GENERAL UROLOGY
Original Article

Evaluation of ureteric jet flow with Doppler ultrasonography during manual compression

Manuel kompresyon sırasında Doppler ultrasonografi ile üreterik jet akım değerlendirmesi

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ABSTRACT

Objective: This study aimed to distinguish between obstructive and non-obstructive dilation of the upper urinary tract using ureterovesical jet flow analysis with Doppler ultrasonography (US) and manual flank compression.

Materials and methods: The study enrolled 54 patients (11 women, 43 men; mean age 27.5 years) with unilateral hydronephrosis. All but 2 pregnant patients underwent the Doppler US and the reference standard test [intravenous pyelogram (IVP)] after standardized hydration. The distended urinary bladder was visualized in the transverse plane to evaluate both ureteral orifices simultaneously. During and after compression of each flank, the jet flows were recorded in Doppler mode. The jet flows were quantified by calculating the longitudinal extent of the color spread into the bladder on both sides. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the test for determining the degree of obstruction were evaluated statistically.

Results: Ureterovesical jet flow could not be visualized with flank compression in 4 cases. Three of these cases had complete obstruction on IVP. In the 22 cases that had markedly reduced flow compared to the contralateral side on Doppler US, the IVP showed similar stasis. In the 19 cases that had mildly diminished flow compared to the contralateral side on Doppler US, no significant difference was detected in the pyelogram and nephrogram phases on IVP.

Conclusion: Doppler examination of the ureterovesical jet flows during flank compression may be a good diagnostic method for evaluating the degree of obstruction, especially in patients in whom magnetic resonance imaging or computerized tomography is contraindicated.

Key words: Doppler ultrasonography; ureter; ureteral obstruction.

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Submitted: 18.06.2011

Accepted: 21.07.2011

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Available online at www.turkishjournalofurology.com

ÖZET

Amaç: Bu çalışmanın amacı, manuel kompresyon sırasında üreteral jet akımların Doppler ultrasonografi (US) ile değerlendirilerek tıkayıcı ve tıkayıcı olmayan üst üriner sistemin dilatasyonlarını ayırt edilmesidir.

Gereç ve yöntem: Çalışmaya tek taraflı hidronefroz tespit edilmiş 54 olgu (11 kadın, 43 erkek; ortalama yaş 27.5 yıl) dahil edildi. Hidrasyon düzeyi standardize edilerek, tüm hastalara Doppler US inceleme ve 2 gebe olgu dışındaki diğer tüm hastalara referans standart test olarak intravenöz piyelografi (İVP) yapıldı. Her iki üreter orifisi görülecek şekilde distandü mesane yatay pozisyonda görüntülendi. Renal lojun kompresyonu sırasında ve sonrasında oluşan jet akımlar Doppler mod ile kaydedildi. Mesane içerisine doğru gelişen renk saçılımının uzunluğu dikkate alınarak jet akımlar kantifiye edildi. Obstrüksiyon derecesinin ayırımında sensisitivite, spesifite, pozitif ve negatif prediktif değerler istatistiksel olarak hesaplandı.

Bulgular: Üreterovezikal bileşke akımı toplam 4 olguda hiç gözlenemedi. Bunlardan biri hariç diğer üçünde İVP ile de tam obstrüksiyon rapor edilmişti. Kalan olguların 22'sinde, Doppler US'de karşı tarafa göre kısalmış jetler sözkonusu iken, İVP'de de bununla uyumlu nonprogresif staz görüldü. Diğer 19 olguda, Doppler US'de karşı tarafa göre hafif azalmış jetler sözkonusu iken İVP incelemelerinde piyelogram ve nefrogram fazlarında anlamlı fark tespit edilmemişti.

Sonuç: Özellikle manyetik rezonans görüntüleme veya bilgisayarlı tomografinin kontrendike olduğu olgularda, renal lojların manuel kompresyonu sırasında Doppler US ile üreterovezikal bileşkenin jet akımlarının değerlendirilmesi obstrüksiyon derecesinin belirlenmesinde iyi bir tanısal yöntem olabilir.

Anahtar sözcükler: Doppler ultrasonografi; üreter; üreteral obstrüksiyon.

