Evaluation of effects of Extracorporeal Shock Wave Lithotripsy on renal vasculature with Doppler ultrasonography

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Abstract

Objectives: In this prospective study, we aimed to demonstrate the effects of Extracorporeal Shock Wave Lithotripsy (ESWL) on renal blood flow in patients treated for renal/ureteral stones. Material and methods: The study group comprised 41 patients (26 males, 15 females), aged between 18-63 years, mean age 45 years), 23 with renal and 18 with ureteral stones, who underwent ESWL between March 2010 and January 2011. Colour Doppler ultrasonography and pulsed wave spectral analysis was performed before, 1 hour, and 7 days after ESWL to both ipsilateral and contralateral kidneys in order to measure resistive index (RI), pulsatility index (PI) and acceleration time (AT) values. Results: One hour after ESWL, RI and PI values showed significant increase from pre-ESWL values in both ipsilateral and contralateral kidneys. However, no significant change was found in AT values. Seven days after ESWL, PI in both ipsilateral and contralateral kidneys and RI in contralateral kidney returned to pre-ESWL values. But, 7 days after ESWL, RI in the ipsilateral kidney did not return to pre-ESWL values, although decrease in RI values were observed. Conclusion: Spectral Doppler analysis can provide valuable information as a non-invasive method to assess the hemodynamic changes and renal microcirculation status in cases managed with ESWL. Keywords: color Doppler ultrasonography, Extracorporeal Shockwave Lithotripsy, kidney, ureter

Introduction

Extracorporeal shock wave lithotripsy (ESWL) has become a routine method for the treatment of upper urinary tract stone disease. Although its reliability and efficacy have been demonstrated, there are a number of studies concerning post-ESWL complications [1-4]. Many methods such as excretory urography (IVU), ultrasonography, computed tomography, magnetic resonance imaging, radionuclide renography, serum analysis and urine analysis have been employed in order to study the effects of ESWL on the kidneys [1-3,5]. There are also many studies in which the renal effects of ESWL using Doppler ultrasonography were investigated [6-10].

In this prospective study, we aimed to demonstrate the effects of ESWL on renal blood flow in patients treated for renal/ureteral stones. For this purpose, intrarenal arterial Doppler parameters such as resistivity index (RI), pulsatility index (PI) and acceleration time (AT) were measured and analyzed.

Materials and methods

The local Ethics Committee approved the study protocol, and written informed consents were obtained from all patients.

Patient Selection

The study group comprised 41 patients (26 males, 15 females), 23 with renal and 18 with ureteral stones, who underwent ESWL between March 2010 and January 2011. Their ages ranged from 18 to 63 years, with mean age of 45 years. Stone diameter ranged from 5 to 18 mm (mean 9.6 mm).
The stones were diagnosed by means of excretory urography (IVU), plain abdominal radiograph (KUB film) and ultrasonography. Patients with normal kidney function on IVU and normal parenchymal echogenicity on ultrasonography were included in the study. Patients with diabetes mellitus, renal parenchymal disease or urinary system infections were excluded. Patients with hypertension (diastolic blood pressure \( \geq 90 \text{ mmHg} \) and/or systolic blood pressure \( \geq 140 \text{ mmHg} \)) and patients receiving anti-hypertensive therapy were also excluded. Among patients with renal and ureteral stones, those with marked pyelectasis (dilation or distension of renal pelvis) or decreased cortical thickness were excluded in order to eliminate false changes in spectral Doppler parameters.

**Ultrasonography**

All examinations were performed by the same experienced radiologist (S.K.) and all ultrasound measurements were made by LOGIQ® 9 system (GE Healthcare, Milwaukee, Wisconsin, USA) equipped with a 3.5-Mhz convex-array transducer. The patients were given an ultrasound exam before and 1 hour and 7 days after ESWL separately.

