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Research Article

Doppler Comparison between Ureteric Obstruction and Ureteric Jet Velocity

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Abstract: The purpose of this study was to provide an indirect, alternative and safe method for the diagnosis of ureteric obstruction because in some cases it is difficult to identify the cause of obstruction with ultrasound. There are also some cases of nonobstructive hydronephrosis that are mistaken for obstructive hydronephrosis. There are also some patients in which ionizing radiations are contraindicated and the diagnosis needs to be done with ultrasound. The aim of our study is to evaluate the urodynamics of ureteric jets, especially the jet velocity, from the obstructive side with the help of color and spectral Doppler and then to compare with the urodynamics of ureteric jets from the nonobstructive contralateral side in order to differentiate obstructive from nonobstructive hydronephrosis.**Objective:**To determine the Doppler comparison between ureteric obstruction and ureteric jet velocity.**Methods:**A cross-sectional comparative study was carried out at Gilani Ultrasound Center, Firozpur Road Lahore. The duration of study was 06 months. A total of 35 patients and 35 normal subjects were included in the study after giving written consent. All data was analyzed by Statistical Software for Social Sciences (SPSS version 24). Mean and standard deviation (SD) were calculated for continuous variables. Frequency and percentages were calculated for categorical variables.**Results:**In control group and in contralateral normal ureters (Group-I), the jet velocity varied from 23.16 to 86.83 cm/ sec (mean 50.89cm/ sec). In obstructed ureters (Group-II), the jet velocity varied from 0 to 71.8cm/ sec (mean 15.8cm/ sec). When compared with contralateral normal side and healthy subjects, the jet in the obstructed side showed reduced velocity (15.8cm/s vs. 50.89cm/s). The mean jet velocities of both sides were nearly similar in normal subjects, but differed significantly in patients.**Conclusions:**Asymmetric ureteric jet velocity is a useful indicator of ureteric obstruction. The severity of ureteric obstruction can be determined by evaluating all jet dynamics including velocity, duration and frequency.

Keywords: Ureteric obstruction, Ureteric jet, Hydronephrosis, Ureteric stone, Obstructive uropathy.

INTRODUCTION:

Ureteric stone may results in obstructive uropathy which can be defined as any structural impedance to urine outflow through the urinary tract. As a result of this impedance, pelvicalyceal dilatation occurs that, if not treated, will result in damage to the kidney. This damage to the kidney due to obstructive uropathy is called "obstructive nephropathy"(Apoku, I. N. *et al.*, 2015). The pelvicalyceal dilatation is called hydronephrosis, which is a symptom of obstructive uropathy. Several criteria are used to classify this condition, like the degree, duration, site of obstruction and whether it is bilateral or unilateral. The degree of obstruction means whether the obstruction to the flow of urine is partial or complete. On the basis of duration, obstructive uropathy is classified into acute and chronic. Acute obstruction is of short duration that causes renal parenchymal damage which is mostly reversible, while chronic obstruction is of long duration, resulting in permanent damage. In setting of more chronic obstruction, there is persistent increased vascular resistance and decreased renal blood flow, eventually resulting in structural changes, including tubular atrophy, interstitial widening, fibrosis, and nephron loss(Mujoomdar, M. *et al.*, 2012; Mourmouris, P. I. *et al.*, 2014). According to most researches if the obstruction remains for more than 6 weeks, it results in irreversible renal damage. The extent of renal damage can be assessed by thinning of renal cortex. According to some other authors if the obstruction remains for