Turkish Journal of Urology 2011; 37(4): 341-349
doi:10.5152/tud.2011.066

Conventional ultrasonography (US) is the main primary non-invasive imaging modality for evaluating the urinary tract. When hydronephrosis is detected, it is crucial to differentiate between obstructive and non-obstructive causes of dilation.[1,2] Persistent dilation and stasis enable urinary infection and increased intrarenal pressure, which can disrupt renal function tests acutely or chronically.[2] To prevent dysfunction, uroradiological diagnosis of these pathologies is essential.[1-3] Conventional US is not useful for diagnosing all obstructive pathologies, especially in ureteric obstruction.[4,5] Several methods are used to diagnose urinary tract obstruction, including intravenous urography, diuretic dynamic scintigraphy, computed tomography (CT), magnetic resonance imaging (MRI), and less commonly retrograde and anterograde pyelography.[4-7] However, some of these methods are invasive and others cause radiation exposure. In addition, physiological variation may be seen as ureteral or pelvicalyceal fullness.[8,9] Color Doppler examination of ureteric jet flows is a non-invasive method that has been used to study a wide spectrum of pathologies, with significant results.[10-14]

Table 1. Different case groups according to distinct pathology types

Groups	n
Ureteropelvic junction stenosis	8
Peripelvic cyst	5
Ureterolitiazis	11
Sequela of caliectasis (history of calculus, vesico ureteral reflux, operation)	7
History of nephrolithotomy	5
History of ureterolithotomy	3
History of nephrolithotripsy	5
History of ureterolithotripsy	3
Prominent extrarenal pelvis variation	5
Hydronephrosis with pregnancy	2

In this study, we examined the grade of obstruction in patients with urinary tract dilation, by evaluating the ureterovesical jet flows in the Doppler US window with manual renal compression.

Materials and methods

Between December 2009 and June 2010, 54 cases (Table 1) (11 women, 43 men; mean age 27±6.5 years) with unilateral hydronephrosis were included in this study. To compare the affected and normal sides, patients with solitary kidneys or bilateral hydronephrosis were excluded from the study. The body mass index (BMI) of the subjects ranged between 18.2 and 31.2 kg/m^2 (mean 24.7±6.5 kg/m^2). Except two pregnant patients in whom the intravenous pyelogram (IVP) was performed after delivery,

Table 2. Quantified jet characterization with related figures, IVP grading of stasis, and grading of the severity of ureteral passage obstruction

Ureteral jet types obtained during renal lodge compression		
Jet from abnormal side, compared with normal side	Jet name	Related figures
Absence of color aliasing during compression	Absent	Fig. 1
Jet shorter than (≤25% of) normal side	Very low	Fig. 2
Jet between 25-75% of normal side	Low	Fig. 3, 4
Jet that has at least ≥75% length of normal side	Normal	Fig. 5
Grade of the pyelocaliceal system stasis		
No dilatation	Grade 0	
Dilated ureter or pelvis but normal calicies	Grade 1	
Dilatation in calicies	Grade 2	
Deformation in calicies and deterioration in papillary impression	Grade 3	
Grade of the ureteral obstruction		
Normal ureteral passage	Grade 0	
Minimal stasis due to physiologic causes (iliac artery cross etc.)	Grade 1	
Passage achieved only manual compression during prone position	Grade 2	
No ureteral passage though compression during prone position or spontaneously till to 240 min of examination	Grade 3	

all patients underwent examination with both the index test (Doppler US) and reference test (IVP). The patients were classified into 10 groups (Table 1).

All patients underwent a brief upper abdominal US to visualize the renal lodges to determine the site of compression. The patients were well hydrated (with 1 L of water, 30 min before the examination) at the time of examination and before bladder evaluation. The bladder was visualized in the transverse plane to evaluate both ureteral orifices at the trigonal level simultaneously. All examinations were performed by the same radiologist using a color Doppler scanner (GE Logic 9 Ultrasound Imager, Milwaukee, WI, USA). During the examination, low pulse repetition frequency settings were used (1000-1500 MHz). The examination was performed with the transducer angled towards the level of the lower ureteral orifices with one hand, while simultaneous flank compression was maintained with the other hand. This was repeated for the other side. During the procedure, images were recorded in cine-mode. The flank compression was repeated three times with a gentle force until the patient experienced mild pain. Then, the ureteral orifices in the color box were visualized to take images during the time required to measure the compression-induced passage of urine for 15-30 sec in each case. From the beginning of the compression, sequential images were obtained for 90-120 sec (mean 98 sec) for each side.

