General Urology Genel Üroloji

Doppler characteristics of the ureteric jet-streams in patients with non-obstructive nephrolithiasis: mechanism of dysfunctional propagation of the peristaltic activity from the pelvic pacemaker to the ureterovesical sphincter

Tıkayıcı olmayan nefrolitiazis hastalarında üreterik jet akımların Doppler özellikleri: Pelvik odaktan üreterovezikal sfinktere peristaltik aktivitenin disfonksiyonel ilerleme mekanizması

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Abstract

Objective: The urine flow, which is also called ureteric jet, can be demonstrated by Doppler ultrasound at the ureterovesical junction (UVJ). The aim of this study was to evaluate the flow pattern changes of the urine at the UVJ in patients with nonobstructive nephrolithiasis.

Materials and methods: Twenty-four patients with uncomplicated renal calculi were included in this prospective study. Transabdominal color Doppler ultrasonography was performed to evaluate the UVJ of 24 patients and 31 healthy volunteers as the control group.

Results: Although there was a slight increase in the duration of the ureteric jet, peak velocity, and frequency of the jet flow in patients with nephrolithiasis; the difference between groups was not statistically significant ($p>0.05$ for all). However, when normal and abnormal (with calculi) sides of the same patient were compared, ureteric jet flow patterns were predominant in monophasic form at the side with calculi. The jet spectrum pattern was monophasic, biphasic, and triphasic in 26, 2, and 2 abnormal sides respectively, while these figures were 13, 32, and 13 for normal sides ($p<0.05$ for all patterns). Spectral form of the both sides of patient group was significantly different from that of the control group ($p<0.0001$).

Conclusion: The assessment of color Doppler pattern of ureteric jet flow at the UVJ is valuable in the diagnosis of nonobstructive nephrolithiasis.

Key words: Doppler ultrasonography; renal calculi; ureteric jet flow.

Özet

Amaç: Üreterik jet olarak adlandırılan idrar akımı üreteroveziak bileşkenin (UVB) Doppler ultarasonografisi ile gösterilebilir. Bu çalışmanın amacı tıkayıcı olmayan nefrolitiazis hastalarında UVB'de idrar akış patern değişikliklerinin değerlendirilmesidir

Gereç ve yöntem: Bu prospektif çalışmaya 24 komplike olmayan böbrek taşı hastası dahil edilmiştir. Bu 24 hastanın ve kontrol grubu olarak 31 sağlıklı gönüllünün UVB'sini değerlendirmek için transabdominal renkli Doppler ultrasonografi yapılmıştır.

Bulgular: Üreterik jet, tepe hızı ve jet akım frekansı nefrolitiazis hastalarında hafifçe artış gösterse de, gruplar arasında istatistiksel olarak anlamlı fark yoktur (tüm karşılaştırmalar için $p>0.05$). Ancak, aynı hastanın normal ve normal olmayan (taşlı) tarafları karşılaştırıldığında, taşlı tarafta üreterik jet akım paterni monofazik formda predominanttır. Jet spektrum paterni normal olmayan 26, 2 ve 2 tarafta sırasıyla monofazik, bifazik ve trifazik olup, bu sayılar normal taraf için 13, 32 ve 13'dür (tüm paternler için $p<0.05$). Hasta grubunun her iki tarafına ait spectral form kontrol grubundan anlamlı olarak farklıdır ($p<0.0001$).

Sonuç: UVB'de üreterik jet akım paterninin renkli Doppler ile değerlendirilmesi tıkayıcı olmayan nefrolitiyazis tanısında değer taşımaktadır.

Anahtar sözcükler: Doppler ultrasonografi; böbrek taşı; üreterik jet akımı.

