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UROLITHIASIS

Evaluation of selected Doppler parameters of renal blood flow in patients undergoing extracorporeal shock wave lithotripsy

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Introduction Despite the risk of complications, which does not exceed several percent, extracorporeal shock wave lithotripsy (ESWL) causes morphological and functional changes in kidneys as a result of the effect of the generated shock wave energy on the renal parenchyma structure.

Material and methods Forty-two patients were included in the study. The mean age in the studied group was 50.9 years (SD ±13.7). Extracorporeal lithotripsy treatments were carried out during the period from January 2014 to April 2014 using an electromagnetic shock wave generator. The spectrum of blood flow of the interlobar arteries of both the treated and the opposite kidney was investigated. On the basis of these spectrums, parameters such as: resistive index (RI), pulsatility index (PI) and acceleration time (AT) were calculated.

Results The ESWL treatment causes a statistically significant increase of the RI parameter in the ipsilateral kidney ($p < 0.0001$) as well as in the opposite kidney ($p < 0.0001$). The RI value decreases after 92 hours after the treatment, reaching statistical significance in both kidneys ($p < 0.005$). The PI parameter substantially increases after treatment in both kidneys ($p < 0.0001$), and decreases after 92 hours ($p < 0.0001$). Statistically significant correlations are shown between RI as well as the PI parameters and the patient's age.

Conclusions Extracorporeal shock wave lithotripsy (ESWL) of renal stones causes temporary impairment of the renal perfusion in both ipsilateral and contralateral kidneys. The main factor that determines the value of the RI and PI parameters is the patient's age.

Key Words: ESWL ‹› nephrolithiasis ‹› resistive index ‹› pulsatility index

INTRODUCTION

Extracorporeal shock wave lithotripsy (ESWL) has been commonly used since the 1980s. It is a minimally invasive and effective method of crushing stones in the upper urinary tract. Despite some defined limitations, this is the treatment of choice for 90% of patients diagnosed with kidney stones and qualified for surgical treatment [1, 2]. Modern ESWL equipment allows precise guidance of the shock wave beam, resulting in improved efficacy and minimal risk of complications. Clinically significant organ complications occur in just a few percent of patients undergoing ESWL, and the majority of them are treated conservatively. However, the impact of energy delivered by the generated shock wave results in morphological and functional changes in kidneys. Renal function disorders, manifested by impaired renal perfusion, can be observed after the ESWL procedure both in treated and contralateral kidneys. Doppler ultrasound examination is a readily available and non-invasive method for assessment of renal blood flow. Based on vascular flow spectra from selected blood vessels in the kidney it is possible to determine Doppler parameters that reflect the renal perfusion status. The purpose of this study was to determine some selected Doppler parameters of renal blood flow in patients with urolithiasis treated with ESWL

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and analyse their usability for the assessment of renal perfusion impairment following the procedure of extracorporeal lithotripsy.

MATERIAL AND METHODS

Patients

Forty-two (42) patients (19 females and 23 males) were qualified into the study. The mean age in the study group was 50.9 years (SD ±13.7). Qualified patients met all inclusion criteria described below:

- urolithiasis diagnosed by ultrasound examination and urography;
- ESWL procedure performed for the first time or repeated (with at least 6-month interval between subsequent procedures);
- maximum crushed stone size of 20 mm;
- normal renal function confirmed by serum creatinine levels and eGFR values.

Exclusion criteria:

- dilation of the pyelocalyceal system of the ipsilateral or contralateral kidney observed before or after the ESWL procedure;
- history of diabetes;
- history of arterial hypertension;
- history of urinary tract infection;
- obesity making effective ESWL and correct assessment of Doppler parameters of the renal blood flow impossible

Lithotripsy

Extracorporeal lithotripsy was perfromed using Dornier Compact Sigma equipment, between January and April 2014. The equipment has the EMSE 140f electromagnetic generator of shock wave. All ESWL's were done in the supine position with sedation anaesthesia (intravenous fentanyl – 2 mL 50 mcg). During the procedures, electrocardiogram and blood pressure of the patients were monitored.

