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Ureteral Jet Flow Angle: An Ultrasonographic Diagnostic Tool in Vesicoureteral Reflux in Children

Üreteral Jet Akım Açısı: Çocuklarda Vezikoüreteral Reflüde Ultrasonografik Tanısal Araç

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Özet

Amaç: Vezikoüreteral reflü (VUR) çocukluk çağında en sık görülen üriner sistem anomalisidir. Tanısında altın standart yöntem voiding sistoüretrografi (VSÜG)'dir. Fakat bu yöntem invazivdir ve kontrast madde kullanımı gerektirir. Çalışmamızın amacı çocuklarda VUR tanısı koymada renkli Doppler ultrasonda belirlenen üreteral jet akım açısının noninvazif bir yöntem olarak tanısal değerini araştırmaktır. **Materyal-Metot:** Bu prospektif kohort çalışmasında VUR tanısını doğrulamak için işeme sistoürografisi planlanan 63 pediyatrik olgu değerlendirildi. Her iki tarafta VUR tespit edilmeyen hastalar kontrol grubu (n=32), en azından tek tarafta VUR tespit edilen hastalar ise VUR grubu (n=31) olarak çalışmaya dahil edilmiştir. Tüm hastalara VSÜG ve Doppler ultrason ile üreteral jet akım açısı ölçümü yapıldı. Başlangıç tanımlayıcı verileri ve üreteral jet akış açıları karşılaştırıldı. **Bulgular:** VUR ve kontrol grupları arasında yaş (p=0,278), cinsiyet (p=0,898) ve mesane volümü (p=0,211) açısından anlamlı bir farklılık yoktu. Üreteral jet akım açısı VUR grubunda hem sağ tarafta (p=0,001) hem de sol tarafta (p<0,001) kontrol grubuyla karşılaştırıldığında daha yüksekti. **Sonuç:** Üreteral jet akım açısı, VUR tanısı konmasına yardımcı olabilecek ipuçları sağlayabilmektedir. Bununla birlikte, bu yeni sonografik belirteci doğrulamak ve geçerliliğini onaylamak için daha geniş serilerde ve daha fazla çok merkezli çalışmaların yürütülmesine ihtiyaç bulunmaktadır.

Anahtar Kelimeler: Vezikoüreteral reflü, ultrason, üreteral jet akım açısı, işeme sistoürografisi.

Abstract

Objective: Vesicoureteral reflux (VUR) is the most common urinary system anomaly in childhood. The gold standard method in diagnosis is voiding cystourethrography (VCUG). However, this method is invasive and requires the use of contrast media. The aim of our study is to investigate the diagnostic value of the ureteral jet flow angle determined in color Doppler ultrasound as a noninvasive method in diagnosing VUR in children. **Material-Method:** In this prospective cohort study, 63 pediatric cases scheduled for VCUG were evaluated to confirm the diagnosis of VUR. Patients not having VUR on both sides included in the control group (n=32), while patients with VUR at least on one side formed the VUR group (n=31). VCUG and ureteral jet flow angle measurement with Doppler ultrasound were performed in all patients. Baseline descriptive data and ureteral jet flow angles were compared. **Results:** There was no significant difference between VUR and control groups in terms of age (p=0.287), gender (p=0.889), and bladder volume (p=0.211). Ureteral jet flow angle was higher in the VUR group on the right side (p=0.001) and on the left side (p<0.001) compared to the control group. **Conclusion:** Ureteral jet flow angle can provide clues that can help diagnose VUR. However, more multicenter studies are needed to confirm this new sonographic marker's validity.

Keywords: Vesicoureteral reflux, ultrasonography, ureteral jet flow angle, voiding cystourethrography.

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Introduction

Vesicoureteral reflux (VUR) is the most common urological anomaly in childhood (1). VUR is described as the retrograde flow of urine from the urinary bladder to upper urinary tract, and it constitutes an important risk factor for the occurrence of urinary tract infections (2). VUR is observed in approximately 40% of patients with acute pyelonephritis. Untreated VUR plays a role in 5-40% of children under the age of 16 who have chronic kidney failure; and in 5-20% of adults over 50 years old (2).