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more than one week, it may results in some permanent damage to the kidney, but with recovery to normal function and if the obstruction remains for more than 12 weeks, it may results in irreversible damage to the kidney with no recovery to normal function of kidney (Mujoomdar, M. *et al.*, 2012). Obstructive uropathy is a clinical emergency that needs prompt diagnosis and treatment. If not treated on time, it will lead to other complications like urinary tract infection, urolithiasis, acute renal failure and chronic end stage renal failure(Apoku, I. N. *et al.*, 2015).The gold standard for the diagnosis of urinary obstruction is unknown, and so different imaging modalities are used(Mujoomdar, M. *et al.*, 2012), such as IVP, antegrade pyelography, retrograde and diuretic renography, computed tomography (CT) magnetic resonance imaging (MRI) and ultrasound. The main disadvantages of these techniques, with exception of ultrasound, are that they use ionizing radiation and radiocontrast material. So these modalities are contraindicated especially in children, pregnant women, those allergic to radiocontrast material and those with renal impairment (Ciftci, H. *et al.*, 2010; Jandaghi, A. B. *et al.*, 2013). Also IVP is expensive and time consuming (Rosen, C. L. *et al.*, 1998). Although CT has the ability to detect ureteral stones, but this technique uses high radiation dose as compared to IVP and is expensive, thus limiting its use (Jandaghi, A. B. *et al.*, 2013; Rosen, C. L. *et al.*, 1998). Ultrasound is widely used as the initial imaging modality in patients with acute renal colic and suspected obstruction (Jandaghi, A. B. *et al.*, 2013; Platt, J. F. *et al.*, 1989) and in the workup of ureteral calculi. It has many advantages over other imaging modalities. It is portable and requires no contrast media. It can readily identify hydronephrosis and hydroureter due to ureteral obstruction. So it is useful in early detection of obstructive uropathy. In some cases it can identify the cause of obstruction. It is also relatively inexpensive and having no ionizing radiation exposure. For these advantages of ultrasound, it is recommended as the primary diagnostic imaging modality for ureteric calculi (Fields, J. M. *et al.*, 2015; Nuraj, P., & Hyseni, N. 2017; Akçar, N. *et al.*, 2004; Webb, J. A. W. 2000; Shokeir, A.A. 1999). Although conventional ultrasound can detect dilatation of collecting system, some studies suggest that it cannot differentiate accurately between obstructive and nonobstructive causes and provide no physiological or functional information about obstruction. Also it is not necessary that the dilatation of collecting system detected by ultrasound is due to obstruction. There are many other nonobstructive conditions that can cause renal dilatation such as external pelvis, prominent renal vessels especially veins, persistent dilatation due to some previous episodes of obstruction, calyceal diverticulum and vesicoureteral reflux, diuretic medications, papillary necrosis, over distended urinary bladder, pyelonephritis, pregnancy, diabetes insipidus, renal artery aneurysm, peripelvic cysts and retroperitoneal or pelvic neoplasms. Ultrasound is also less useful in obese patients and in those with midureteric stones (Ciftci, H. *et al.*, 2010; Jandaghi, A. B.*et al.*, 2013; Platt, J. F. *et al.*, 1989; Nuraj, P., & Hyseni, N. 2017; Webb, J. A. W. 2000; Shokeir, A.A. 1999) Dilatation of ureter and collecting system may be secondary to a gravid uterus[9]. Ssimilarly conventional ultrasound may fail to diagnose obstruction in many cases. Up to 5% of patients may not show dilatation of collecting system. The reason for this is not clear, in some patients it may be due to dehydration (Webb, J. A. W. 2000; Gulmi, F. A. *et al.*, 2002). Even the dilatation of collecting system may not be developed in early cases of obstruction and develops latter. So there are chances of both overdiagnosis (false positive) and underdiagnosis (false negative) to occur (Gulmi, F. A. *et al.*, 2002; Opdenakker, L. *et al.*, 1998; Pepe, P. *et al.*, 2005) According to Platt *et al.*, 30% of acutely obstructed kidneys showed no dilatation of collecting system (Shokeir, A.A. 1999). According to laing *et al.*, there was 35% false negative results in the diagnosis of acute obstructive uropathy, when hydronephrosis was diagnosed (Mourmouris, P. I. *et al.*, 2014). Gray-scale ultrasound has a high sensitivity (98%) in detection of ureteric obstruction, but a low specificity due false positive. Ssimilarly in detection of urinary calculi the sensitivity and specificity of gray-scale ultrasound is 78 and 31%, respectively. In order to increase the diagnostic accuracy of gray-scale ultrasound, many authors considered Doppler ultrasound[11]. Doppler ultrasound can provide important information to distinguish obstructive from nonobstructive dilatation (Ciftci, H. *et al.*, 2010; Pepe, P. *et al.*, 2005). Some authors considered renal resistive index greater than 0.7 as diagnostic of obstructive uropathy (Mourmouris, P. I. *et al.