Original Research Article

Utility of color Doppler in diagnosing ureteric calculi: a useful adjunct

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Abstract

Background: Renal colic is a common presenting complaint in patients report to the out patient department. Usually the first investigation these patients undergo is ultrasound because of its widespread availability. Using color Doppler to study the characteristics of urine jet emanating from the vesicoureteric junction might prove useful in improving the diagnostic accuracy of ultrasound in patients with suspected ureteric calculi. **Methods:** All patients found to have unilateral ureteric calculi on non-enhanced computerized tomography between March 2015 to August 2016 were subject to sonographic assessment. Color Doppler interrogation was done to study the ureterovesical jet characteristics. The cut-off values for differences between obstructed and unobstructed side were calculated on the basis of Receiver Operating Characteristic (ROC) curve. **Results:** A total of 67 patients conforming to our inclusion criteria were selected for the study. There were significant differences of jet frequency ($P < 0.05$), duration ($P < 0.05$) and peak velocity ($P < 0.05$) between obstructed and non-obstructed ureters. The cut-off values for these parameters based on our study population for ureterovesical jet frequency, uration and peak velocity were <1 jet per minute, <2.5 seconds and <7 cm/sec respectively. The combined sensitivity and specificity of these three parameters was calculated as 99.45% and of 99.99% respectively. **Conclusion:** Flow dynamics studies of ureterovesical jet characteristics using color Doppler significantly increase the sensitivity and specificity of ultrasound for diagnosis of ureteric obstruction. It may be incorporated as an adjunct to gray-scale ultrasound in routine practice to improve accuracy.

Keywords: Ureteral calculi, Hydronephrosis, Color Doppler, Ureterovesical jet dynamics

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Introduction

It is estimated that about 12% of the general population suffers from urolithiasis and about 2.3% of these patients are reported to experience renal colic during their lifetime [1].

Although non-enhanced computerized tomography (CT) is considered superior to other modalities in detection of urinary tract calculi, the disadvantages of exposure to ionizing radiation and lack of widespread availability make ultrasound a viable alternative for evaluation of patients with suspected renal and/or ureteral stones [2]. In addition to gray-scale ultrasound, using color Doppler ultrasound to calculate the frequency of the intermittent urine jet emanating from the vesicoureteric junction as well as the duration and peak velocity of the ureterovesical jet might prove useful as appropriate adjuncts in improving the diagnostic accuracy of ultrasound exam especially in patients with suspected ureteric calculi [3].

A major shortcoming of the ultrasound examination is the limited visualization of ureter in its entire extent, which is dependent on factors like favourable patient habitus and bowel preparation. There are few studies assessing the importance of the ureterovesical jet flow in improving diagnostic accuracy of ultrasound in detecting ureteric calculi [3].

The purpose of the present study was to compare the ureterovesical jet dynamics in obstructed ureters with unobstructed ureters in patients diagnosed with ureteric calculi and to find whether urinary obstruction and ureterovesical jet flow characteristics are correlated.

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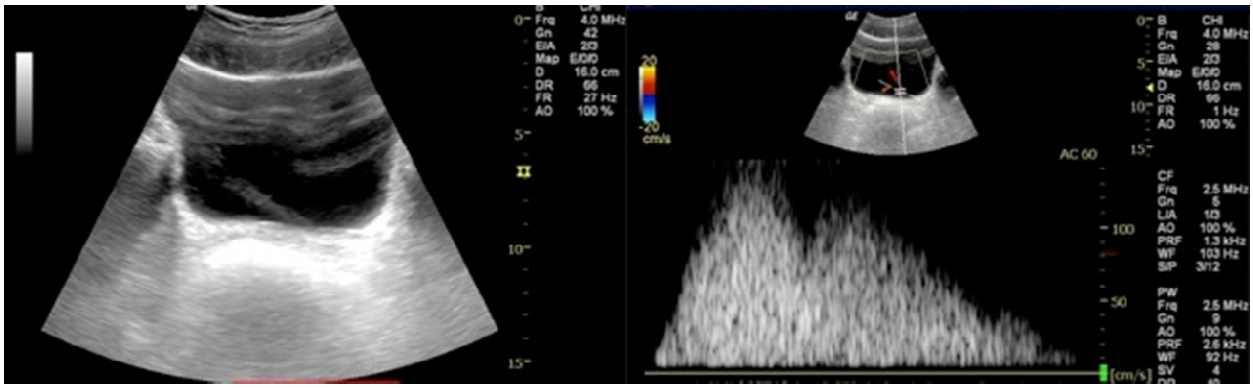
Materials and Methods

All patients presenting with suspected renal colic to our emergency department between March 2015 to August 2016 were evaluated with non-enhanced CT. All patients found to have ureteric calculi on non-enhanced CT were subject to sonographic assessment including color Doppler examination.

