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ORIGINAL PAPER

Study of the ureterovesical jet flow by means of dupplex Doppler ultrasonography in patients with residual ureteral stone after extracorporeal shock wave lithotripsy

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Abstract The aims of our study are to evaluate ureterovesical jet flow Doppler ultrasound (US) in patients with residual ureteral stone after extracorporeal shock wave lithotripsy (ESWL) and to compare with unobstructed contralateral ureter. Patients who have residual ureteral stone in intravenous pyelography (IVP) and/or computed tomography (CT) after ESWL and unobstructed contralateral ureter in 20 patients were prospectively evaluated with Doppler US. The mean peak velocity of the Doppler waveforms was obtained on the residual ureteral stone and contralateral non-obstructed ureter (17.10 ± 20), (56.0 ± 32), respectively ($P < 0.05$). In conclusion, due to the absence of contraindications and side-effects, Doppler US is sensitive and highly specific that can contribute significantly to the diagnosis of residual ureteral stone after ESWL. It can replace IVP and/or CT, in condition where IVP is undesirable and in addition Doppler US can supply a functional investigation of the obstructed ureter.

Keywords Ureterovesical jet flow · Doppler ultrasound · Ureteral stone · ESWL

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Introduction

When the bolus of urine being transmitted through the ureter and reaches the terminal portion, it is ejected forcefully into the bladder through the vesicoureteric junction (VUJ). This flow is intermittent as a result of the ureteral peristalsis, and can be easily observed with Doppler ultrasound (US) [1]. The ureteric jet is also occasionally visible during intravenous pyelography (IVP), cystoscopy and voiding cystourethrography (VCU) [2]. Several methods such as IVP, diuretic renography, retrograde and antegrade pyelography and other less commonly used methods, e.g., computed tomography (CT), magnetic resonance imaging (MRI) are used to diagnose upper urinary tract obstruction. However, these techniques utilize ionizing radiation and are invasive examinations methods and in addition, IVP could not be used in patients with renal impairment and those allergic to radiocontrast material [3]. Doppler US holds promise as a non-invasive means of investigating urodynamics [4] and, in particular, of confirming or excluding ureteric obstruction. To date, reported work with Doppler US in obstruction has been based entirely on the presence or absence of jets, subjective assessment of flow patterns, and relative frequency of jets [5]. Doppler US appearance of the jet has been documented in a number of studies and the jet can be consistently demonstrated in both humans [2] and animals such as the dog [6]. This is a safe and non-invasive method, allowing the evaluation of either normal or pathological structural anatomical details [7]. The arrival of the Doppler US has allowed, besides the analysis of internal organs shape, contour, echo texture and dimensions, the study of the blood flow inside arteries and veins and real visualization of the ureterovesical jet [8]. However, little attention has been focused on the effect of urinary tract obstruction on the ureteral jet phenomenon. The present study is to evaluate the ureterovesical jet flow by means of Doppler US in patients with residual ureteral stone after extracorporeal shock wave lithotripsy (ESWL) and to compare unobstructed contralateral ureter.

Patients and methods

The sample of the present study consisted of 20 patients (6 male and 14 female) with ages ranging between 20 and 45 years (mean age 34.9 ± 7.6 years). All patients gave written informed consent before they were enrolled in the study, which had been approved by the institutional review board. The subjects had normal routine blood biochemistry, including urea and creatinine assay. The number of the cases preESWL according to the location (pyeloureteral junction, proximal ureter, and midureteral stone) was 5, 8 and 7, respectively. The stone size varies between 1 and 2 cm for all patients. Both kidneys were scanned prior to ureteral jet evaluation to assess the degree of hydronephrosis, ureteral dilation, and their chronicity for any discrepancy in size that might result in impaired renal function. Patients who have hydroureteronephrosis, recent surgery, ureteral narrowing, and stricture which can affect mean peak velocity of jets were excluded from the study. Baseline renal functions of the patients were in normal range. All patients who have residual ureteral stone (for stone location, proximal and midureteral) by means of renographic findings, IVP and CT after ESWL course and unobstructed contralateral ureter in 20 patients were prospectively evaluated with Doppler US. There were at least 2-week intervals between ESWL and the Doppler US. Stone size was measured by IVP and/or CT. All patients were then categorized into two groups based on the presence or absence of ureteral jet in the residual ureteral stone side. Group I consisted of patients with no ureteral jets, group II consisted of patients with continuous low-level ureteral jets. Hydronephrosis was graded mild, moderate, or severe on the basis of criteria established by Ellenbogen et al. [9]. Then, for each patient the jets were evaluated after drinking 750–1,000 cc of water. All examinations were performed by the same radiologist using color Doppler scanner (Logiq 7 Pro; General Electric, Milwaukee, WI) with a 3, 5 MHz convex probe. The color scale was adjusted as needed, and flow toward the transducer was assigned a red color. Color gain was set just below the level at which noise was seen. A wide sample gate was applied to cover the ureteral jet. Doppler angle was limited within 30°–60°. Doppler US studies were carried out with transverse scans at the trigone and with the scan plane rotated on the ureterovesical junction.