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Although, ultrasonography (US) has become an indispensable tool in the evaluation of renal calculi, with recent technologic advances such as new generation high frequency matrix transducers, the posterior acoustic shadowing is paradoxically reduced. In addition, color aliasing posterior to the calculi which is named twinkling artefact has also been reduced because of the increased sound beam penetration. These may be challenging in the diagnosis of renal calculi, especially of milimetric ones. Visualization of ureteric jet with color Doppler US is a well-recognized phenomenon. It is easy to demonstrate the jet flows with color or power Doppler techniques. The Doppler waveform of the ureteric jets are formed by propagation of the peristaltic waves which arise from the renal pelvic pacemaker units.[1,2] These waves modify the ureteral peristaltism in order to relax the sphincteric mechanism of the ureterovesical junction.[1,2] Although there are many published studies about the dynamics of the ureteric jet flow, the basic peristaltic mechanisms (renal pelvic pacemaker, ureteral peristaltism, vesicoureteric sphincter mechanism) are rarely mentioned.[1,2] In this prospective study, we aimed to show the pelvic pacemaker dysfunction by measuring the ureteric jet flow characteristics in patients with uncomplicated (lithiasis without pelvicaliceal dilatation) nephrolithiasis. As to our knowledge, this is the first study to investigate the relationship between nephrolithiasis and the dysfunctional peristaltic activity, which is produced by pelvic pacemaker cells in order to propagate urine into the ureters.

Materials and methods

Twenty-four patients [20 men, 4 women; mean age, 33.4 (21-43) years] with the suspicion of nephrolithiasis whose US findings were equivocal were included in this study. Plain films (n=17) and/or computed tomography (CT) (n=7) was performed in these patients for the definite diagnosis. In 13 subjects, intravenous pyelography (IVP) was also obtained for clinical necessity. Informed consent was obtained from each patient to be included in the study. Control group included 31 asymptomatic subjects [24 men, 7 women; mean age, 35.2 (23-48) years] whose abdominopelvic CT examinations were unremarkable for the urinary system. Subjects with acute symptomatology, ureteric calculi, or hydronephrosis were not included in this study. All subjects had normal renal function tests. Dimensions of the kidneys and the parenchymal features were normal. There was no history of diabetes, hypertension or previous urogenital system surgery in any of the subjects.

The sonographic examinations were performed in the morning before breakfast. US examinations were performed after hydration and following micturation of the first morning urine to eliminate huge density differences of the urine between subjects. Hydration was standardized; each subject received 15 mL/kg water approximately one hour prior to the US examination.

US examinations were performed with 5 mHz phased array convex transducer using the same US equipment (GE Logic 9, Milwauquee, WI, USA). Initially, the upper urinary tract was examined. For each examination, low pulse repetition frequency (PRF) settings were used (1500-1700 mHz). During evaluation of the lower urinary tract, both of the distal ureteral orifices are visualized in the transverse plane, and Doppler window is inserted on the distal ureteral orifices. The gate width has been standardized as 1.5 mm with the Doppler angle of 45 degrees according to the entrance ureteral axis. With this scan technique, jet flows from both ureteral orifices into the bladder were demonstrated with Doppler scale and examined in spectral window in both groups. Approximately for 10 (range 8-14) min peak jet flow velocity (cm/sec), duration of jet flow (sec), jet frequency (units/min), and the spectral waveform were recorded for each case (Fig. 1, 2). In both groups, quantitative values and wave types (qualitative) were recorded. Afterwards, data were grouped separately (Table 1, 2), and summarized by using descriptive statistical methods (frequency, mean, median, standart deviation). Study groups were compared by using Chi-square, Kruskal Wallis H test, and Mann Whitney U test. The side with calculi is accepted as the abnormal side. In addition, statistical differences between each group were evaluated as “patient group abnormal side and control group”, “patient group normal side and control group”, “patient group normal side and patient group abnormal side” with the chi-square test.

Results

All of the renal calculi were demonstrated with plain films (43 calculi in 17 subjects) or CT (8 calculi in 7 subjects). With sonographic measurements, these renal calculi [mean diameter 7.8 (5-14) mm] were unilateral in 18 of 24 patients, and bilateral in 6 of 24 patients. There was no hydronephrosis in any of the examined kidneys. There was no significant difference of demographic features between the patient and control groups.