*, 2014), but there is considerable controversy in the literature regarding the value of RI with poor sensitivity. According to some authors increase in renal RI occurs at least 6 hours after obstruction. And if the kidney is obstructed for longer period of time (more than 12 hours) or if the obstruction is severe then there is no significant increase in RI values. This means normal values of RI is not sufficient to exclude obstruction (Apoku, I. N. *et al.*, 2015; Akçar, N. *et al.*, 2004; Webb, J. A. W. 2000; Shokeir, A.A. 1999; Opdenakker, L. *et al.*, 1998; Platt, J. F. *et al.*, 1993). According to one study 12 obstructed kidneys showed mean RI values less than 0.70, and 7 of nonobstructed kidneys showed mean RI values greater than 0.70. According to Platt *et al.*, and Rodgers *et al.*, mean RI may not be increased in patients with partial obstruction (Tublin, M. E. *et al.*, 1994). RI may be normally greater than 0.70 in children. There are also conditions other than obstruction that can increase the RI values, such as acute tubular necrosis, renal parenchymal disease, haemolytic uremic syndrome, acute renal vein thrombosis, acute pyelonephritis, renal transplant rejection and subcapsular fluid collections. RI is also increased when the heart rate is decreased. RI value is also affected by the degree of hydration. When diuresis is performed by the patient, higher RI values are obtained. According to Rawashdesh *et al.*, there is no change in RI in setting of chronic renal obstruction with parenchymal loss. Some medications like NSAIDs used as pain killers in patients with renal colic are vasodilators, affecting RI values. According to Shokeir *et al.*, there is significant reduction in the values of RI in patients with acutely obstructed kidneys who used NSAIDs. There may be technical problems while measuring RI (Apoku, I. N. *et al.*, 2015; Webb, J. A. W. 2000; Shokeir, A.A. 1999; Kmetec, A. *et al.*, 2002; Platt, J. F. *et al.*, 1990). Ureteric jet was first described ultrasonographically by Dubbins *et al.*, (2010). Ureteral jet refers to the forceful flow of urine into the urinary bladder through the UVJ, which can be visualized with different imaging modalities, including color Doppler ultrasound. It is produced by a bolus of urine as a result of peristaltic contraction of the ureter (Leung, V. Y. F. *et al.*, 2007). Ureter is filled by continuous discrete boluses of urine form pelvis and when the ureter is filled wholly then a jet is produced by autonomic, myogenic and ureteral peristalsis (Wu C-C. 2010), which is forcefully ejected into the urinary bladder through VUJ. The flow of urine from ureter into the urinary bladder in the form of jet is intermittent because of ureteral peristalsis which can easily be detected by Doppler ultrasound[4]. On real time gray-scale ultrasound, the ureteric jet can be seen as a stream of low strength echoes entering the urinary bladder (Burge, H. J. *et al.*, 1991; Leung, V. Y. F. *et al.*, 2002). Six basic patterns of jet have been described including monophasic, biphasic, triphasic, polyphasic, square and continuous. The square and continuous are seen in setting of diuretic stress, and the monophasic is the immature mode which is common in infants and in children of about 4 years of age. The biphasic, triphasic and polyphasic patterns are mature complex jets which show a complex of two or more peaks (Leung, V. Y. F. *et al.*, 2007; Leung, V. Y. F. *et al.*, 2002; Burke, B. J., & Washowich, T. L. 1998). It is important to note that the character of jet alters, depending on the state of hydration and degree of filling of the bladder and in some diseases especially in setting of ureteral obstruction. Previously both color Doppler and duplex Doppler ultrasound were utilized in obstructive uropathy and proved useful in providing functional information in setting of acute renal pain (Wu C-C. 2010; Burke, B. J., & Washowich, T. L. 1998), thus increase the diagnostic accuracy of gray-scale ultrasound in detection of ureteric obstruction (Pepe, F., & Pepe, P. 2013). Alterations in renal and cardiac function may alter the detection of ureteral jets with Doppler US (Ciftci, H. *et al.*, 2010). According to one study there is good correlation of jet data with urographic results (Strehlau, J. *et al.*, 1997). Thus Doppler ultrasound of ureteric jet, especially its peak velocity, frequency and duration can provide important functional information and increase the diagnostic accuracy of gray-scale ultrasound in detection of ureteric obstruction (Ciftci, H. *et al.*, 2010; Jandaghi, A. B. *et al.*, 2013; Wu C-C. 2010; Patel, U., & Kellett, M. J. 1996). According to a study, there is significant reduction in peak velocity, frequency, duration and even absence of jet in the obstructed side when compared to contralateral normal side (Jandaghi, A. B. *et al.*, 2013; Fields, J. M. *et al.*, 2015). Duplex Doppler ultrasound of ureteral jets can increase the diagnostic accuracy of gray scale ultrasound in detection of partial or complete ureteric obstruction by detecting asymmetry in jet patterns. According to some authors a combined study of ureteric jet and renal RI alone or in combination with unenhanced helical CT, may replace the IVU (Jandaghi, A. B. *et al.*, 2013; Pepe, P. *et al.*, 2005).