Doppler assessment of kidneys

Doppler assessment of intrarenal blood vessels was performed using the ultrasonograph EsoateMyLab 70. Doppler examinations involved pulse wave method with a convex type head. The Doppler angle was below 60 degrees in all measurements. Flow spectrum in renal interlobular arteries was assessed. The flow in interlobular arteries in the ipsilateral and in the contralateral kidneys was assessed in enrolled patients. Each kidney was assessed in three projections – the superior pole, the middle part, and the inferior pole. Examinations were performed in constant intervals: directly before the procedure, directly after the procedure and 92 hours after the procedure. The following parameters were calculated based on the flow spectrum in interlobular arteries: resistive index (RI), pulsatility index (PI) and acceleration time (AT).

RESULTS

The mean age in the study group was 50.9 years (SD ±13.73). The mean number of pulses generated during a single procedure was 3048 (SD ±238). The mean size of the crushed stone was 8.2 mm. The mean value of energy used for a single ESWL procedure was 14.26 J (SD ±2.23). Values of the RI in the ipsilateral kidney changed significantly ($p < 0.0001$) depending on time of measurement (Figure 1). Before the extracorporeal lithotripsy procedure the mean RI value was 0.54 (median 0.54). Directly after the procedure the value significantly increased (mean 0.65, median 0.64) ($p < 0.0001$), and after 92 hours it was significantly reduced (mean 0.57, median 0.57) ($p < 0.0001$). Also the difference between results obtained before the procedure and 92 hours after the procedure was significant ($p = 0.0191$). Values of the RI in the contralateral kidney also changed significantly ($p < 0.0001$) depending on time of measurement (Figure 2). Before the extracorporeal lithotripsy procedure the mean RI value was 0.53 (median 0.53). Directly after the procedure the value significantly increased (mean 0.67, median 0.62) ($p < 0.0001$), and after 92 hours it was significantly reduced (mean 0.56, median 0.56) ($p < 0.0001$). The difference between results obtained before the procedure and 92 hours after the procedure was significant ($p = 0.0047$).

Values of the PI parameter in the ipsilateral kidney changed significantly ($p < 0.0001$) depending on time of measurement (Figure 3). Before the extracorporeal lithotripsy procedure the mean PI value was 0.93 (median 0.92). Directly after the procedure the PI value significantly increased (mean 1.14, median 1.13) ($p < 0.0001$), and after 92 hours it was significantly reduced (mean 0.97, median 0.95) ($p < 0.0001$). The difference between results obtained before the procedure and 92 hours after the procedure was not significant ($p = 0.1145$).

Values of the PI parameter in the contralateral kidney changed significantly ($p < 0.0001$) depending on time of measurement (Figure 4). Before the extracorporeal lithotripsy procedure the PI value was the lowest (mean 0.93, median 0.94). Directly after the procedure the value significantly increased (mean 1.12, median 1.11) ($p < 0.0001$), and after 92 hours it was significantly reduced (mean 0.95, median 0.91) ($p < 0.0001$). The difference between results obtained before the procedure and 92 hours after the procedure was not significant ($p = 0.3051$).

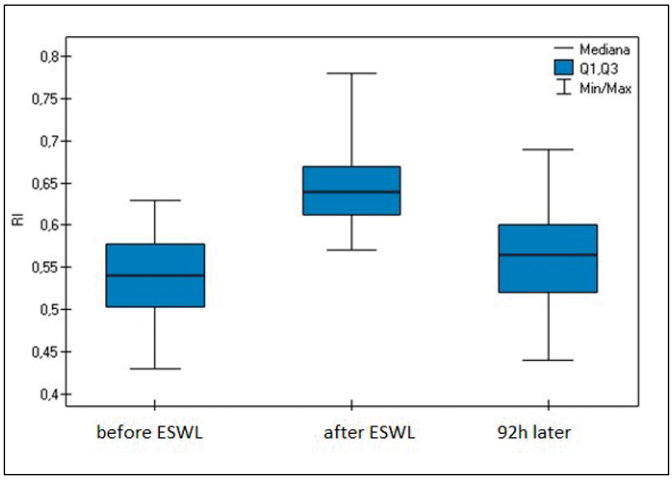

Figure 1. *Distribution of results of RI parameters in the ipsilateral kidney depending on the date of measurement.*