Voiding cystourethrography (VCUG) is the gold standard method in the diagnosis of VUR and provides anatomical information about the bladder, ureters and urethra (3). VCUG is a pediatric uroradiological test, based on the filling of the empty bladder with radio-opaque contrast medium (4). Detailed anatomy of the bladder and urethra can be traced, especially the ureters in which the reflux is monitored. VCUG has an invasive nature since it calls for urethral catheterization. It also contains ionizing radiation and requires the use of non-ionic contrast media (5). In diagnosing VUR among children, the diagnostic precision of contrast-enhanced ultrasonography (US) is similar to VCUG, particularly in younger children and for high-grade VUR (6). Both methods involve catheterization, but safety profile of contrast-enhanced US is much better, and it has absence of radiation (7). Nevertheless, when contrast-enhanced US is being used, the operator dependence and technical expertise requirements of this method should be considered. Owing to the limited availability of the contrast medium, its cost, and required expertise by the radiologist, applying contrast-enhanced US as the universal standard for detecting VUR is arguable. For these reasons, noninvasive, contrast-free, and radiation-free methods are needed to diagnose VUR.

In the present study, we defined the angle between the bladder base and jet flow as the ureteral jet flow angle and assumed that the ureteral jet flow was perpendicular to the bladder in patients with VUR. Ureteral jet flow angle can be easily measured on color Doppler ultrasound and can have significant diagnostic value as a practical and noninvasive method in the diagnosis of VUR. The aim of the study was to investigate the diagnostic value of the ureteral jet flow angle displayed on Doppler ultrasound as an alternative to VCUG as a noninvasive method in the diagnosis of VUR.

Material and Methods

Study design: This prospective cohort study was conducted in the pediatric surgery and radiology departments of a tertiary health care center following the approval of the local institutional review board (dated: 11.03.2015, no: 73799008). Adherence to the principles announced in the revised version of Helsinki Declaration was provided. The study population consisted of 63 pediatric cases who were scheduled for voiding cystourethrography to confirm the diagnosis of VUR. As a result of the VCUG examination, two study groups were compared. Control group consisted 32 patients (15 boys, 17 girls) without VUR on either side (n=32); while VUR group consisted 31 patients (14 boys, 17 girls) with VUR on at least one side (n=31).

Outcome parameters: Radiologically, ureteral jet flow angles were measured and noted. The relationship between VCUG results and ureteral jet flow angles was determined. Urinary bladder capacity (ml) was calculated according to the formula developed by Koff et al. (8) as (age (years) + 2) X 30. Baseline descriptive data including age, gender and body-mass index were recorded. VCUG results were assigned as positive and negative for diagnosis of VUR.

Voiding cystourethrography: After administration of the indwelling catheter, normal saline solution and the iodinated contrast medium namely, Iohexol (Omnipaque 300, Schering, Berlin, Germany) were gradually introduced to the emptied bladder under fluoroscopic monitoring. Standard VCUG was done with intermittent fluoroscopy and spot-film documentation.

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Measurement of VUR angle: A 5 mHz convex probe (Toshiba Aplio, XV model, Japan) was used for ultrasonographic examination. The cases were well hydrated and then examined in the supine position for about 5-10 minutes. Following the adjustment of the appropriate imaging parameters (including focus, depth and B-modal tone), jet flows detected for at least 10 minutes were used to identify the sites of orifices under grey scale. Images were frozen on visualization of ureteral jet flows bilaterally. At this point, angles were measured at ureterovesical orifices. The angle between the trace of jet flow and the basal line which passes through the base of the full urinary bladder was measured (Figures 1 and 2). Since the vesicoureteral jet flows on both sides are not identical in the majority of cases, the images were frozen upon identification of distinct jet flows on right and left sides. On the axial plane, intersection of jet flow axis and the axis at the base of the urinary bladder was taken into account at the level of ureterovesical orifices for measurement of the narrow angle medially. Following the selection of optimal grey scale parameters, images were captured at the point where physiological urethrovesical jet flows are observed. On this view, baseline angular plane is drawn at the site of orifices on the base of urinary bladder. Another straight line which passes through the linear image of physiological jet flow at the orifice is plotted. The intersection of these 2 lines at the ureterovesical orifice constitutes the ureterovesical or VUR angle.