METHODS:

It was a cross-sectional comparative study. 35 patients with diagnosis of unilateral hydronephrosis due to ureteral stone, based on imaging findings in ultrasound, (17 on right side and 18 on left side) and 35 normal subjects (control group) with the absence of history of kidney or bladder diseases and with normal sonographic findings of both kidneys and bladder (61 male, 9 female, age range 12-60 years, mean age 32.8 years) were evaluated with simultaneous color Doppler and duplex Doppler ultrasound. The study was performed in Gilani Ultrasound Center, Firozpur road, Lahore. Patients with ureteral stent, renal transplant, recent surgery, UTI, bladder outlet obstruction, neurogenic bladder, stricture, pelvic organ prolapse, duplex system or VUR which can affect mean peak velocity of jets were excluded from the study. Ureteric jets were evaluated using Toshiba (xario) with convex transducer, frequency range 3-6 MHZ with color, power and pulsed Doppler. All the participants were scanned in supine position and the bladder was visualized in the transverse plane to simultaneously evaluate the left and right ureteral orifices at the level of trigone and color Doppler ultrasound was applied to visualize the ureteral jets. Low wall filter was used, as well as the low pulse repetition frequency. Prior to ultrasound examination the patients were well hydrated until the bladder was moderately full. The bladder was evaluated for a maximum of 5 minutes period. Flow towards the transducer was assigned a red color. To optimize visualization of ureteral jets, 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°. To obtain the peak velocity of urine jet, the Doppler cursor was adjusted near the ureteral orifice. The location of the colour signal of the jet was found by trial and error. After the colour signals were found, both colour and simultaneous Doppler waveform of the jet from the orifice were obtained from each side in turn. For each subject, three consecutive waveforms were obtained for mean peak velocity measurement. All ureteric units were then categorized into two groups based on the presence or absence of ureteral stone. Group-I consisted of normal ureters (total of 105 ureteric units, 70 ureters in health subjects and 35 normal ureters in patients on contralateral normal side) and Group-II consisted of obstructed ureters (35 ureteric units). The collected data were recorded and analyzed on excel sheets and SPSS version 24.0. Results were presented in the form of mean ± S.D and percentages.

RESULTS:

In both healthy subjects and patients ureteral jets were visualized in the urinary bladder in at least one side during 5 minutes of observation. In Group-II, the stone was located in proximal ureter, mid ureter, distal ureter, PUJ and VUJ in 4 (11.42%), 6 (17.14%), 4 (11.42%), 7 (20%) and 14 (40%) cases respectively (figure 1) with size ranging from 5 to 16.7mm (mean 9mm) (table 4). In Group-II, hydronephrosis was present in 34 (97.14%) cases, 17 (48.57%) left sided and 17 (48.57%) right sided, and absent in 1(2.85%) case (figure 2). On obstructed sides, jets were visualized in 24 (68.57%) cases and not seen in 11 (31.42%) cases. In Group-I, the jets were visualized in almost all ureteric units (100%). In Group-I, the jet velocity varied from 23.16 to 86.83 cm/ sec (mean 50.89cm/ sec), while in Group-II, the jet velocity varied from 0 to 71.8cm/ sec (mean 15.8cm/ sec) (table 5, figure 3). In one patient with 10.2mm VUJ stone, there was no hydronephrosis and the jet velocity was higher on the obstructed side from that of the contralateral normal side. In three other patients with 8.5 and 8mm mid ureteric stone and 5mm VUJ stone, there was no significant variation in jet velocity between obstructed and nonobstructed sides. The velocity of jets was asymmetric between obstructed and unobstructed sides in 32 (91.42%) cases and symmetric in 3 (8.57%) cases. When compared with contralateral normal side and healthy subjects, the jet in the obstructed side showed reduced velocity (15.8cm/s vs. 50.89cm/s) as shown in figure 4 (b). The mean jet velocities of both sides were nearly similar in health subjects as shown in figure 5 (a & b).

