RESEARCH ARTICLE

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Diagnostic accuracy of kidney shear wave elastography at the diagnosis of ureteral stones

Üreter taşlarının tanısında böbrek shear wave elastografinin tanısal doğruluğunun araştırması

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ABSTRACT

Aim: To determine the efficacy of kidney shear wave elastography (SWE) in patients diagnosed with ureteral stones
Method: Both kidneys of 30 patients were evaluated prospectively with SWE. The ureteral stone size and the degree of hydronephrosis were determined by sonographic examination. The contralateral kidney was accepted as the control parameter. Stone size, grade of hydronephrosis and kidney shear wave speed changes were noted and their relations were examined for statistical significance.
Results: Affected kidney group had significantly increased SWE values than the control group. (3.87+-1.22 vs 2.06+-0.72 m/sec) (p=0.01). Neither the stone size nor the kidney SWE values showed a correlation with the gender. There was a positive correlation between the grade of hydronephrosis and the stone size (p=0.047, r=0,36). Kidneys with grade 2 hydronephrosis had significantly higher SWE values than those with grade 1 hydronephrosis.
Conclusion: SWE is a promising tool to observe the parenchymal elasticity changes in patients with hydronephrosis secondary to ureteral stones. Further studies are necessary to confirm the research results.

Key words: elasticity imaging techniques, ureterolithiasis

ÖZ

Amaç: Üreter taşı olan hastalarda böbrek shear wave elastografi (SWE) incelemenin tanısal etkinliğinin değerlendirilmesi.
Metot: 30 hastanın her iki böbreği prospektif olarak SWE ile incelendi. Üreter taşı boyutu ve hidronefroz derecesi ultrasonografi incelemesi ile değerlendirildi. Karşı taraf normal böbrek kontrol grubu olarak değerlendirildi. Üreter taşı boyutu, hidronefrozun derecesi ve böbrek shear wave hızındaki değişiklikler not edildi ve aralarındaki ilişkiler istatiksel anlamlılık açısından incelendi.
Bulgular: Üreter taşından etkilenen böbrek SWE değerlerinde normal böbrek ile karşılaştırıldığında anlamlı artış mevcuttur (3.87+-1.22 vs 2.06+-0.72 m/sec) (p=0.01). Cinsiyet ile üreter taşı boyutu arasında ve SWE değerleri arasında korelasyon yoktur. Hidronefroz derecesi ile ureter taşı boyutu arasında pozitif korelasyon saptandı (p=0.047, r=0,36). İkinci derece ve üstünde hidronefroz saptanan böbreklerde SWE değerleri grade 1 olanlara göre daha fazladır.
Sonuç: Üreter taşına bağlı hidronefrozu olan hastalarda böbrek parankim elastisitesindeki değişiklikleri değerlerndirmede SWE gelecek vadeden bir yöntemdir. Gelecek çalışmalar sonuçlarımızı netleştirecektir.

Anahtar kelimeler: Kesme, dalga, elastografi, ureter, taş

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Introduction

Ureteral stones, over 5 mm, usually cause hydronephrosis. They can be painless or may present with colic-like pain extending from the flank to the groin, which is more often in stones that cause obstruction [1]. Early management of ureteral stones allows immediate relief of the patient's symptoms and early return to normal life. Kidney functions are better preserved with an early diagnosis [2]. Ultrasonography is a safe and sensitive imaging method for detecting ureteral stones, especially in pregnant women and children. Ultrasound imaging has high specificity (81%) and sensitivity (100%) in detecting renal stones and hydronephrosis but it has low sensitivity (46%) in detecting ureteral stones and this is an important drawback. Non-contrast CT is the gold standard imaging examination in the diagnosis of ureteral stones [3]. A fast, efficient and safe non-invasive method to support ultrasonographic findings in the detection of ureteral stones would be beneficial.

Ultrasound elastography (UE) is a growing alternative method for assessing the elastic tissues in recent years, which has already been demonstrated in the liver [4]. Ultrasound elastography of the kidney has also shown satisfactory results. However, the kidney is a more complex organ than the liver. In contrast to the liver, the kidney consists of two separate compartments which cause inhomogeneity. High vascularity is another difficult characteristic of the kidney [5]. Two-dimensional (2D) shear wave elastography (SWE) is the most recent elastography technique that uses acoustic radiation force and the main advantages are real-time visualization of a color quantitative elastogram, superimposed on a gray scale image, and it reveals tissue stiffness in numeric information simultaneously with the provided anatomical information [6-7].