Statistical analysis was performed with the Statistical Package for Social Sciences computer Program version 9.0 (SPSS Inc, Chicago, IL). The ratios of values obtained on the obstructed (who have residual ureteral stone) and unobstructed sides were calculated for peak velocity, jet flow frequency, and duration between two sides were analyzed using the unpaired Student's t test. Pearson correlation test was used for obstructed side of patients for stone location, stone size, and degree of hydronephrosis. P values less than or equal to 0.05 indicated a statistical significant difference.

Results

On the residual ureteral stone side in group I, there was complete absence of detectable jets (12 patients), and eight patients in group II had continuous, low-level ureteral jets (Fig. 1). In group I, two, four, and six patients had mild, moderate, and severe hydronephrosis, respectively. In group II, three and five patients had mild and moderate hydronephrosis, respectively. The data from these groups are shown in Table 1. No statistically significant differences were found between stone location and degree of hydronephrosis ($P > 0.05$), but the differences between groups I and II for degree of hydronephrosis and stone size were significant ($P < 0.05$). The measured peak velocity of affected side jets varied from 0 to 52 cm/s. The average peak velocity, 17.10 ± 20, was decreased in magnitude when

Fig. 1 Continuous low-level flow in patient with proximal ureteral stone that caused severe hydronephrosis. Ureteral jet was less intense than normal, and it continued

Table 1 Ureteral jets and grade of hydronephrosis associated with residual ureteral stone location and size after extracorporeal shock wave lithotripsy

Type of ureteral jet	Hydronephrosis	Stone location/size		
		Proximal	Midureteral	Size (mm)
Absent (12 patients)	Severe (6)	Proximal (5)	Midureteral (2)	10–12
	Moderate (4)	Proximal (2)	Midureteral (1)	6–9
	Mild (2)	–	Midureteral (2)	5
Continuous low-level (8 patients)	Moderate (5)	Proximal (3)	Midureteral (2)	4
	Mild (3)	Proximal (2)	Midureteral (1)	3

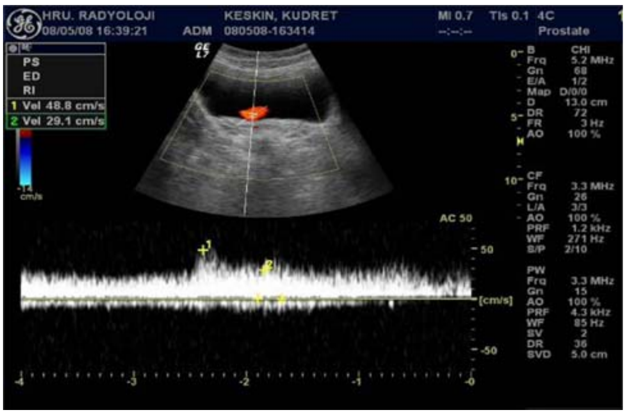

Fig. 2 The normal jet was in the unaffected side

compared with the normal periodic jets from the unaffected side. In unaffected side, the peak velocity varied from 37 to 108 cm/s, the average peak velocity was 56.0 ± 32. The mean difference between the peak velocity of the residual ureteral stone and their contralateral non-obstructed ureter was significant ($P < 0.05$). The mean frequency of jets from unaffected side was 5.1 jets/min, while the mean frequency of jets from affected side was 2.3 jets/min. The frequency of jets was asymmetric between affected and unaffected sides. The differences in jet frequency between two sides were statistically significant ($P < 0.05$). Mean duration of jet was 11 s in unaffected sides and 17 s in affected side. The jet was abnormal in the affected side in all patients; it was slow, continuous, decreased in volume and intensity, and prolonged, when compared to unaffected side (Fig. 2).