All cases were evaluated symmetrically to compare the pathological and normal sides. The jet flows were quantified by calculating the longitudinal extent of the color spread (aliasing) into the bladder for both sides. Based on the IVP findings, the pyelocalyceal system dilation and ureteral stasis or obstruction were divided into four grades (Table 2).

All examinations were performed under standard conditions of hydration and waiting time, and were correlated with an IVP taken in the same week, except for two pregnant patients, for whom the postpartum IVP examinations were considered the reference for interpreting the jet dynamics during compression.

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the compression test for measuring the grade of obstruction were determined statistically.

Results

In one case with ureteropelvic junction (UPJ) stenosis, although no jet flow was detected with Doppler US, contrast passage was seen through that ureter on IVP with flank massage. The ureteral passage was obstructed completely on IVP examination in three patients (two ureteral calculi, one obstruction due to post-nephrolithotomy edema) in whom no jet flow was detected (Table 3).

Although the IVP was reported as normal in one case each with a ureteral calculus, nephrolithotomy history, and extrarenal pelvis, the ureterovesical jet flows were very low on the Doppler jet examination. In addition, the ureterovesical jet with flank compression was very low in one case with UPJ stenosis, two parapelvic cysts, two ureteral stones, one nephrolithotomy history, two nephrolithotripsy histories, and one extrarenal prominent pelvis in whom the IVPs were reported as normal, except minimal dilation (Grade 1 or smaller) (Table 4). The Doppler US jet flow with flank compression was reported as "very low," although the ureteral passages on the IVP were totally free in one patient each with a parapelvic cyst, nephrolithotomy history, extrarenal pelvis, and persistent caliectasis after stone expulsion.

Table 3. IVP correlation findings in patients with "absent" jet flow detected by flank compression

Pathology	Number of patients	Jet flow is "absent" in Doppler US	IVP correlation findings in "absent" jet flow cases
Ureteropelvic junction stricture	8	1	Dilatation: Grade 3 Ureteral passage: Grade 2
Peripelvic-parapelvic cyst	5	-	
Ureterolithiasis	11	2	Dilatation: Grade 3 Ureteral passage: Grade 3
Sequela of caliectasis (history of calculus, vesico ureteral reflux, operation)	7	-	
History of nephrolithotomy	5	1	Dilatation: Grade 3 Ureteral passage: Grade 3
History of nephrolithotripsy	5		
History of ureterolithotripsy	3		
Prominent extrarenal pelvis variation	5	-	
Pregnancy and hydronephrosis	2	-	
History of ureterolithotomy (ureteroscopic)	3	-	

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doi:10.5152/tud.2011.066

Table 4. IVP correlation findings in patients with "very low" jet flow detected by flank compression

Pathology	Number of patients	Jet flow is "very low" in Doppler US	IVP correlation findings in "very low" jet flow cases
Ureteropelvic junction stricture	8	4	Dilatation: Grade 3 (n=2), Grade 2 (n=2) Ureteral passage: Grade 2 (n=3), Grade 1 (n=1), Grade 0 (n=1)
Peripelvic-parapelvic cyst	5	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 1 (n=2)
Ureterolitiazis	11	3	Dilatation: Grade 3 (n=1), Grade 2 (n=2) Ureteral passage: Grade 2 (n=1), Grade 1 (n=2)
Sequela of caliectasis (history of calculus, vesico ureteral reflux, operation)	7	3	Dilatation: Grade 3 (n=3) Ureteral passage: Grade 2 (n=3)
History of nephrolithotomy	5	2	Dilatation: Grade 2 (n=1), Grade 1 (n=1) Ureteral passage: Grade 1 (n=1), Grade 0 (n=1)
History of nephrolithotripsy	5	2	Dilatation: Grade 2 (n=1), Grade 0 (n=1) Ureteral passage: Grade 1 (n=2)
History of ureterolithotripsy	3	2	
Prominent extrarenal pelvis variation	5	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 1 (n=1), Grade 0 (n=1)
Pregnancy and hydronephrosis	2	1	Dilatation: Grade 3 (n=1) (Calicial deformation in US) Ureteral passage could not be compared with reference test IVP was normal after pregnancy
History of ureterolithotomy (ureteroscopic)	3	1	Dilatation: Grade 3 (n=1) Ureteral passage: Grade 2 (n=1)

Although the ureteral passages were totally open on the IVP in one case each with a parapelvic cyst, persistent caliectasis after stone expulsion, nephrolithotomy history, and extrarenal pelvis, the ureterovesical jet flow with Doppler US during flank compression was low (Table 5).