Ureteral stones may cause ureteral obstruction, leading to urinary pressure elevation, which may be responsible for elasticity changes. The aim of the present study was to analyze the role of point shear wave elastography in patients with ureteral stones and to identify the factors affecting the kidney shear wave speed.

Material and method

Patients

The study was launched on July 3, 2020 at Izmir University of Economics Radiology Department and the study was approved by the local ethics committee (Izmir University of Economics B.30.2.İEÜSB.0.05.05-20-095). It was conducted in accordance with the Helsinki Declaration of 1975. All patients signed an informed consent; we collected thirty patients’ data after the ethical committee approval and the study concluded January 6, 2021.

Thirty patients with ureteral stones detected with initial ultrasound were included in our prospective case-control study. The patients suspected of having ureteral stones were first examined by the urology clinic and their laboratory tests were evaluated. The presence of stones was confirmed by second Ultrasound imaging. The stone size and the degree of dilatation of the collecting system detected in ultrasonography were noted. All thirty patients with demonstrated ureteral stones were shown with Ultrasonography to have unilateral ureteral stones; their contralateral kidney and collecting system were normal. Contralateral kidney had to be within normal limits, whereas exclusion criteria were bilateral ureteral stones, renal stones, vesicoureteral reflux disease and other causes of postrenal obstruction of contralateral normal kidney. Further exclusion criteria included that both kidneys should not have stones and no history of ureterolithiasis or parenchymal disease.

All ureteral stones were clearly visible with the ultrasound imaging. We did not use CT imaging as a complimentary test for any of patients. The initial ultrasound was not noted and was performed by different radiologist. The present study’s corresponding author did the second ultrasound examination, UE and recorded for the study.

Ultrasound examination

Ultrasound examinations and ultrasound elastography were performed in each subject, on the same day. The presence and grade of hydronephrosis were evaluated with the radiological grading system as follows: Grade 0: no dilatation, calyceal walls are opposed to each other; Grade 1: only the renal pelvis is visible and the renal pelvis anterior-posterior diameter: 5-7 mm; Grade 2: some calyces visible, AP diameter: 7-10 mm; Grade 3: marked dilation of calyces and AP diameter: >10 mm; Grade 4: narrowing parenchyma; Grade 5: extreme hydronephrosis with only a thin, membrane-like renal parenchyma) [8]. The location of the ureteral stone and its size, kidney length and parenchymal thickness was recorded.

Ultrasound Elastography examination

SWE was performed in all patients with the Aplio 500 series ultrasound system and Acoustic Structure QuantificationTM (ASQ) software by Toshiba. This system enables real-time visualization of a color quantitative elastogram superimposed on a grayscale image (Fig. 1). We used convex array probe (1–6 MHz) for all patients.

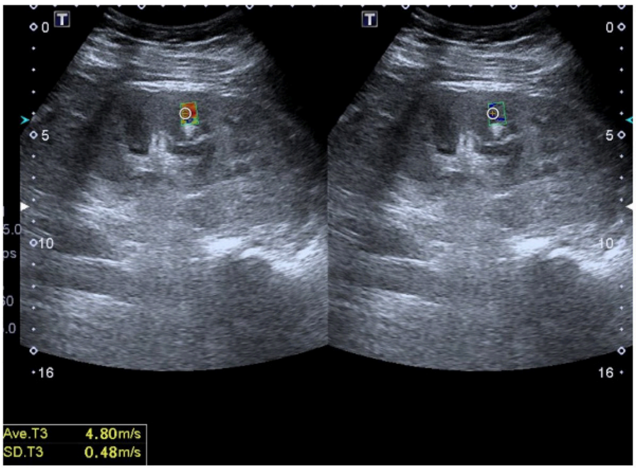

Figure 1. Two-dimensional (2D) shear wave elastography (SWE) images of a patient with long axis of normal kidney (contralateral side) real-time visualization of a color quantitative elastogram superimposed on a gray scale image and it reveals normal calyceal system without dilatation. Tissue stiffness in numeric information SWE values calculated from the region of interest (10 mm x 10 mm square) was placed on the superficial area in the mid-portion of the kidney cortex.

The lateral decubitus position and breath control (during the SWE imaging) were executed to reduce the motion artefacts. The region of interest (10 mm x 10 mm square) was placed on the superficial area in the mid-portion of the kidney cortex (renal medulla was not included as much as possible) and we used the long axis of kidney for ultrasound examination (Fig. 2). The UE was performed without pressure. In all patients, three different ASQ shear wave elastography sequences were aimed and eight measurements from different parts of the range of interest box were collected. The median elastography values (meters/second (m/sec)) were calculated for each kidney.