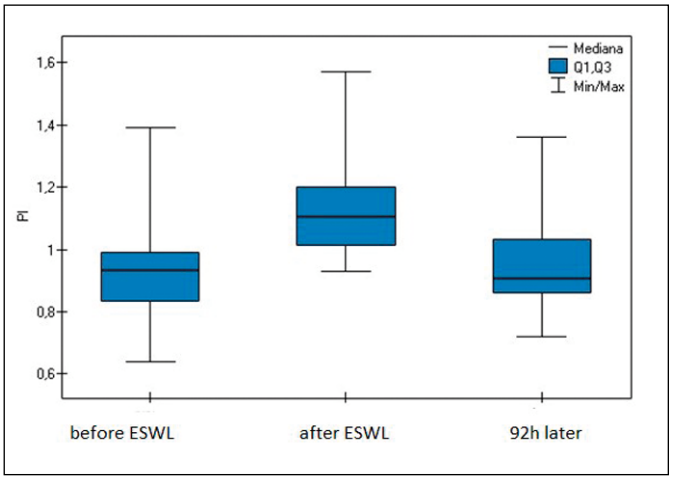

Figure 4. *Distribution of results of PI parameters in the contralateral kidney depending on the date of measurement.*

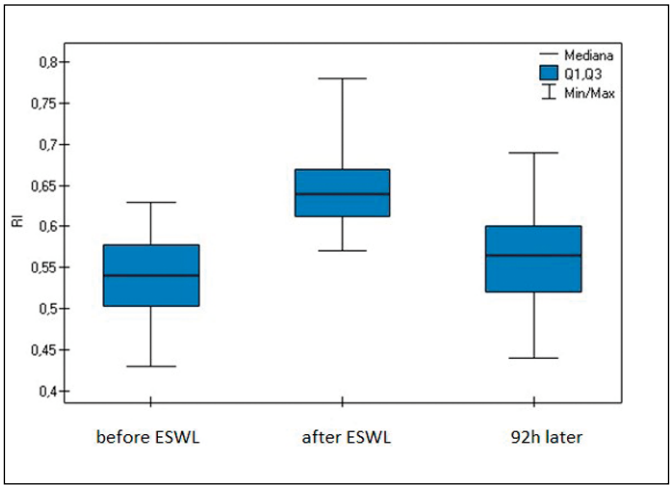

Figure 2. *Distribution of results of RI parameters in the contralateral kidney depending on the date of measurement.*

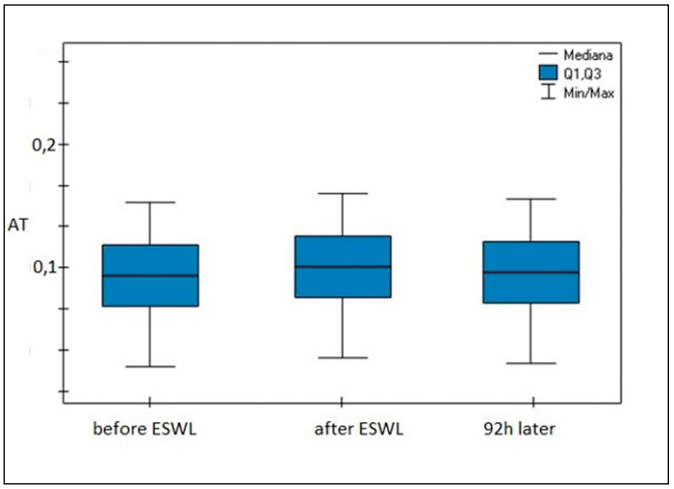

Figure 5. *Distribution of results of AT parameters in the ipsilateral kidney depending on the date of measurement.*