In cases in which the Doppler US jet flow was compatible with the normal side with a difference of 25% or less, the IVP findings were reported as Grade 1 in 2 patients with a UPJ stricture and subsequent vesicoureteral reflux; in the remaining cases, the IVP findings were reported as Grade 0 (Table 6).

The statistical analyses showed that our method had 94.8% sensitivity, 46% specificity, 82% PPV, 77% NPV, and 81.4% accuracy for detecting the degree of hydronephrosis and ureteral passage obstruction.

Discussion

Improvements in technology provide a wide range of ways to visualize the urinary system to obtain anatomical, morphological, and functional information.[14-17] Conventional US is the first-line modality for evaluating the urinary tract. However, sound beam attenuation in obesity and superposition of colonic gas may prevent optimal visualization for diagnosis.[18] In such cases, CT is very useful for detecting and localizing urinary calculi. New-generation CT systems (i.e., multi-detector CT) can also assess stone composition and stone burden.[19] Despite these advantages, CT may cause considerable radiation exposure, especially when performing excretory urography examinations. Moreover, with the need to evaluate the nephrogram and ureterogram phases, and calculus opacities, each additional dynamic CT scan increases the dose and these exams require contrast administration.[20] Although rare, the contrast medium itself may cause serious acute (anaphylactic reaction) or late-onset (nephropathy) side effects.[21,22] Conspicuous uncomplicated or asymptomatic urinary pathologies, such as mild dilation or mild stasis due to conditions such as a peripelvic cyst, persistent caliectasis, or prominent extrarenal pelvis, should be able to be evaluated using methods other than those involving contrast enhancement or radiation exposure, especially in young patients who are the most sensitive to the hazards of radiation or anaphylaxis. In addition, cross-sectional, contrast-enhanced procedures can be time-consuming and more expensive. If only functional abnormalities were the issue, intravenous pyelography alone might be the preferred technique to delineate the problem (e.g., stasis, dilatation, obstruction).

Alternatively, MRI, while not exposing patients to ionizing radiation directly, is much more expensive and time-consuming than other modalities. In addition, there are some absolute (neurostimulator or cardiac pacemakers) or relative (claustrophobia, allergic reaction history) contraindications to MRI,

Table 5. IVP correlation findings in patients with "low" jet flow detected by flank compression

Pathology	Number of patients	Jet flow is "low" in Doppler US	IVP correlation findings in "low" jet flow cases
Ureteropelvic junction stricture	8	2	Dilatation: Grade 2 (n=1), Grade 1 (n=1) Ureteral passage: Grade 1 (n=2)
Peripelvic-parapelvic cyst	5	1	Dilatation: Grade 3 (n=1) Ureteral passage: Grade 0 (n=1)
Ureterolitiazis	11	4	Dilatation: Grade 3 (n=2), Grade 2 (n=3), Grade 1 (n=1) Ureteral passage: Grade 2 (n=1), Grade 1(n=3)
Sequela of caliectasis (history of calculus, vesico ureteral reflux, operation)	7	2	Dilatation: Grade 3 (n=1), Grade 2 (n=1) Ureteral passage: Grade 1 (n=1), Grade 0 (n=1)
History of nephrolithotomy	5	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 0 (n=2)
History of nephrolithotripsy	5	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 1 (n=2)
History of ureterolithotripsy	3	1	Dilatation: Grade 1 (n=1) Ureteral passage: Grade 2 (n=1)
Prominent extrarenal pelvis variation	5	3	Dilatation: Grade 2 (n=3) Ureteral passage: Grade 1 (n=1), Grade 0 (n=2)
Pregnancy and hydronephrosis	2	1	Dilatation: Grade 2 (n=1) (Calicial dilatation in US) Ureteral passage could not be compared with reference test IVP was normal after pregnancy
History of ureterolithotomy (ureteroscopic)	3	1	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 1 (n=2)

Table 6. IVP correlation findings in patients with "normal" jet flow detected by flank compression