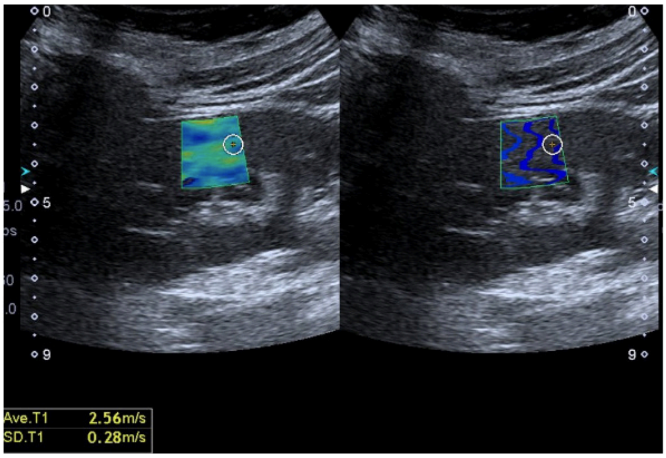

Figure 2. Two-dimensional (2D) shear wave elastography (SWE) images of a patient with long axis of kidney (ureteral stone side) real-time visualization of a color quantitative elastogram superimposed on a gray scale image and it reveals grade 1 hydronephrosis. Tissue stiffness in numeric information SWE values was calculated from the region of interest (10 mm x 10 mm square) placed on the superficial area in the mid-portion of the kidney cortex.

Statistical Analysis

The statistical package program (SPPS 25, IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used to evaluate the data. Mean and median values, standard deviation, maximum, minimum, number and percentiles were calculated (for the continuous and categorical variables). Homogeneity of the variances was checked with the Levene test. The normality assumption was examined with the "Shapiro-Wilk" test. "Student's T Test" was used when the parametric test met its prerequisites, and if it did not, we used "Mann Whitney-U test". Relationship between two continuous variables were interpreted with the Pearson Correlation Coefficient. The Spearman Correlation Coefficient was used if the parametric test did not meet the prerequisites. The relationships between the categorical variables were analyzed using the Chi-Square test and Fisher's Exact Test. A p level of <0.05 and <0.01 were accepted as statistically significant.

Results

Twelve female and eighteen male patients aged 24 to 57 (mean 40.8 +- 10,9 years) were included in the study. Twenty-one patients had grade 1 hydronephrosis and nine patients had grade 2 hydronephrosis. Seventeen patients had left sided renal pathology and thirteen had right sided pathology. There was no significant difference between the groups with regard to the gender and age (p=0.28).

The mean stone size was 6.2 mm ± 1.9 mm (3.2-11mm). The mean SWE value for the pathologic kidney was 3.8±1.2 (2.2-6.2) m/sec and the normal side was 2,06 (0,7-3,3) m/sec. Gender and side of the ureter stone did not significantly affect stone size and SWE (Table 1).

Table-1. Comparison of SWE values of Kidneys of Affected Side and Stone Size Variables

	Left n=17	Right n=13	Test Statistic	P value
Pathological Side of Kidney	3,85±1,20	3,82±1,32	0,079	0,938*
Stone size	6,30±2,41	6,11±1,34	-0,222	0,825**

* Two Independent Group T test (Student's t test), € Mann Whitney-U test

The mean SWE value was found to be 3.87 m/sec on the affected kidney, while the mean SWE value was 2.065 m/sec on the normal side. The kidney on the affected side had a statically significant increase in the SWE values than the normal side (3.87±1.22 vs 2.06±0.72 m/sec) (p=0.01).

There was a statistically significant difference between grade of hydronephrosis and SWE values (p<0.05). The mean SWE value of the patients with Grade 2 hydronephrosis was significantly higher than that of Grade 1.

There was a statistically significant difference between grade of hydronephrosis and stone size (p<0.05). The mean stone size detected in the patients with Grade 2 hydronephrosis was significantly higher than that of Grade 1 (Table 2).

Table-2. Comparison of Hydronephrosis Grade with SWE and stone size variables

	Female n=12	Male n=18	Test Statistic	P value
Gender	4,08±1,17	3,74±1,27	-0,868	0,385*
Stone size	6,52±2,14	5,96±1,90	0,756	0,456**

* Two Independent Group T test (Student's t test), € Mann Whitney-U test

There was a significant positive correlation of 45.4% between SWE and grade of hydronephrosis. There was a significant positive correlation of 36.6% between the stone size and the grade of hydronephrosis (Table 3).