Prior to the ultrasound examination, the patients were orally hydrated with 750-1000 mL of water.
Inclusion criteria- All patients found to have documented ureteric calculi on non-contrast enhanced CT.
Exclusion criteria

1. Prior history of surgery/intervention involving the urinary tract.
2. Previous history of renal or vesical dysfunction.
3. No identifiable ureterovesical jet flow after initial hydration in 10 minutes of continuous real time observation.
4. Initiation of medical expulsive therapy before sonographic assessment

Imaging- All the patients were evaluated in the supine position with Logiq P5 system (GE, USA), using 3.5 MHz probe, with the bladder being observed in the transverse plane. The ureteric jets were identified with the aid of color Doppler followed by ten minutes of continuous real-time observation of both ureterovesical orifices in axial plane by the means of color Doppler ultrasonography. The color flow system assigned a red color to the direction of flow toward the transducer. Thereafter, the frequency and mean duration of ureterovesical jets were calculated retrospectively. (Fig-1)



To obtain the peak velocity of urine jet, the Doppler cursor was adjusted near the ureteral orifice and samples of the spectral curves were obtained for each ureteric jet. The Doppler sample volume was sufficiently wide to comprise the whole ureteric jet and was positioned on the center of the jet that corresponded to the point of largest flow. The angle was limited to remain between 30° and 60°.

Statistical Analysis- The differences in jet flow frequency, peak velocity and jet duration between the obstructed and unobstructed sides were calculated. The cut-off values for differences in frequency, duration and peak velocity between obstructed and normal side were calculated on the basis of Receiver Operating Characteristic (ROC) curve. The sensitivity and specificity of the cut-off values for obstructed and unobstructed ureters were calculated. Few confounding factors,like the influence of the degree of prior hydration on ureteric jets, were further avoided by comparing the jet characteristics in the same patient's affected side with the contralateralunobstructed side.

Results

A total of 76 patients were selected for the study out of which 55 were males and 21 were females. In 67 of the 76 patients with documented ureteric calculi, ureterovesical jet was identified during 10 min of observation, while no ureterovesical jet was observed in 9 patients and hence were excluded from the study. All cases had unilateral obstruction. The location of the calculus was at the ureteropelvic junction, proximal, mid and distal thirds of the ureter in 9 (13%), 17 (26%), 18 (28%) and 10 (32%) patients, respectively. The mean frequencies of ureterovesical jets were found to be 3.04 and 0.59 jets per minute on unobstructed and affected sides, respectively. The mean duration of jets in

normal ureters was 5.26 seconds; whereas, the mean duration of jets in the obstructed ureters was about 1.24 seconds. The average peak velocities of detected jets were 32.09 cm/sec and 5.41 cm/sec in normal and obstructed ureters, respectively (Table1).

Table-1: Comparison between the parameters on obstructed and unobstructed ureters.

	Unobstructed ureter	Obstructed ureter
Mean frequency (seconds)	3.04	0.59
Mean duration (seconds)	5.26	1.24
Mean peak velocity (cm/seconds)	32.09	5.41

It was noted that the there were significant differences of jet frequency ($P < 0.05$), duration ($P < 0.05$) and peak velocity ($P < 0.05$) between obstructed and non-obstructed ureters. The cut-off values for differences in frequency, duration and peak velocity between obstructed and normal side were calculated on the basis of Receiver Operating Characteristic (ROC) curve. For jet frequency a cut off of <1 jet per minute is having a sensitivity of 86.57% and specificity of 98.51%. For jet duration, the cut-off calculated was <2.5 seconds with sensitivity for diagnosing ureteric calculi being 74.63% and specificity of 88.06%. With a cut-off value for peak jet velocity as <7 cm/sec, we calculated sensitivity of 86.56% and specificity of 97.8%. Factoring all the three parameters, the composite sensitivity and specificity for the test was 99.45% and 99.99% respectively.

Discussion

Initially documented ureteral jets were scanned with IVP as a stream of radio-opaque medium seen in the urinary bladder. In addition, urine jets emanating from ureterovesical orifice can also be visualized on ultrasound, CT and cystoscopy. On ultrasonography, ureterovesical jet is postulated to be detected due to reflection of sound waves resulting from difference in urine density between the ureter and the urinary bladder [4]. Ureteral obstruction could result in asymmetry of the ureterovesical jets.