Pathology	Number of patients	Jet flow is "normal" in Doppler US	IVP correlation findings in "normal" jet flow cases
Ureteropelvic junction stricture	8	1	Dilatation: Grade 2 (n=1) Ureteral passage: Grade 1 (n=1)
Peripelvic-parapelvic cyst	5	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 0 (n=2)
Ureterolitiazis	11	2	Dilatation: Grade 1 (n=1), Grade 0 (n=1) Ureteral passage: Grade 1 (n=2)
Sequela of caliectasis (history of calculus, vesico ureteral reflux, operation)	7	2	Dilatation: Grade 2 (n=2) Ureteral passage: Grade 1 (n=1), Grade 0 (n=1)
History of nephrolithotomy	5	-	
History of nephrolithotripsy	5	1	Dilatation: Grade 1 (n=1) Ureteral passage: Grade 0 (n=1)
History of ureterolithotripsy	3	-	
Prominent extrarenal pelvis variation	5	-	
Pregnancy and hydronephrosis	2	-	
History of ureterolithotomy (ureteroscopic)	3	1	Dilatation: Grade 1 (n=1) Ureteral passage: Grade 0 (n=1)

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doi:10.5152/tud.2011.066

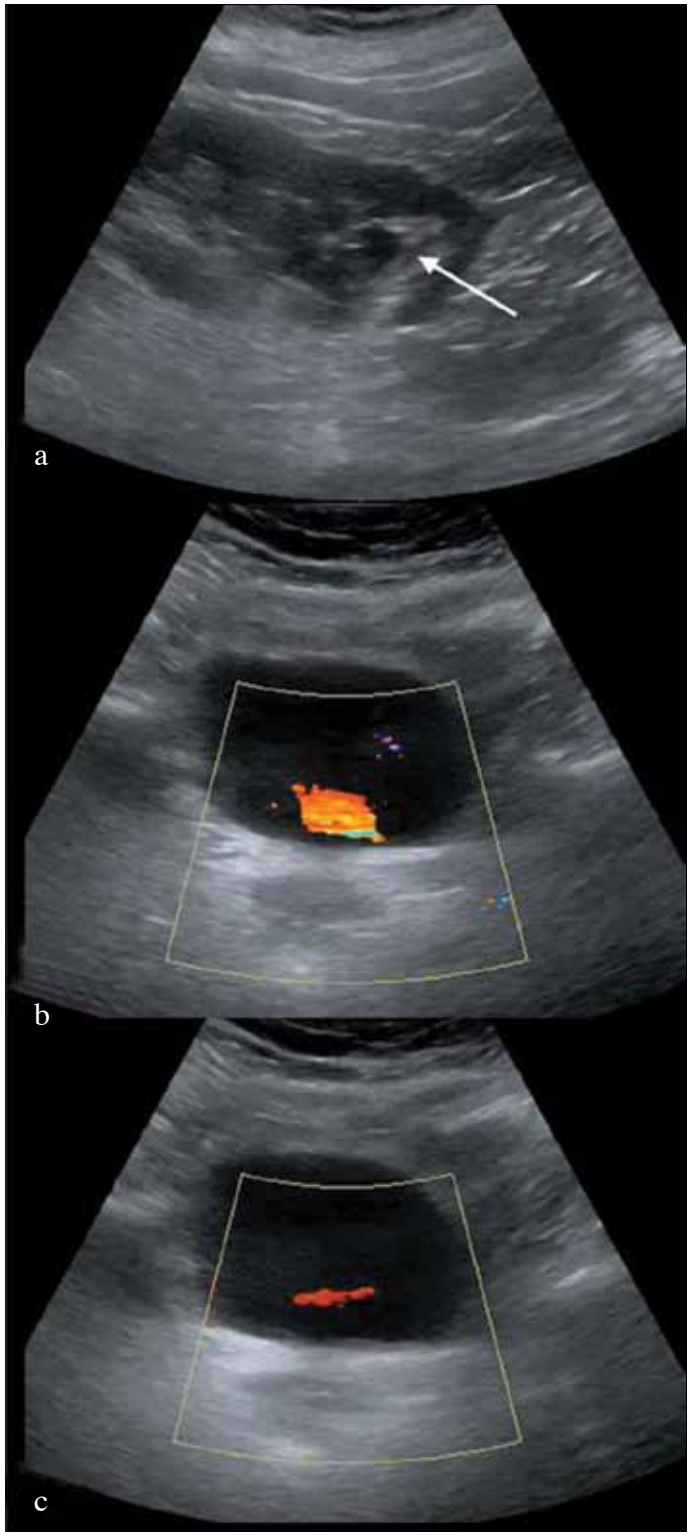

Figure 1. Caliectasis of the lower pole (a, arrow) following a nephrolithotomy shown on gray-scale longitudinal axis image of the right kidney. Comparing the flank compression-induced jet flows, the right jet (b) was significantly shorter than the left one (c).