Table 1: Age wise distribution

Descriptive Statistics					
Age (Year)	N	Minimum	Maximum	Mean	Std. Deviation
	75	12	60	32.8	12.75

Table 2: Gender wise distribution

Gender		
Gender	Frequency	Percent
Female	9	12.85
Male	61	87.14
Total	70	100

Table 3: Right & Left ureteric stone

Right & Left Ureteric Stone		
Ureteric stone	Frequency	Percent
Right	17	48.57
Left	18	51.42
Total	35	100

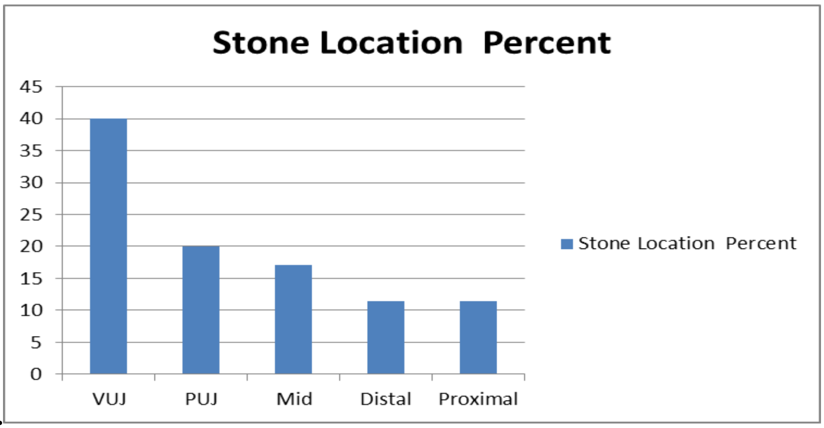

Figure 1: Stone location

Table 4: Stone size

	Minimum	Maximum	Mean	Std. Deviation
Size of stone (mm)	5	16.7	9.08	3.10

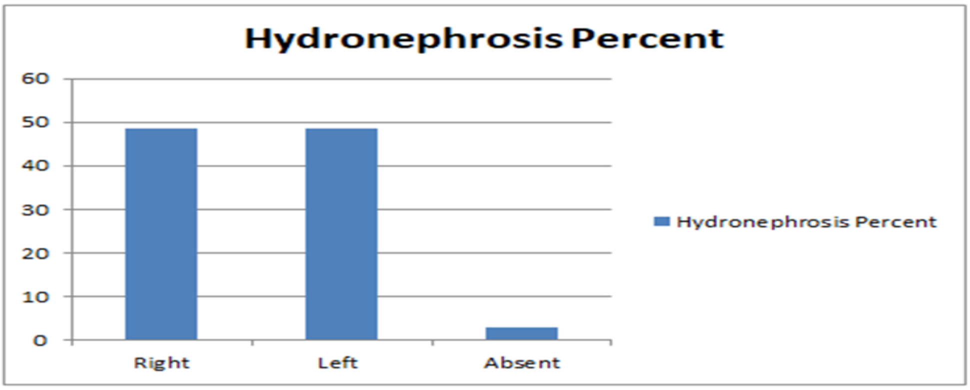

Figure 2: Hydronephrosis

Table 5: Jet Velocity in obstructed & normal ureters (Total ureters = 140)

Descriptive Statistics					
Ureters	**Total No**	**Minimum Jet Velocity (cm/ sec)**	**Maximum Jet Velocity (cm/ sec)**	**Mean Jet Velocity (cm/ sec)**	**Std. Deviation**
Obstructed Ureters	35	0	71.8	15.8	16.71
Nonobstructed Ureters (Controls + Contralateral Normal)	105	23.16	86.83	50.89	14.31