Discussion

At normal flow rates, as the renal pelvis fills, the pressure within it rises and urine is extruded into the upper ureter, which is initially collapsed. When a sufficient volume of urine is in the ureter, a contraction wave is allowed to pass down from the pelvis. The urine is formed into a bolus as the contraction wave moves distally down the ureter. Normal urine is devoid of microgas bubbles and particles. US visualization and production of a Doppler US signal from an aparticulate jet of urine depend on differences in density and associated compressibility changes between the urine in the bladder and that in the ureter [10, 11]. Importantly, when the urine density in the ureter is the same as that in the bladder, the jets cannot be visualized [11]. Ureteral jets were first imaged with IVU [12]. Ureteric jets are also occasionally visible during cystoscopy and VCU [2]. The scanning time used by Doppler US in our study is minimum of 10 min. Although there is no well-established examination time for the evaluation of ureteral jets, most previous studies [13, 14] have used 5 min scanning time. Cox et al. [2] reported that at least 30 min of color Doppler US is necessary to document that asymmetry of jet frequency is a true finding, because of the period between jets was reported to range from 2 to 45 min in most patients [2]. In our study, prolonged scanning time in this population may potentially reduce the false positive results.

To detect asymmetry by Doppler US, it is important to have a system that is as sensitive as possible for detection of urine flow from the ureteral orifice. In our study, Doppler US detection of ureteral jets reflects urine flow from the ureteral orifice. Therefore, unilateral ureteral obstruction may be suggested in the presence of unilateral absence of jets or continuous low-level flow and asymmetry between residual ureteral stone and unobstructed contralateral ureter. This finding corroborates with previous studies reported by Burge et al. [5]. The scanning time used by Doppler US in our study is minimum of 10 min that might have caused a comparatively higher proportion of unilaterally absent or continuous low-level jets in the residual ureteral stone side.

This study also demonstrated that the detection of asymmetric ureteral jets with Doppler US may be another means of identifying patients with hydronephrosis who are likely to have obstruction. However, we did not find relationship existed between the degree of hydronephrosis, the pattern of ureteral jets, or stone location. The reason of hydronephrosis may due to many entities other than obstruction. These include normal variants, overhydration, diuretic medications, overdistention of the bladder, or reflux; alterations in renal and cardiac function may alter the detection of ureteral jets with Doppler US. However, recent surgery and recently passed stone fragment may result in ureteral or ureterovesical junction edema which can also affect mean peak velocity of jets. In addition, ureteral narrowing or stricture disease may also affect this velocity. We also evaluate correlations between degree of hydronephrosis and stone size. In contrast to previous studies [12], our results demonstrate that there was a significant difference between degree of hydronephrosis and stone size. Some studies have discussed to look at changes of ureteric jet patterns under specific physiological conditions. In a series of 125 healthy asymptomatic gravid women, Asrat et al. [13] reported that the frequency and symmetry of ureteral jets were not affected in pregnancy thus they could be used in the work-up of suspected urolithiasis in pregnant patients. On the contrary, Burke and Washowich [14] reported that variation occurred in jet bilaterality and symmetry during the later stages of pregnancy and caution is thus recommended in the use of the color Doppler technique to diagnose urolithiasis in the pregnant population. Another study from Pepe et al. [15] reported that Doppler US in patients with renal colic and/or pelvicaliectasis improves the diagnostic accuracy of Doppler US in distinguishing between obstructive and non-obstructive dilatation. Combined with unenhanced CT, Doppler US has a 100% sensitivity and specificity. Moreover, due to the absence of contraindications and side-effects, Doppler US is indicated for the follow-up of patients after ESWL, pregnant women and children. Catalano et al. [16] reported that Doppler US of the ureteral jet is a valuable tool in urinary colics because it yields in real time more pieces of functional information than radiography and B mode Doppler US and also demonstrates the grade of urinary obstruction. These above-mentioned studies support our studies. Cox et al. reported in their study that the measured peak velocity of individual jets varied from 16 to 150 cm/s. The average peak velocity in 12 subjects ranged from 30 to 70 cm/s; mean values of 20 and 122 cm/s were calculated for the other two subjects (mean for all 14, 57 cm/s; SD 29, 9 cm/s) [2]. In an another study by Vivian et al., it was found that the mean velocity in adults was 57.65 cm/s for the monophasic pattern and 78.89 cm/s for the complex pattern [17]. Matsuda and Sperandeo et al. have also previously reported the similar values [18, 19]. In our study, the average peak velocity was 17.10 ± 20 for affected side and $56.\ 0 \pm 32$ for unaffected side. In our results, while the range was very large for the maximum velocity, however, the mean peak velocity was similar in comparison with the literature. The main limitation of this study is limited number of patients. Nevertheless, further prospective studies with larger sample sizes will be beneficial to clarify this issue.

In conclusion, due to the absence of contraindications and side-effects, Doppler US is sensitive and highly specific that can contribute significantly to the diagnosis of residual ureteral stone after ESWL. It can replace IVP and/or CT, in condition where IVP is undesirable and in addition Doppler US can supply a functional investigation of the obstructed ureter.

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