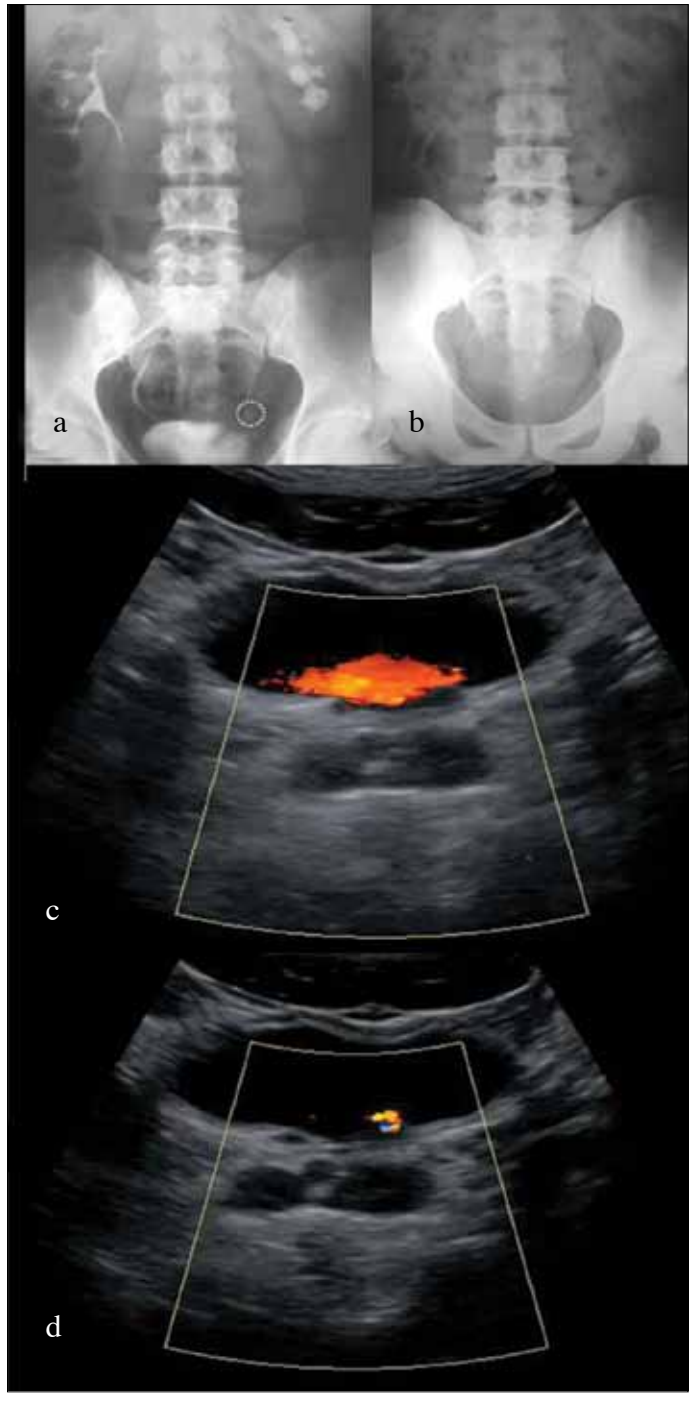

Figure 2. A patient with a calculus in the left lower ureter. The IVP demonstrates stasis and hydronephrosis on the left side due to the obstruction (a). A calculus was seen in the circled area. While there was a normal jet on the right side after compression (b), no flow was seen on the left side initially (not shown). After removing the calculus via ureteroscopic lithotomy, the symptoms persisted for 2 days. A follow-up Doppler exam confirmed a present, but reduced left ureteric jet flow (c). Confirmatory ureteroscopy showed localized edema due to the calculus or procedure causing partial obstruction of the lumen. Two weeks later, both jets were normal.