The mean jet duration (5.7 sec), mean peak velocity (35.5 cm/sec), and mean frequency of the jet (4.4 times per 10 min) was higher at the site with calculi in the patient group, than both the normal side and control group. There was no statistically significant difference between both sides of the control group, between normal and abnormal sides of the patient group or between patient and control groups.

When spectrum wave types were considered; ureteric jet flow patterns were predominantly monophasic at the abnormal side of the patient group (monophasic, triphasic, and biphasic was 26, 2, and 2, respectively for abnormal side; 13, 32, and 13 for normal side). The difference between the patients' normal and abnormal sides was not significant (p=0.44), but there was statistically significant difference between both sides of the patient and control groups (p<0.0001).

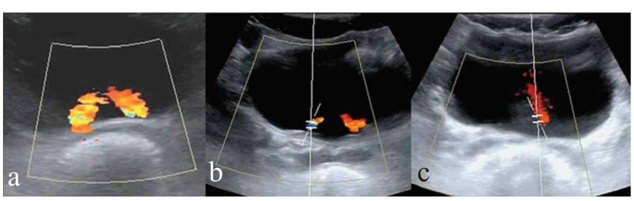

Figure 1 Determination of the jet flow and measurement technique. Symmetric flow from the bilateral ureteral orifices into the bladder lumen through the trigone was demonstrated with color window (a). Spectral waveform, and measurement of the velocities from this spectral window for the right (b) and for the left (c) ureters using the suitable gate size (1.5 mm) and angle (about 45 degrees).

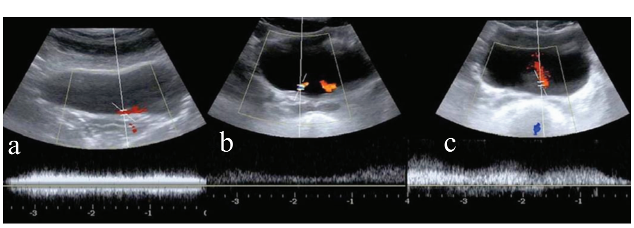

Figure 2 Monophasic (a), biphasic (b), and triphasic patterns (c) of the spectral wave forms of the ureteric jet flow. Spectral terms were different from the vascular spectral examination reports. This classification concerning the phasicity was a misnomer. Here, the dissimilarity is the phasicity and wave peak numbers from the derived spectral window that totally differs from the venous or arterial spectral waveforms.

Discussion

It is well known that the sound beam penetration power of the US equipments has increased in parallel to the technologic advances in radiology. The power of the sound beam, thus, penetration has been increased with new innovations, which allowed higher resolution. In spite of the increased resolution, the detectability of the calculi, especially the smaller ones (<5 mm), has been more difficult with the new systems due to reduced posterior acoustic shadowing. Furthermore, in the determination of the mild collecting system dilatation, it is well known that the US has only 50% predictability value.[3] In a variety of situations other than obstructive uropathy, such as in the normal variants, with excessive hydration, during diuretic treatment, in case of bladder overdistension, with the structural variations (extrarenal pelvis, caliceal diverticulum, etc.) or with distension of the renal vascular structures or in vesicoureteral reflux disease; gray scale US may show mild dilatation,[4,5] which may mimic hydronephrosis. Given the low sensitivity of gray scale US, there are lots of studies in the literature which have investigated new methods that may help to differentiate the obstructive and non-obstructive causes of the collecting system dilatation.[6-10] In a study including pediatric patient population, the role of color Doppler US in the detection of vascular impression with resultant hydronephrosis was investigated.[6] The resistivity index and ureteric jet flow characteristics were studied in patients with hydronephrosis.[7,8-10] We believe that one of the most important indications for Doppler US in nephrolithiasis is the well-known twinkling artefact.[9] In various studies including patients with hydronephrosis, ureteric jet flow and resistivity index parameters were used to evaluate response to therapeutic methods.[4,11,12]

Although many studies have been published about the ureteric jet phenomenon, which is demonstrated by color Doppler ultrasonography; there are only a few articles about the deranged mechanism and physiology of the assumed urinary peristaltic system.[1,2] Apart from focusing on the obstructive uropathy; the present study is the first to determine the dysfunctional pelvic pacemaker activity by measuring the jet patterns indirectly in patients with non-complicated nephrolithiasis.