Measurements were made in the ipsilateral and contralateral kidneys. The intrarenal vessels were then identified using color flow Doppler, and Doppler signals were obtained from interlobar arteries along the border of medullary pyramids. The Doppler sample width was set at 2–5 mm. The individual arteries were sampled while the patient held his or her breath. Recordings were obtained from at least three separate vessels in each kidney. To maximize the size of the Doppler spectrum and decrease the percentage error in the measurements, we selected a low frequency range setting (low pulse repetition frequency) and low wall filter (50 Hz). Evaluation included obtaining waveforms in the upper, mid aspect, and lower pole of the kidneys. Multiple Doppler waveforms were obtained from at least 3-5 vessels, and the values for each kidney were averaged. The angle correction cursor was adjusted parallel to the direction of flow and always less than 60°. This correction was performed in all spectral Doppler measurements. The resistive index (RI), pulsatility index (PI) and acceleration time (AT) values were recorded. Measurement of the RI and PI were performed with the use of online calculation software. RI was calculated as “(Peak Systolic Velocity [PSV]–minimum diastolic velocity)/PSV” from the Doppler spectral waveforms using the built-in software of the sonographic equipment. An average RI was calculated from all the RI values from each kidney. PI was calculated as “(PSV-End Diastolic Velocity)/ mean velocity”. An average PI was calculated from all the PI values from each kidney.

**ESWL**

ESWL was performed using a Multimed Classic™ (Elmed Electronics & Medical Industry & Trade Inc., Ankara, Turkey) lithotripter. The average number of shock waves per patient was 3000. The mean maximum voltage was 14.7 kV (±2.79).

Statistical analysis was undertaken using the Statistical Packa ge for Social Science (SPSS version 18.0, Chicago, Illinois. The definitive statistics for numerical variables were expressed in average ± standard deviation and those for categorial data were expressed in numbers and percentages. The conformity of the variables to normal distribution was assessed by means of Shapiro-Wilk test. The time dependent intergroup comparisons of the variables were performed using the Wilcoxon two sample test. For analysis of the differences between the groups with regard to variables, Mann-Whitney U test for two group-comparisons and Kruskal Wallis test for three group-comparisons were used. A 95% confidence interval was obtained when evaluating the results. Results were considered significant when the \( p \) value was <0.05 (fig 1).

**Results**

Colour Doppler ultrasonography was performed to a total of 82 kidneys (41 patients). In this group the ESWL was performed for renal stones in 23 patients and for ureteral stones in the remaining patients (12 patients – 66.6% – with proximal, 3 patients – 16.6% – with middle and 3 patients – 16.6% – with distal ureteral stones).

The mean RI, PI and AT for the two groups of patients are detailed in table I and II.

For the patients who underwent ESWL for renal stones, a comparison of the mean RI and PI, values for the ipsilateral side before ESWL and those 1 hour and 7 days after ESWL revealed a statistically significant difference (al \( p<0.05 \)). In the contralateral kidney RI and PI were sig-
significant different before and 1 hour after ESWL (p<0.05) but the significance disappeared 7 days after intervention (p>0.05). For both kidneys the AT values before and after ESWL were not significant different (p>0.05).

In patients with ureteral stones RI and PI values had significant differences before and 1 hour after ESWL in ESWL-applied and contralateral kidneys (al p<0.05) but the significance was not maintained in the 7th days (p>0.05). AT values were without significant difference before and after ESWL in both kidneys.

Seventeen (41.6%) patients had mild or moderate hydronephrosis. A comparison of the two groups (with and without hydronephrosis) did not reveal statistically significant differences when mean RI, PI and AT values obtained from ESWL-applied and contralateral sides were analyzed (al p>0.05).

**Discussion**

Duplex Doppler sonography allows a high-quality and noninvasive demonstration of renal blood flow as well as the measurement of flow parameters that may be a key for identifying a variety of renal diseases [11-13]. In order to define renal Doppler findings on kidney diseases, renal arterial Doppler parameters are employed, such as RI, PI and AT.

It has been proved that RI is a sensitive parameter for monitoring vascular and tubulointerstitial diseases of the kidneys. In theoretical terms, RI and PI refer to vascular resistance. As PI includes mean speed, it may better reflect flow when compared to RI [14].

AT measurement, is useful in identifying the renal arterial stenosis, acute renal insufficiency and transplant rejection [15-17]. Following ESWL, perivascular thickening may arise as a result of cellular infiltration and edema occurring around the peripheral branches of the renal arteries and these may cause an increase in intravascular resistance [3,18].