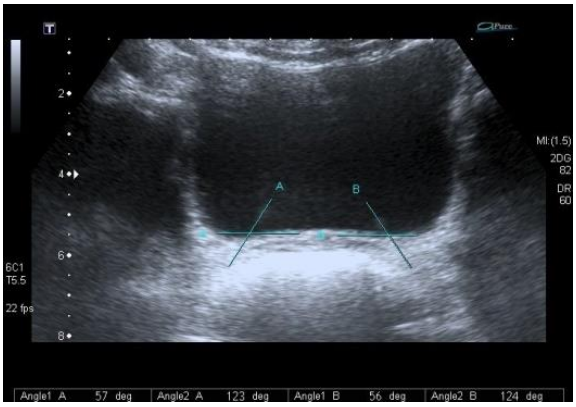

Figure 1. US measurements and images in voiding cystourethrography of 10-year-old female patient in the control group with physiological ureter jet flow angles.

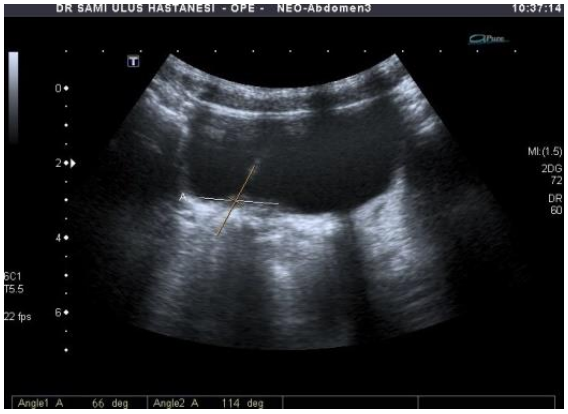

Figure 2. A 7-year-old girl with stage 4 VUR detected on the left side after voiding cystourethrography, the physiological ureteral jet flow angle was measured on the right, but on the left side normal jet flow image could not be obtained because the physiological flow was disrupted on this side.

Statistical analysis: Our data was analyzed with IBM Statistical Package for Social Sciences Statistics 20 software (SPSS Inc., Chicago, IL, USA). In order to evaluate the normal distribution of variables, Kolmogorov Smirnov test was applied. Parametric tests were employed for variables with normal distribution, while non-parametric tests were administered for variables without normal distribution. To compare 2 independent groups, Independent-Samples T test (parametric test) and Mann Whitney U test (non-parametric test) were applied. Pearson chi square test was utilized for the assessment of categorical variables. Quantitative variables were described with mean, median, standard deviation

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and interquartile range measures. Confidence interval was 95% and level of significance was set at p values less than 0.05.

Results

Thirty-four cases were female and 29 were male. The mean age of all patients was 9.79±3.83 (range, 4-16) years. Patients who did not have VUR on both sides were included in this study as the control group (n=32), and patients with VUR at least on one side were included as the VUR group (n=31). Descriptive and radiological data of the patients in the VUR and control groups are presented in Table 1. No significant difference was found between VUR and control groups regarding age (p=0.278) and gender (p=0.898) distribution. Body mass index was significantly lower in the VUR group in comparison with the control group (p=0.014). There was no significant difference between VUR and control groups in terms of bladder volume (p=0.211) (Table 1).

Table 1. Baseline descriptives and ultrasonographic data in vesicoureteral reflux patients and the control group

Variable	VUR Group (n=31)	Control Group (n=32)	p
Gender distribution (M/F)	14/17	15/17	0.898
Age (years)	10.3±3.8	9.3±3.8	0.278
Body-mass index (kg/m²)	21.00±3.10	19.27±2.22	**0.014***
Urinary bladder volume (ml)	382.6±108.4	347.3±113.3	0.211

(Abbreviations: *: statistically significant; M: male; F: female)

In 31 patients with vesicoureteral reflux, reflux was detected on both sides in 1, on the right side in 8 and on the left side in 11 patients. A total of 43 kidneys were diagnosed with VUR. VUR grades in 43 kidneys diagnosed with VUR were as follows: Grade 1, n=18; Grade 2, n=13; Grade 3, n=7: Grade 4, n=3 patients, and Grade 5, n=2.