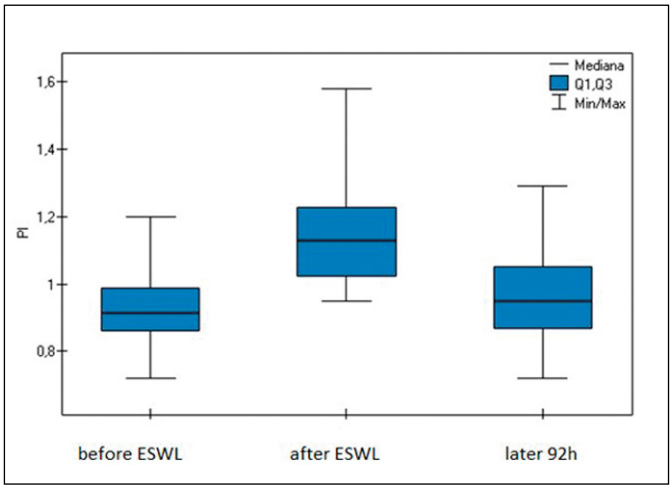

Figure 3. *Distribution of results of PI parameters in the ipsilateral kidney depending on the date of measurement.*

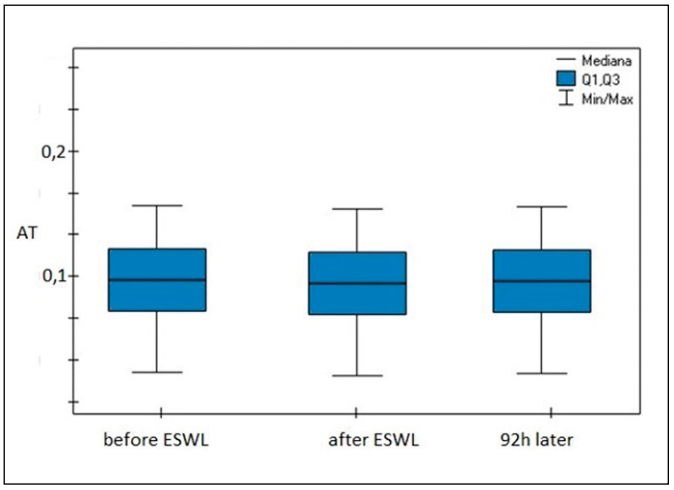

Figure 6. *Distribution of results of AT parameters in the contralateral kidney depending on the date of measurement.*

Time variability of the AT parameter was not statistically significant for both the ipsilateral and the contralateral kidneys (Figures 5, 6).

The analysis of relations between Doppler parameters and patient's age demonstrated a significant positive correlation between age of participants and RI and PI parameters measured before the procedure, directly after the procedure, and 92 hours after the procedure. No statistically significant relation was demonstrated between all parameters measured directly after the procedure and measured 92 hours after the procedure and the number of pulses ($p > 0.05$) and the consumed energy ($p > 0.05$) in the study group. There was also no significant relation between changes in Doppler parameters and crushed stone size ($p > 0.05$).

DISCUSSION

The development of a new generation of lithotripters, as well as modification of principles of extracorporeal lithotripsy have made ESWL a commonly used procedure, perceived as minimally invasive and associated with a low risk of complications. Introduction of lithotripters capable of highly concentrating the induced energy at the site of a stone and observation of the 'best clinical practice' principles have improved the efficacy of the procedure and reduced the risk of complications down to a few percent. Vascular resistance index (RI) is the best known and the most commonly used Doppler parameter of renal blood flow. This parameter is broadly used in the monitoring of vascular and interstitial pathologies in kidneys [3]. This study demonstrated, in a group of 42 patients, a significant increase of RI value measured directly after the procedure based on the interlobular artery blood flow both in the kidney subject to lithotripsy and in the contralateral kidney, and a gradual normalisation of RI values in both kidneys 92 hours after the procedure. Aoki et al. [3] in the Doppler examinations of 70 patients subjected to ESWL also demonstrated a significant increase of the RI value directly after the procedure in the ipsilateral kidney. Nazaroglu et al. [4] in their analysis of 43 patients observed a significant increase of RI in the ipsilateral kidney directly after the procedure and 3 hours after the procedure. This study additionally assessed differences in RI values in interlobular arteries of the ipsilateral kidney located in the direct vicinity of a stone, and in vessels within a distance of several centimetres away from a calculus. Comparable results were obtained by Knapp et al. [5], who reported significantly higher RI values for arteries located in the direct vicinity of the lithotripsy area. A different study demonstrated no significant differences in RI values measured in various areas of the kidney post-ESWL [6, 7]. Hiros et al. [8] assessed ESWL-induced kidney perfusion disorders in both kidneys on days 1, 3 and 5 after the procedure. In the kidney subjected to ESWL, a significant increase of RI was demonstrated on days 1 and 3 after the procedure, and in the contralateral kidney the value was increased only on the first day after lithotripsy. A variety of published results of Doppler ultrasound studies on the effect of ESWL on kidney perfusion seems to be a result of various generations of lithotripters, and of different intervals between the procedure and the measurement of parameters.