Table-3. Relationships between SWE and all variables

		SWE	Stone size	Age	Normal kidney SWE	Gender	Hydro-nephrosis Grade
Stone size	r	0,088					
	p	0,646					
	N	30					
Age	r	0,167	0,358				
	p	0,376	0,052				
	N	30	30				
Normal kidney SWE	r	0,335	-0,008	0,254			
	p	0,076	0,967	0,184			
	N	30	30	30			
Gender	r	-0,137	-0,141	-0,099	0,264		
	p	0,469	0,456	0,605	0,167		
	N	30	30	30	29		
Hydronephrosis Grade	r	0,454	0,366	0,278	0,290	-0,208	
	p	0,012	0,047	0,137	0,128	0,270	
	N	30	30	30	29	30	
Pathological Side of Kidney	r	-0,015	-0,046	0,071	0,149	-0,147	0,108
	p	0,938	0,814	0,715	0,442	0,447	0,577
	N	30	30	30	30	30	30

Discussion

Ureteral stones cause hydronephrosis and increased pressure in the pyelocalyceal system. Urinary pressure changes have an impact on the SWE values. In our prospective case-control study, we investigated the changes in the kidney shear wave speed secondary to ureter stones.

We found that the affected side had a statically significant increase in the SWE values than the normal side (p=0.01). To the best of our knowledge, our study is the first to assess the SWE values changes during ureteral stone and hydronephrosis and report in the English literature.

In an in vivo study on pigs, the relationship between renal elasticity and urinary pressure has been investigated. In this study, the gradual increase in pressure was simulated by injecting retrograde fluid from the ureter. As a result, a progressive increase in renal elasticity was observed with the elevation of urinary pressure, and the increase in elasticity was correlated to the increase in urinary pressure [9]. Similarly, in our study, a statistically significant increase in kidney elasticity was found in the kidneys with hydronephrosis. There was a positive correlation between increased hydronephrosis and increased SWE values. Patients with grade 2 hydronephrosis had higher parenchymal SWE values than patients with grade 1 hydronephrosis. We found a positive correlation between the stone size and hydronephrosis and have concluded that the larger the stone, the greater the increase in pressure, resulting in more hydronephrosis and an increase in renal elasticity (and SWE values). Increased elasticity due to increased urinary pressure should be considered when evaluating the transplanted kidney USG elastography. In many studies on transplanted kidneys, inconsistent results were more common than native kidney elastography studies [10]. In light of the results we have reached in our study, we think that the elasticity evaluations may be inconsistent in transplanted kidneys due to the short ureters and the higher reflection of the pressure of the full bladder, on kidney elasticity.

There are many studies investigating the relationship between reduced kidney elasticity and fibrosis. In one study, the SWE values were measured in patients with diabetes mellitus causing fibrosis, in order to predict chronic kidney disease. It was revealed that patients with diabetic kidney disease had a significantly lower kidney shear wave speed compared to patients without chronic kidney disease [11].

Similar to ours, the only study in which an increase in renal elasticity was found is the study examining the changes in SWE values after ESWL. In that study, the authors suggested that the increase was related to the acute inflammation due to the examination performed immediately after ESWL. The authors assumed that edema and inflammation after ESWL might be detected as an increase in SWE values [12]. We suggest that urinary retention may also occur immediately after ESWL and urinary pressure increases simultaneously with an increase in SWE values. We did not encounter any post ESWL procedure related hydronephrosis in our study.

This presented study which relates to renal shear wave elastography in patients with high ureteral pressure may be the first prospective study in the English literature as far as we could investigate.

Limitations: firstly, the study population was limited to thirty patients. A large cohort study would indicate better results for evaluation. Secondly, we did not have an adequate number of patients in the grade 3 and grade 4 hydronephrosis group. Evidently, the examination of patients with higher grade dilatation would be helpful to better understand the evaluation of renal parenchymal tissue damage. In addition, we aimed to diagnose patients in the adult age group: a research study group including the childhood age, such as vesicoureteral reflux, would be beneficial to the literature. Finally, we didn't include transplanted kidneys in our study group: evaluation of ureteral stenosis or ureteral stones with UE would be beneficial in this group, due to short length of the ureter.

Conclusion

SWE is a fast, accurate, accessible non-ionizing diagnostic tool to identify renal parenchymal tissue elasticity in the adult age group, and may be used for diagnosing ureteral stones.

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critical review. **BÖ (0000-0002-9471-7031):** İnterpretation, analysis, writing, critical review. **SS (0000-0001-5364-2398):** Practices, processing, literature search, writing.

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