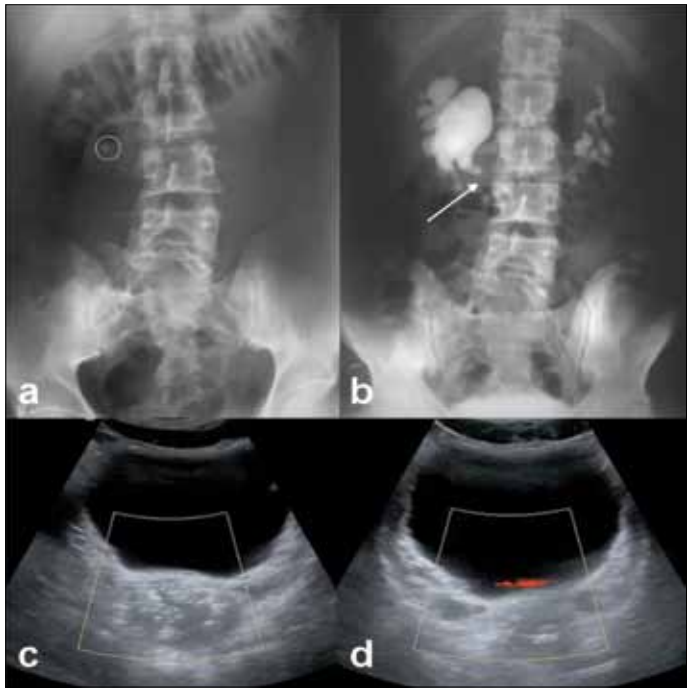

Figure 3. A patient with a horseshoe kidney. A calculus visualized on direct urinary X-ray (a, encircled area) was causing obstruction at the level of the right ureteropelvic junction on IVP. (b) The jet flow on the right side (c, arrow) was not visualized, even with compression, confirming the total obstruction. The left jet was visualized (d), but with a small amplitude, probably caused by ineffective compression due to the midline rotation of the left horseshoe kidney.

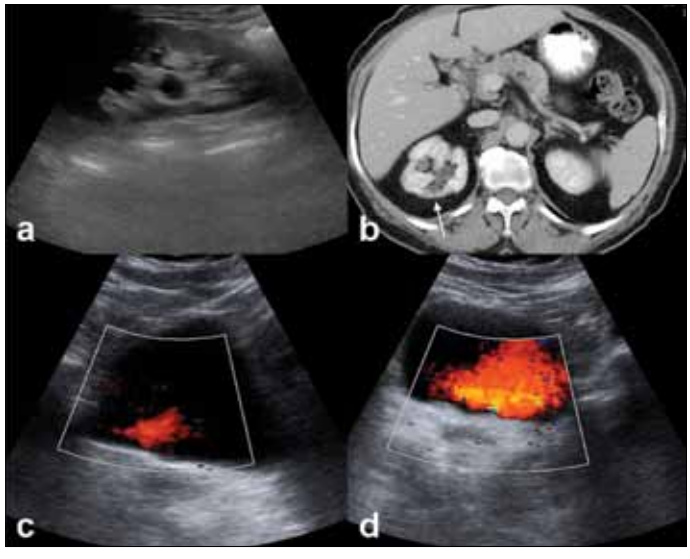

Figure 4. A patient with a history of right-sided vesicoureteral reflux disease. US shows anechoic calyceal dilation (a). CT delineates the focal parenchymal volume loss at the right upper pole (b, arrow). The amplitude of the ureterovesical jet flow was smaller on the right side (c) than on the normal left side (d).