Several authors [9, 10] have focused on the effect of a shock wave on renal parenchyma in elderly patients. Both pre- and post-procedural RI values are higher in elderly compared to younger patients. Also, normalisation time of measured parameters is extended. This is mostly a result of the condition of blood vessels in elderly patients: an increased vascular resistance secondary to atherosclerotic changes, and a reduced compliance of vascular walls. In this study, baseline RI values in the group of the oldest patients were higher compared to other groups, but also statistically significant differences between age groups were observed for both kidneys, with higher RI values measured in the group of the oldest patients. Additionally, the study indicated a statistically significant positive correlation between the RI value and patient's age both before and after the ESWL procedure. Similar conclusions are drawn in the study by Knapp et al., indicating a positive linear correlation between the RI value and patient's age. On the other hand, Zolfaghari et al. [11] and Roshdy et al. [12] found no such correlations in their studies. Janetschek et al. [7] demonstrated a significant increase of RI in the Doppler assessment of ESWL-exposed kidneys 3 hours after the procedure only in the group of patients over the age of 60. The results mentioned above indicate a need for careful qualification of elderly patients to ESWL, with a particular consideration of the risk of complications resulting from injury of renal vessels.

Results of the effect of ESWL on renal perfusion based on the assessment of three Doppler parameters of renal blood flow: RI, PI and AT, were first published in 2013. The study involved a group of 42 patients subjected to extracorporeal lithotripsy of both renal and ureteral stones. In the group of patients with kidney stones, some significant differences of the RI parameter were found in the ipsilateral kidney in 1 hour, and one week after the procedure. On the other hand, in the contralateral kidney, in the group of patients with kidney stones, the statistical significance was foundby measure-

ments directly before and directly after the procedure [13]. On day 7 after the procedure, RI values were comparable to those measured before the procedure. Similar intervals were applied for assessment of post-ESWL RI values by Zolfaghari et al. [11]. Fifty-five (55) patients treated with ESWL using the Lithostar equipment (electromagnetic generator) were enrolled in the study. A significant increase of the RI value was found in the ipsilateral kidney directly after the procedure, but RI measurements on day 7 after the procedure were not of statistical significance [11].

Different results were obtained by Sheir and Gad [14] who found no significant RI value differences before and after ESWL in the treated kidney. Absence of significant RI differences before and after the procedure, both in the ipsilateral and the contralateral kidney, was also demonstrated by Juan et al. [15]. In their study, lithotripsy was performed in cases of stones localised in the ureteropelvic junction, which could explain a lesser effect of the shock wave on renal parenchyma. Absence of any significant RI variability was also confirmed by Bedűk et al. [16] who analysed RI values in a group of 20 patients, before and 24 hours after the ESWL procedure. Doppler assessment of renal blood flow before the ESWL procedure may also constitute a predictive factor of lithotripsy efficacy. Roshdy et al. [12] published results of their analysis of correlation between the baseline RI value and SFR, and stated that a higher pre-procedural RI value is associated with lower efficacy of stone crushing. Assuming the cut-off value of baseline RI is 0.68, the authors could predict efficacy of the procedure with a probability close to 90%. The RI assessment as a part of the ESWL qualification process may constitute an additional predictor of ESWL efficacy. As the Doppler option is available in all modern ultrasonographs, examination of blood flow may be an effective tool facilitating correct qualification of a patient for surgical treatment of urolithiasis.