Aoki et al compared the RI values obtained from an area close to a renal stone before, 30 minutes and 1 week after ESWL and found a significant increase in RI values 30 minutes after ESWL but the mean RI values returned

**Table I.** The mean RI, PI and AT values in patients with renal stones with relevant p values

<table>
<thead>
<tr>
<th></th>
<th>Before ESWL</th>
<th>1 hour after ESWL</th>
<th>7 days after ESWL</th>
<th>p* value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral kidney RI</td>
<td>0.58±0.04</td>
<td>0.64±0.04a</td>
<td>0.59±0.04b</td>
<td>0.002</td>
</tr>
<tr>
<td>Ipsilateral kidney PI</td>
<td>0.97±0.15</td>
<td>1.10±0.21c</td>
<td>0.97±0.13d</td>
<td>0.04</td>
</tr>
<tr>
<td>Ipsilateral kidney AT</td>
<td>0.15±0.07</td>
<td>0.18±0.04</td>
<td>0.15±0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Contralateral kidney RI</td>
<td>0.57±0.04</td>
<td>0.62±0.04e</td>
<td>0.58±0.03f</td>
<td>0.04</td>
</tr>
<tr>
<td>Contralateral kidney PI</td>
<td>0.92±0.11</td>
<td>1.04±0.12g</td>
<td>0.95±0.10h</td>
<td>0.04</td>
</tr>
<tr>
<td>Contralateral kidney AT</td>
<td>0.15±0.05</td>
<td>0.15±0.05</td>
<td>0.13±0.03</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Values are presented as means ± standard deviations
* Kruskal-Wallis test
a- p=0.0001, b- p=0.05, c- p=0.0001, f- p>0.05 when compared with “before ESWL mean RI”, Mann-Whitney U test, c- p=0.0002, d- p>0.05, g- p=0.0002, h- p>0.05 when compared with “before ESWL mean PI”, Mann-Whitney U test

**Table II.** The mean RI, PI and AT values in patients with ureteral stones with relevant p values

<table>
<thead>
<tr>
<th></th>
<th>Before ESWL</th>
<th>1 hour after ESWL</th>
<th>7 days after ESWL</th>
<th>p* value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral kidney RI</td>
<td>0.58±0.04</td>
<td>0.64±0.04a</td>
<td>0.58±0.04b</td>
<td>0.004</td>
</tr>
<tr>
<td>Ipsilateral kidney PI</td>
<td>0.94±0.12</td>
<td>1.06±0.12c</td>
<td>0.93±0.11d</td>
<td>0.03</td>
</tr>
<tr>
<td>Ipsilateral kidney AT</td>
<td>0.13±0.03</td>
<td>0.12±0.04</td>
<td>0.11±0.03</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Contralateral kidney RI</td>
<td>0.57±0.03</td>
<td>0.62±0.04e</td>
<td>0.57±0.04f</td>
<td>0.04</td>
</tr>
<tr>
<td>Contralateral kidney PI</td>
<td>0.85±0.20</td>
<td>1.03±0.11g</td>
<td>0.92±0.11h</td>
<td>0.04</td>
</tr>
<tr>
<td>Contralateral kidney AT</td>
<td>0.12±0.04</td>
<td>0.12±0.04</td>
<td>0.12±0.03</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Values are presented as means ± standard deviations
* Kruskal-Wallis test
a- p=0.0001, b- p=0.05, c- p=0.0002, f- p>0.05 when compared with “before ESWL mean RI”, Mann-Whitney U test, c- p=0.004, d- p>0.05, g- p=0.0003, h p>0.05 when compared with “before ESWL mean PI”, Mann-Whitney U test
to the pre-ESWL levels after 1 week [8]. Similarly, Knapp et al investigated the changes in RI values obtained from an area close to a stone within 3 hours after ESWL and observed that there was a tendency to increase the RI values 3 hours after ESWL. The authors did not detect any difference in the RI values in the contralateral kidney [9].

Hiros et al found that the RI values were significantly increased in the ipsilateral kidneys on the first day and 2 days after ESWL, whereas there was an increase in RI in the contralateral kidneys only on the first day [19]. Nazaroglu et al determined that, following ESWL, there was a temporary increase in the RI values in both the ipsilateral and contralateral kidneys and they observed that RI values returned to normal within two weeks [5]. Beduk et al observed no differences between pre-ESWL RI values and 24 hours post-ESWL RI values [7].

Our study revealed that 1 hour after ESWL the RI values increase on the ipsilateral and contralateral sides and this increment continues in the ipsilateral kidney on the seventh day as well. In contrast, the RI value in the contralateral kidney was within normal limits on the seventh day.