Ureteric jet flows have first been described from the IVP visions.[13] Later, their description with US has also been described. When the urine density dif-

Table 1. Spectral data of the groups

Groups	Number of patients	Peak Velocity (cm/s)	Average jet flow time (sec)	Jet flow frequency (/10 mins)
Patient-nephrolithiasis side	30	35.5	5.7	4.4
Patient-normal side	18	31.5	4.7	3.6
Control-right side	31	29.9	4.5	3.5
Control-left side	31	29.8	4.4	3.6

Table 2. Distribution of spectral flow patterns through the patient and the control groups

Groups	Spectral wave patterns		
	Monophasic	Biphasic	Triphasic
Patients-nephrolithiasis side	26	2	2
Patients-normal side	13	2	3
Control- both sides	17	32	13

ferences between the ureter jets and the bladder is too high, jets can also be identified with the gray scale US.[3,14] However, jet flows may be identified more easily in the Doppler US window of these flows, even not seen in the gray scale when densities are equal.[2,15] Jet flows have been analysed in various patient groups like vesicoureteral reflux, urinary obstruction, ureteral injury; and significant results have been reported.[2,15-17] But, the comments and hypothesis are still going on about the pathophysiological characteristics.[18-22] In this study, in addition to the examination of the ureteric jet flow pattern in coloured scale; we characterized the flow wave features by examining the spectral window.

It has been hypothesized that renal pelvic contraction is initiated by the pacemaker units. This unit is made up of pacemaker units, which produce stimuli in response to the tension exerted by urine.[2] This system also provides the continuity of urine flow from the pelvis to the ureters.[2] The flow of urine, which passes through the ureterovesical junction against a pressure gradient, has its own velocity and a special phasic pattern.[4] The ureteric jet flows from both sides continue for the whole day. It is noteworthy to mention that flow rate of urine in both ureters are equal and symmetric in the settings of standard measurements and in patients with symmetric renal function.[5] For evaluation of the symmetry of renal function, the observation should ideally take about at least 10-15 min, rather than spontaneous measurements.[5] It is not practical to image the distal ureter for 10-15 min from clinical point of view. Even if the evaluation is performed for the appropriate time period, the frequency of the ureteric jet flow shows variations among healthy individuals.[1-4] In our study, the time period (10 min) was appropriate for the evaluation of ureteric jet flow and also multiple parameters (jet frequency, peak velocity, jet flow duration, and jet spectrum wave type) were determined to obtain quantitative data.

In our study, although not statistically significant, the amplitude (peak velocity), frequency, and the duration of the ureteric jet activity had an incremental course of 10 min examination time for the abnormal side of patients.

Peak velocity, mean jet duration, and jet frequencies were measured as 30.97±14.66 cm/sec, 5.75±2.22 sec, and 4.37±1.49 times per 10 min, respectively for the abnormal side of the patient group, whereas these values were 35.55±12 cm/sec, 5.73±2.23 sec, and 4.95±1.27 for the normal side of the patient group.

Peak velocity, mean jet duration, and jet frequencies were 29.97±11.95 cm/sec, 4.84±1.41 sec, and 3.55±1.12 times per 10 min for the right side of the control group, and 29.8±13.69 cm/sec, 5.23±1.81 sec, and 3.68±1.10 times for the left side of the control group.