Another Doppler parameter of renal blood flow assessed in our study was the pulsatility index (PI). Directly after the procedure PI values significantly rose, and after 92 hours they decrease while also reaching the level of statistical significance. The pulsatility index in ESWL patients was assessed in the study by Kurt et al. [13]. The authors analysed PI measured in three intervals – directly before the procedure, one hour after the procedure and 7 days after the procedure, in 41 patients treated with ESWL. Statistically significant differences of PI in all measurements were demonstrated for the ipsilateral kidney. The PI value increased after the procedure, and normalised within 7 days. Similar differences were demonstrated in the contralateral kidney, but only measurements performed before and one hour after the procedure reached the level of statistical significance [13].

Parameters of vascular resistance assessed in this study indicate a temporary impairment of perfusion in both kidneys after the ESWL procedure. The pathologic mechanism of perfusion impairment in the kidney treated with extracorporeal lithotripsy, and in the contralateral kidney remaining beyond the range of direct effect of a shock wave, has not been fully explained, and is only scantly discussed in published papers. One theory indicates the development of interstitial oedema around peripheral branches of renal vessels as a possible cause of disorders of renal haemodynamic [17]. As a result of cellular infiltration and oedema, perivascular tissues increase their vascular resistance, as reflected by increased resistance parameters in Doppler examination [17, 18]. Post-ESWL impairment of renal perfusion also depends on the cellular response of the vascular endothelium to the shock wave, expressed by the release of vascular status mediators. Release of factors including prostacyclin, nitrous oxide, and endothelin, causes changes in the vascular wall tone. The reactive release of substances responsible for regulation of vascular wall tone may explain perfusion disorders occurring in the contralateral kidney.

The third parameter of renal blood flow assessed in this study was the acceleration time (AT). Our analysis demonstrated no significant differences of the AT parameter both in the treated kidney and in the contralateral one, directly after the procedure and 92 hours after lithotripsy. Similarly, Kurt et al. [13] found no significant ESWL-associated AT differences in either kidney. The assessment of the acceleration time in patients treated with extracorporeal lithotripsy does not reflect perfusion disorders resulting from the impact of a shock wave on renal parenchyma, and thus has no practical use.

In this study no statistically significant relation was demonstrated between all parameters measured directly after the procedure and measured 92 hours post the procedure and the number of pulses or the energy consumed for disintegration of the urinary stone. Comparable results were obtained by Knapp et al. [9], who found no association between the value of energy and the RI parameter. Zolfaghari et al. [11] failed to demonstrate a correlation between the number of pulses, energy and the RI value. Results of this study and of previously published ones allow the drawing of an indirect conclusion of an absence of any therapeutically significant effect of the number of applied pulses or the amount

of applied energy on perfusion of ESWL-treated kidney. The principal criteria for selection of number of pulses and the amount of applied energy are: patient's age, tolerance of pain, and the level of disintegration of crushed stone in the therapeutic range resulting from the type of used shockwave generator. Possible limitations to our study should be considered. Foremost, one could reasonably offer to form an independent control group composed of non- treated healthy subjects. On the other hand we thought that it would be more reliable to evaluate the contralateral kidneys of the ESWL-treated patients. Secondly, our sample size does not seem small considering the literature related to our study, but we hope that prospective studies with bigger series may give more valuable data in the future.

CONCLUSIONS

Extracorporeal shock wave lithotripsy (ESWL) of renal stones causes temporary impairment of the renal perfusion in both ipsilateral and contralateral kidneys. The main factor that determines the values of the RI and PI parameters is the patient's age. In this study, a lack of usefulness of the AT parameter measurement in the evaluation of renal flow in patients treated with ESWL was found. The number of pulses and energy dose used during ESWL treatment have no significant influence on the value of Doppler parameters of the renal blood flow.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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