Willis et al investigated the effects of ESWL on pig kidneys and reported that at the first and fourth hours, renal plasma flow decreased in both ipsilateral and contralateral kidneys. This decrease was more marked in the kidney subjected to ESWL [20]. In support to this finding, our study revealed that in the early stage, following ESWL, the RI values in the contralateral kidneys were found to be higher than those prior to ESWL but to a smaller degree compared with the ipsilateral kidneys. In addition, we noticed that 1 hour before and after ESWL, the PI values exhibited a significant increase similar to that of RI. By comparison, the measurements carried out 7 days after ESWL indicated that the PI values in both kidneys returned to the pre-ESWL values 7 days after the ESWL procedure. Also, the AT values before and after ESWL displayed no difference in the ipsilateral kidneys.

Platt et al described the use of Doppler ultrasonography as a non-invasive test to distinguish obstructive pyelectasia from non-obstructive pyelectasia. They showed that obstructed kidneys had increased RI values [21]. A study carried out on stable partial ureteral obstruction using a dog model revealed that, RI is correlated with the degree of obstruction [22].

In our study were included only patients group with no or mild and moderate hydronephrosis. Regarding the whole study group, significant increases in the RI values on the ipsilateral and contralateral sides 1 hour before and after ESWL were documented. However, no significant differences in RI values were identified when comparison was made between patient with and without hydronephrosis.

A recent study regarding the changes in renal blood flow after ESWL was published by Abd Ellah et al [23]. They evaluated 13 patients with renal stone disease with magnetic resonance (MR) imaging and Doppler ultrasound 12 hours before and 12 hours after SWL. They excluded cases with hydronephrosis and acute renal colic. The mean intra-arterial RI and the difference of mean RI (delta RI) were measured from interlobar arteries as in our study. They observed a significant increase in RI in both treated and untreated kidneys. Arterial spin labeling MR imaging findings supported this data but no significant changes in the kidneys were noticed on contrast enhanced dynamic MR imaging. We recently investigated the changes in renal Doppler ultrasonographic parameters in patients managed with rigid ureteroscopy [24]. In this study, RI and delta RI values of the operated kidneys were found to be significantly higher than the values for non-operated kidneys. We discussed this issue in a previous published paper [25] and we concluded that Doppler ultrasonographic evaluation may offer suggestions regarding the stress exerted on operated/ treated renal units. In urology practice, this can help both clinicians and patients in the choice of best treatment in urinary stone disease.

Potential limitations in this study should be considered. First of all, one could reasonably offer to form an independent control group composed of non-treated healthy subjects. But we thought that it would be more homogenous and reliable to evaluate the normal contralateral kidneys of the ESWL-treated patients. So, as many authors have suggested, we preferred to evaluate the contralateral kidneys as a control group. Secondly, we included cases without hydronephrosis and with mild to moderate hydronephrosis and, excluded patients with severe hydronephrosis and pyelectasia. A more homogenous study group may be provided by including non-hydronephrotic cases only and thus more reliable RI values should be obtained. In addition, our sample size does not seem small considering the literature related to our trial, but we hope prospective studies with larger series in near future may give more valuable data.

In conclusion, we can say that spectral Doppler analysis may provide valuable information as a non-invasive method to assess the hemodynamic changes and renal microcirculation status in cases managed with ESWL.

In the early stages after ESWL procedure, tendency to increase in vascular resistance parameters, such as RI and PI, might be indicative for the temporary increase in renovascular resistance that are envisaged in the early stage. We already know that baseline RI and changes
in RI values can demonstrate altered renal perfusion. So, significant changes in RI and PI values in patients treated with ESWL reveal that ESWL procedure itself is a functionally traumatic event and can cause significant increase in renal vascular resistance that may eventually lead to a decrease in renal blood flow. Hopefully, those changes were temporary and renal vascular parameters may be normalized within 7 days. In the current trial, although 7 days after ESWL the RI in ipsilateral kidney did not return to pre-ESWL values, a decrease in RI values were noticed. Thus, in a clinical perspective we think that if ESWL would be advised for a certain patient with renal/ureteral stone, the minimum shockwave possible must be applied and unnecessary extra-ESWL sessions must be prevented.

Conflict of interest: No conflict of interest exists.

References