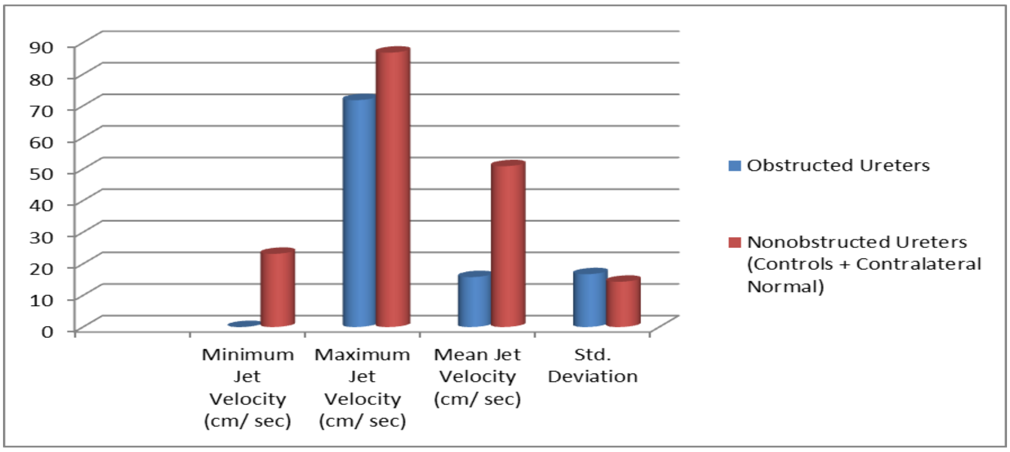

Figure 3: Jet velocity in obstructed and normal ureters

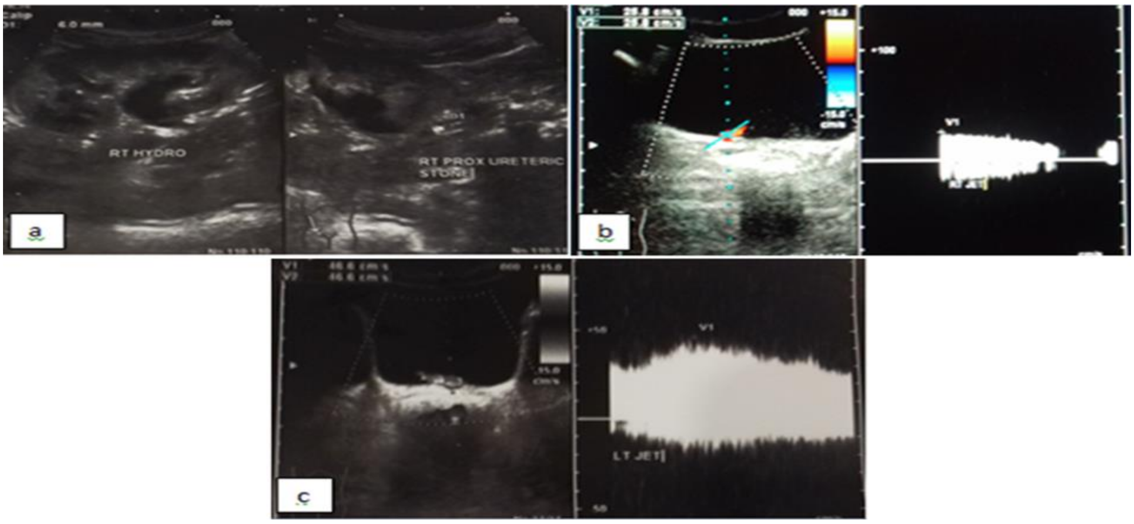

Figure 4: 12 years old male patient with right hydronephrosis due to 6mm proximal ureteral stone (a), both ureteral jets are visualized, right mean jet velocity is 24.6 cm/ sec (b), left mean jet velocity is 45.6cm/ sec (c). There is significant asymmetry in jet velocity between obstructed and nonobstructed side with relatively reduced jet velocity on obstructed side.

