed to be associated with changes in lifestyle modifications such as lack of physical activity and dietary habits and global warming ^[10].

In Indian population, about 12% of them are expected to have urinary stones and out of which 50% may end up with loss of kidney functions [11]. The lifetime prevalence of kidney stones in the India is 12% among men and 7% among women. [12] Kidney stones develop when urine becomes "supersaturated" with insoluble compounds containing calcium, oxalate (CaOx), and phosphate (CaP), resulting from dehydration or a genetic predisposition to over-excrete these ions in the urine. About 5-10% of Indian have this predisposition [13].

Ultrasound (USG) is the most appropriate and useful screening tool as it is easily available, radiation-free, reproducible, inexpensive and non-invasive [14]. A 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 [15]. Its significant advantages over other modalities in the detection of urolithiasis includes accuracy, non-usage of intravenous contrast media, as well as the abilities to evaluate secondary effects of obstruction, and detect other potential sources of pain but patients are inevitably exposed to radiation [16].

There has been little direct comparison between USG and CTU in the detection of urolithiasis. CTU as being the gold standard, our study aims to determine the sensitivity of USG in detecting urinary tract calculi. The patients suspected of having renal tract calculi undergo a work-up that includes urine analysis, KUB radiograph, and USG as first line investigations. A positive USG may or may not proceed to CTU but all negative USG will undergo CTU for further evaluation. But is it really necessary for patients to be exposed to the radiation by a CTU? i.e why, 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 obtained as this is a prospective study.

Subjects

This is a Prospective study involving patients at our centre who had USG and CTU for suspected urinary tract calculi over a period of 1 year, from September 2019 to August 2020. A pilot study conducted in July 2019 showed that 30 patients had CTU during that particular month.

Examination technique

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

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 25th was used for statistical analyses.

Results

A total of 130 patients were included in the study.

Table 1: Distribution of age groups

Age group	No. of patients	Percentage
25-39 Years	54	41.5
40-59 Years	41	31.5
60-79 Years	35	26.9
Total	130	100

In table 1, the patients were predominantly in the late adulthood and elderly age groups, with 54 patients (41.5%), 41 patients (31.5%) and 35 patients (26.9%) aged between 25-39, 40-59 and 60-79 years old respectively.

Table 2: Distribution of sex

Sex	No. of patients	Percentage
Male	74	56.9
Female	56	43.1
Total	130	100

In table 2, the mean age was 52 years old. Gender wise distribution, there were maximum no. of patients were 74 males and 56 females.

Table 3: Calculi described as staghorn have been classified as \geq 10.1 mm

Findings	% Error in USG
True positive	41
True negative	31
False positive	9
False negative	49
Total	150

Detection of renal calculi

In table 3, from the 130 data collected patients, 41 renal calculi were detected on both USG and CTU. There were 9 false positive cases. The sensitivity and specificity of renal calculi detection on ultrasound were 52% and 86% respectively. The positive predictive value (PPV) was 84% and negative predictive value (NPV) was 57%. The accuracy of ultrasound in detecting renal calculi was 68%. Of the 45 renal calculi detected on USG, 33 calculi were measured. The remaining 7 calculi not measured were too small and described as tiny or too large and described as staghorn calculi.

Table 4: Size of detected and undetected renal calculi on USG

Calculus size (mm)	Number detected (%)	Number undetected (%)
≤ 5	14 (32.5)	31 (86.1)
5.1 – 10	18 (41.8)	4 (11.1)
≥ 10.1	11 (25.5)	1 (2.7)
Total	43 (100)	36 (100)

In table 4, the majority of calculi detected by USG measured 5.1-10 mm. The minimum, maximum and average size documented was 3.5 mm, 22 mm and 6.8 mm ± 3.8 mm respectively. 43 renal calculus detected and 36 renal calculi were not detected on USG but positive on CTU and 31 findings were true negative. Of the 36 calculi not detected on USG but detected on CTU, 9 were described as tiny and the other 29 were measured on CTU. The majority of calculi not detected by USG measured ≤ 5 mm. The minimum, maximum and average size of calculi that were not detected on USG was 3 mm, 11 mm and 3.7 mm ± 2.1 mm respectively.

Table 5: Detection of ureteric calculi on USG and CTU

USG	CTU Percentage		
	Normal	Abnormal	Total
Normal	73	53	126
Abnormal	1	3	4
Total	74	56	130

In table 5, ultrasound detected only 4 of the 26 ureteric calculi that were detected on CTU giving a low sensitivity of 12%. 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.

Table 6: Detection of urinary bladder calculi on USG and CTU

USG	CTU Percentage		
	Normal	Abnormal	Total
Normal	126	2	128
Abnormal	1	1	2
Total	127	3	130

In table 6, detection of urinary bladder calculi for the detection of urinary bladder calculi, ultrasound achieved 20% sensitivity and 100% specificity. 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 [17]. However, our sensitivity exceeded that of another study, which reported a sensitivity of 24%, but a slightly higher specificity of 90% [18]. 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 [19]. The other factors would be the body habitus, 6 the selection of the transducer power, and focal length [20]. 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, especially the ureters.

In this study, the false positive rate (FP) was 15% for USG and may have been due to renal vascular calcification. [21] 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 [22]. Seventy-three percent of calculi not visualized on USG were 3 mm or less in size [23].

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. [24] However, the reason for a large calculus not being identified on USG is not clear. One way 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% [25]. Another study in 2007 showed a slightly higher sensitivity of 23% and specificity of 100%. [26] 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 [27]. 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 [28]. 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.

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 [29].

Conclusion

The sensitivity and specificity of USG in detecting renal calculi was 52% and 86% respectively and the mean size of renal calculi not visualized on USG was 3.5 mm ± 2.7 mm.

Our study showed that the accuracy of USG in detecting renal, ureteric and urinary bladder calculi was 68%, 80% and 99% respectively.

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