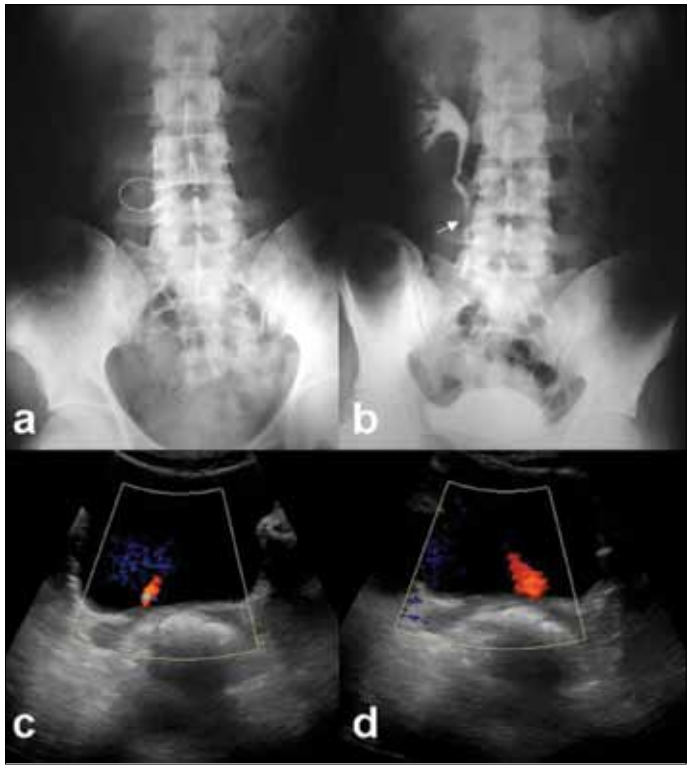

Figure 5. A patient with vague pains in the right upper quadrant. Direct urinary system X-ray (a, circled area) showed an opacity on the right side at the level of the L4-L5 disc. IVP (b, arrow) confirmed that it was a ureteric calculus causing mild obstruction, which allowed contrast passage. Jet flows were obtained after flank compression, matching the IVP findings. The amplitude of the right jet (c) was slightly smaller than that of the left jet (d).

which is also not sensitive for detecting or localizing urinary calculi. Moreover, gadolinium-based MRI contrast agents can cause acute (anaphylaxis) or late-onset (nephrogenic systemic sclerosis) adverse reactions.

Obstructive pathologies of the urinary system at the suprapubic level affect the younger population relatively more frequently.[23] In addition, allergic reactions caused by contrast medium have a mortality risk of up to 0.1% and can expose the patient to ionizing radiation of up to 15 mSv. In comparison, US is a non-invasive, real-time, inexpensive method that does not require iodinated contrast administration or radiation exposure.[21,22] Moreover, for defining obstructive pathologies, gray-scale US can also be a guide for localizing the lower ureteral orifices and examining the ureteric jet flows into the bladder.

Many studies have examined ureterovesical jet flow using color Doppler mode.[23-27] These studies examined the jet flow characteristics, focusing on the evaluation of specific pathologies (e.g., reflux, ureteral calculi). In all of these studies, it was

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doi:10.5152/tud.2011.066

necessary to wait for spontaneous jet flow formation to interpret the results. However, with spontaneous ureterovesical jet flow, it can take 30 min to evaluate differences bilaterally.[28] We overcame this problem by forcing ureteral flow with gentle flank compression. In addition, our study did not focus on a special pathology. All of the upper urinary tract dilations were recorded and examined using the flank compression method in Doppler mode. Consequently, we identified different etiologic causes of the obstructive pathologies, rather than focusing on a specific pathology. The efficacy of the method was confirmed by IVP findings. As a result, we showed that the presence of stasis in urinary tract dilation or obstructive pathology can be detected with 81.4% accuracy within 1.5 min. This is the first study to enhance ureterovesical jet formation by compressing the renal lodges to reveal any static/obstructive pathology between the calyceal level and the lower ureteral orifices.

This technique also has some limitations. Patients may feel pain during the procedure, although our subjects described it as tolerable. In addition, the technique may not work for obese patients unless a second person compresses the flank, while the first makes the Doppler measurement. In our study, we achieved results compatible with the IVP results in patients with a BMI as high as 31.2 kg/m^2. Furthermore, compression of the renal lodge may disrupt or even perforate the dilated system in thin patients with marked dilation and a distended collecting system. A brief US examination of the upper urinary system before the procedure may help to prevent such complications, especially in very thin patients, although there are no definitive data on this.

Therefore, if the primary goal of an examination is to ascertain the degree of obstruction and the existence of ureteral passage, a compression-induced ureteral jet flow examination may be indicated, especially in patients in whom MRI (e.g., neurostimulator implant, serious claustrophobia) or CT (e.g., pregnancy) is contraindicated.

In conclusion, despite its low specificity, the high sensitivity and high accuracy of observing ureteral jets with flank compression makes it an easy, useful method for obtaining information on patients with probable obstruction.

Conflict of interest

No conflict of interest was declared by the authors.

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