In the comparison of patients diagnosed with VUR based on voiding cystourethrography measurements with control group patients, the mean ureteral jet flow angles on the right side in the VUR, and the control groups were 18.40°±6.64° and 35.70°±6.97°, respectively (p<0.001) in the control group and VUR. While the mean ureteral jet flow angle on the left side in the VUR, and control groups were 19.90°±3.98° and 35.00°±4.88°, respectively (p<0.001) (Table 2).

Table 2. Comparison of ureteral jet flow angles on right and left sides in cases with positive and negative voiding cystourethrography results

Ureteral jet flow angle	Voiding cystourethrography	Mean value	p
Right	**Negative**	35.70°±6.97°	**<0.001***
	Positive	18.40°±6.64°	
Left	**Negative**	35.00°±4.88°	**<0.001***
	Positive	19.90°±3.98°	

(Abbreviations: *: statistically significant)

Discussion

Studies are underway to reveal less invasive methods than VCUG in the diagnosis of vesicoureteral reflux. In the present study, we aimed to investigate the diagnostic value of the ureteral jet flow angle as a noninvasive method in diagnosing VUR in children. According to the results of our study, ureteral jet flow angle can provide clues that can help diagnose VUR.

Grading of VUR is critical since children with early renal abnormalities related with reflux may lead to deterioration of renal function (9). Utilization of novel sonographic markers such as VUR angle may alert the physician for early diagnosis and performance of timely treatment regimen. Analysis of the correlation between the degree of VUR disease and the angle should be investigated in further trials. In the diagnosis of VUR in children, previous publications indicated the reliability of color flow Doppler sonography (10). There is controversial data on the link between different levels of renal collecting system dilatation and VUR (3,10).

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Asanuma et al. (11) proposed that color Doppler ultrasound evaluation of ureteral jet angle could be used to detect VUR in children. They reported that this practical and noninvasive tool could be used for screening particularly high-grade reflux. Interestingly, a cutoff angle of 70° or greater was associated with grade IV or V reflux (11). Even though our findings support that VUR angle can be a useful tool for screening of VUR in children; we noted that there was an inverse relationship between presence of VUR and VUR angle. The decrease in VUR angle in patients with VUR may be attributed to the fact that jet flow velocity is supposed to decline in the presence of reflux. This data is controversial to the publication by Asanuma et al. (11), but it must be remembered that our sample size was smaller, and we did not classify the patients according to the grade of VUR disease. In contrast to our results, Mahant et al. (12) suggested that ultrasonography was not predictive of VUR on VCUG. According to their data, some cases with high grade VUR by VCUG could not be diagnosed with renal ultrasound. They concluded that clinicians should not utilize renal ultrasound results for establishing the diagnosis of VUR (12).

It has been reported that moderate to severe renal scarring is linked with grade IV and V VUR. The prevalence of renal scarring was found to be remarkably lower in infants in whom high grade VUR is determined by means of screening prior to the occurrence of urinary tract infection. Therefore, early detection could avoid renal parenchymal scarring due to urinary tract infections (10).

It must be remembered that our preliminary results are important since they encourage investigation of the significance of VUR angle in children suspected for VUR. Its diagnostic accuracy, validation of results and relationship between the degree of disease and VUR angle should be investigated in further trials. Other restrictions of this study involve small sample size and data limited to the experience of a single institution. On the other hand, we suggest that VUR angle can be a promising clue for diagnosis of VUR in children and may provide a safer non-radiation diagnostic measure in evaluation of kidneys for changes attributed to VUR.

Vesicoureteral reflux disease has a multifactorial nature and early diagnosis is crucial to avoid deterioration of renal function. Our preliminary results yielded that VUR angle, which is defined as the angle between the trace of jet flow and the basal line passing through the base of the full urinary bladder, may serve as a practical and reliable marker which avoids the use of unnecessary imaging modalities. To conclude, assessment of VUR angle during ultrasonography may provide useful clues which may aid in diagnosis of VUR. However, further multicentric trials on larger series should be carried out to confirm and validate this novel sonographic parameter.

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