This process may be related to the hyperactivity of the pacemaker cells due to microstasis from local obstruction or irritation and/or inflammation induced by the stone. Since there is no significant difference between the normal and abnormal sides in the patient group, it can be hypothesized that, the primary abnormality is the dysfunctional propagative peristaltic activity, which induces stasis and later formation of calculi. Also the presence of the immature and monophasic jet type dominancy in the patient group supports this theory and these findings correlate well with the previous literature.[2,18,20]

This study has some limitations. First of all, study procedure was time consuming. There are some information in the literature in order to identify and classify the ureteric jet stream patterns.[4,5] It is difficult to perform this procedure for such long periods because of routine work load. We believe that we have allowed enough time, and it is possible to perform the same procedures in practice during daily routine. The other problem, on the other hand, was that the effect of dimensional or locational differences of calculi has not been determined separately because it would disperse smaller groups. This may threat the consistency of findings because of the insufficient number of patients for each subgroup. Another minor limitation was the presence of various other artefacts during the evaluation of jet flows with Doppler US. Familiarity with these artefacts may help reduction of the negative effects on image quality or may diminish examination time. During the evaluation of the ureteric jet flows, bladder compression may cause urinary bulk movement without the jet flow. Also intestinal peristalsis, iliac artery pulsations or abdominal wall movement during respiration may cause vibration artefact. Lower ureteral stones may create disruptions in the Doppler scale or can degrade the spectral form.[9] We have also faced with these kinds of artefacts with many cases during the study (Fig. 3). These artefacts, which occur frequently in the presence of low PRF values, are mostly familiar to the radiologists in daily practice, thus can easily be overcome.

In conclusion, patients with nonobstructive, uncomplicated, asymptomatic nephrolithiasis demonstrate ureteric jet flow, which is predominant in the monophasic spectral waveform. In the nephrolithiasis group, despite not being statistically significant; peak velocity, jet time, and jet frequencies were also increased. Not only a structural abnormality or the calculi itself can be the primary cause, but the irritative and local inflammatory effect which is induced by the calculi that produce stimulation of the pelvic pacemaker cells may cause these findings. Our findings, which were obtained in standardized conditions, also support that both sides (with or without calculi) of the nephrolithiasis group has been producing abnormal jet flows as monophasic immature waves. Thus, instead of induction of lithiasis by stimulating effect, the dysfunctional peristaltic mechanism may be the primary or accompanying cause for local stasis, which facilitate calculi formation.

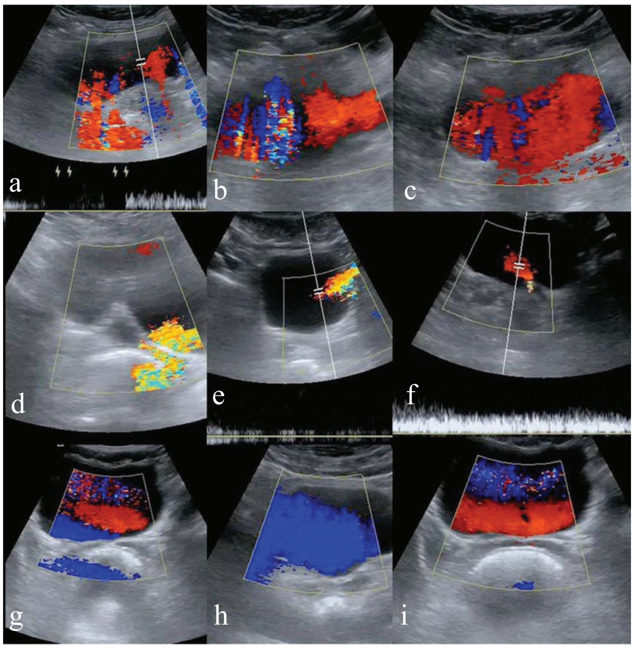

Figure 3 Type of artefacts during color Doppler ultrasonography imaging. These artefacts were formed due to the uncontrolled movements of the patients or abdominal wall during the deep breathing, reflex or twitching motions (a, b, c); peristaltic motion of the gas in rectosigmoid colon causing the aliasing (d), involuntary transducer motion (e); distal ureteral calculi and posterior twinkling (f). Urine that was layered because of the density differences can move randomly in a bulky way with compression-decompression during examination (g, h, i).

Conflict of interest

No conflict of interest was declared by the authors.

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