Burge et al [5] found that complete or partial ureteric obstruction caused by ureteric calculi could be visualized on color Doppler examination. Color Doppler sonography has at least two advantages over gray-scale sonography namely, the inability of gray-scale sonography in differentiating between obstructive hydronephrosis and non-obstructive hydronephrosis and a low positive predictive value for hydronephrosis in detecting urinary obstruction as urinary obstruction does not always result in hydronephrosis [6]. Non-obstructive causes of hydronephrosis include normal variants, diuretic medications, overhydration, overdistended bladder, calyceal diverticulum and vesicoureteral reflux [3]. Strehlau et al [7] studied the utility of duplex Doppler sonography as a functional diagnostic tool in children with hydronephrosis. Eighty-five percent of their patients showed absence of jets on the affected side; whereas, theremaining fifteen percent had marked asymmetryin the frequency of ureterovesical jet with reduced flow on the obstructed side. They found significant results (P<0.05) ureterovesical as well as ureteropelvic lesions and concluded that duplex study can be used as a reliable screeningtool in children with unilateral hydronephrosis.

The patients included in our study were adequately hydrated prior to ultrasound exam in order to shorten the scanning time needed, in a manner similar to those of previously reported studies [3,5]. Even though Cox et al [3] reported aperiod ranging from 2 to 45 min for detection of urine jets intheir patients and they recommend that at least 30 min ofcolor Doppler exam is needed to document the asymmetryof jet frequency, most of the previous studiesused the scanning time of about 5–10 min. Although increasing the time of interrogationmay improve the accuracy of the ultrasound exam, itappears to be less practical for everyday utilization. In our study we successfully demonstrated ureterovesical jets on the obstructed side within 10 minutes of continuous observation in 80.26% (n=67) of the study population. With the advent of widely available duplex examination in ultrasound machines, possible limitations of previous studies indetecting the ureteral jets dynamics can be overcome and their results reevaluated. We found a significant decrease in duration, frequency and peak velocity of ureterovesical jet in the obstructed side when compared to the contralateral side as mentioned in more detail earlier. Our findings thus corroborate with those in previous studies. Furthermore, our study also resulted in

more practical findings by defining the cut-off points of the characteristics of ureterovesical jets. We concluded that the a frequency of <1 jet/min, jet duration of <2.5 s and peakvelocity of <7 cm/s in ureteral jets between obstructedand normal ureters might be reasonable cut-off points toconfidently diagnose ureteral obstruction in patients withsuspected urinary stone. However, there are few studies so far the ureterovesical jet characteristics and further investigation in this direction seems necessary to confirm our results. We also recommend further studies to compare ureterovesical jet dynamics in healthy individuals between two non-obstructed sides as well as in patients with chronic renal colic due to causes other than ureteric calculi. The correlation of ureteral jet flowpattern with patients' clinical symptoms, findings during surgical intervention andrenal function impairment may be necessary to generalizethe results of this study. Furthermore, there is no standardization of the amount of oralhydration required for the adequate detection of ureterovesical jet.

Conclusion

The ureterovesical jet in obstructed ureter exhibited significantly different characteristics when compared with the contralateral normal side. The average jet frequency on obstructed side was 0.59 jets/minute compared with 3.04 jets/minute on the contra-lateral side. The mean duration of was1.24 seconds on obstructed side and 5.26 seconds on unobstructed side.

While the mean peak velocity on obstructed and unobstructed sides was 5.41 cm/sec and 32.09 cm/sec respectively. Based on the ROC curves, cut-off points for difference between obstructed and contralateral normal ureters were obtained for ureterovesical jet frequency, duration and peak velocity. These cut-off values for ureterovesical jet frequency, duration and peak velocity were<1 jetper minute, <2.5 seconds and <7 cm/sec respectively. The respective sensitivities for diagnosis of ureteral obstructionusing these individual cut-off values were 86.57%, 74.63% and 86.56% while the specificities were 98.51%, 88.06% and 97.8%, respectively. The combinedsensitivityand specificity of these three parameters was calculated as 99.45% and of 99.99%.

Given our findings of extremely high sensitivity and specificityof flow dynamics studies in obstructed versus unobstructed ureterscombined with the safety and widespread availability of Doppler study, it can prove to be a useful adjunct to gray-scale ultrasound in improving the accuracy for diagnosis of ureteric obstruction.

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