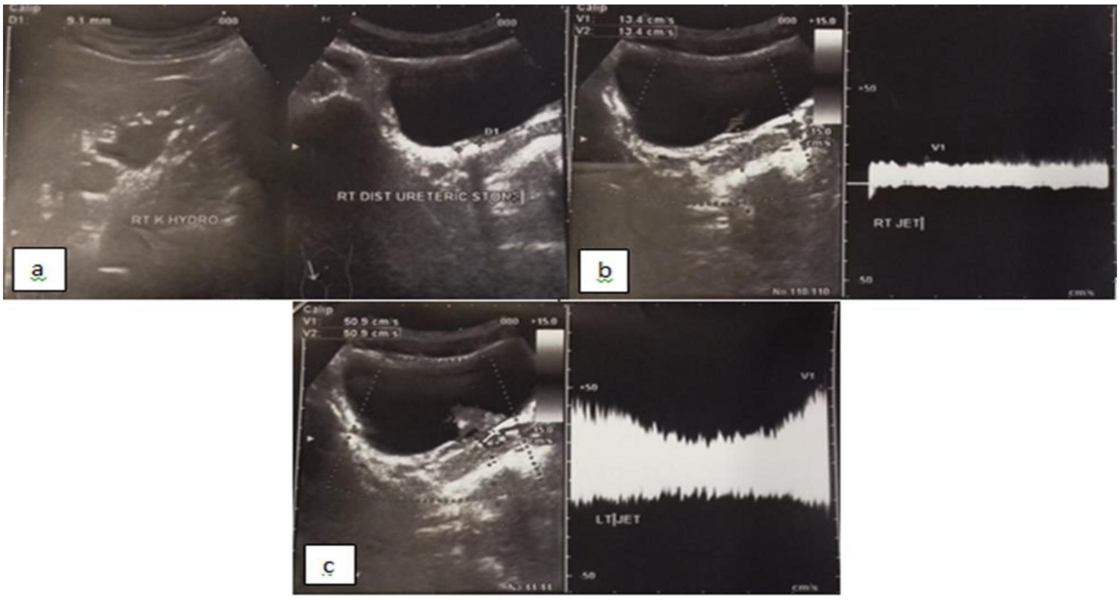

Figure 5: 22 years old male patient with right hydronephrosis due to 9.1mm distal ureteral stone (a), both ureteral jets are visualized, right mean jet velocity is 13.3cm/ sec (b), left mean jet velocity is 50.8cm/ sec (c). There is significant asymmetry in jet velocity between obstructed and nonobstructed side with relatively reduced velocity on obstructed side.

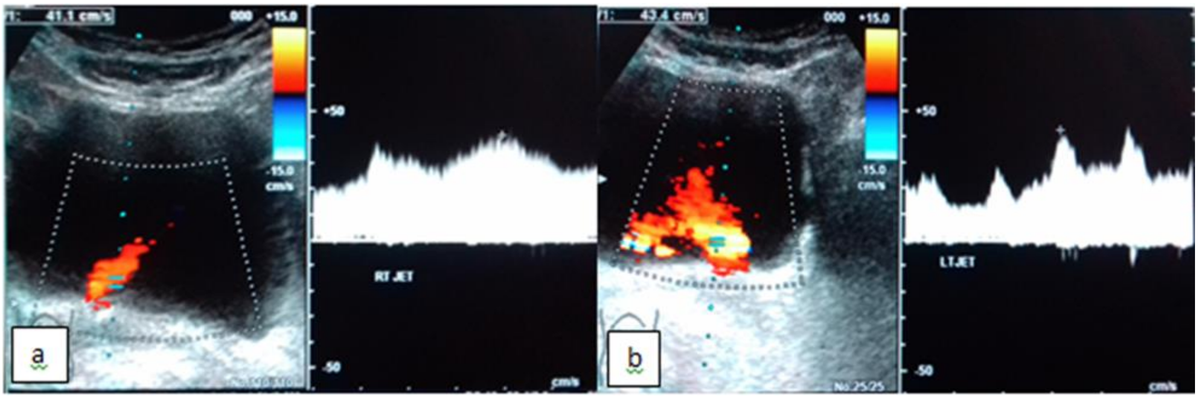

Figure 6: Normal right (41.1 cm/s) and left jet velocity in 52 years female

DISCUSSION:

This research was designed to provide an indirect, alternative and a safe method for the diagnosis of ureteric obstruction. The results of my study were comparable with the result of the research conducted by H. Ciftci *et al.*, (2017), 2010. The purpose of this study was 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. The outcome of this study demonstrated that 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 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 nonobstructed ureter was significant ($P < 0.05$). Although assessment of ureteric jet velocity can provide important information regarding ureteric obstruction, only one parameter of jet dynamics is not sufficient to determine the severity of ureteric obstruction, we have to consider all jet dynamics including velocity, frequency and duration of jet and there is need of further study over all these parameters. No specific value of jet velocity can be fixed to show obstruction, as considered by some authors, in spite the symmetry of jet is an important tool to consider. This is because in our study we observed one patient with ureteric stone but with very high jet velocity compared to normal contralateral side. Recent hydration is also an important factor in jet dynamics because we observed that when the patient was already hydrated 4-5 hours before the examination, fewer jets or even no jet is observed during 5 minutes observation in normal subjects. In contrast, with recent hydration we observed increased jet frequency and strength.

CONCLUSION:

Asymmetric ureteric jet velocity is a useful indicator of ureteric obstruction. The severity of ureteric obstruction can be determined by evaluating all jet dynamics including velocity, duration and frequency.

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