ORIGINAL ARTICLE

Extracorporeal shock wave lithotripsy effect on renal arterial resistive index changing

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ABSTRACT

Aim To investigate a correlation between resistive index (RI) level changes following extracorporeal shock wave lithotripsy (ESWL) in treated and non-treated kidneys depending on the ESWL treatment intensity.

The study was conducted on 60 subjects, which were divided in two groups according to age and treatment protocol.

Results In the group of patients younger than 55 years of age there was a significant increase in mean RI values, on the first (p=0.001) and second day after the treatment (p=0.007). In the group older than 55 years of age, the resulting increase in mean RI levels was also significant on the first (p=0.003) and second (p=0.011) day following the treatment. The RI values in the non-treated kidney on the first day after the treatment grew significantly (p=0.033). In the group older than 55, RI values in the non-treated kidney grew significantly on the first day after the treatment (p=0.044). In the group who received 2000 SWs, RI levels grew significantly (p=0.044) as well as in the group who received 4000 SWs during the treatment, where the significance was more pronounced (p=0.007).

Conclusion There is a correlation between RI changes and the degree and localization of changes in vascular elements of the kidney. Post-ESWL treatment changes are existent and reversible, over a period of one week after the treatment.

Key words: treatment, renal circulation, safety

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INTRODUCTION

Extracorporeal Shock Wave Lithotripsy (ESWL), as a treatment option of nephrotic calculosis, affects the pathophysiology of the kidney itself (1). A correct assessment of renal vascular resistance is made by obtaining clear spectra from at least three different intrarenal arteries in various parts of the kidney (2). The resistive index (RI) is most often used for quantification of Doppler spectra and pulsatility index (PI) less frequently (3). Spectra in intrarenal arteries have the same form as the spectra in the main renal artery, but their systolic window is completely filled in, which is not a pathological finding (4). Numerous studies have identified normal RI levels in intrarenal arteries, ranging from 0.58 to 0.64 (5). The process of aging results in a physiological increase of renal vascular resistance, which is not manifested by changes in serum creatinine or creatinine clearance level, so in healthy elderly persons RI levels are 10-15% higher than normal ones (5). In adults, the RI limit is 0.70, while all levels that are equal to or higher than 0.70 indicate an increase in renal vascular resistance, in certain parenchymal renal diseases (6,7). Apart from renal diseases, RI levels may be affected by other conditions, such as hypotension, bradycardia, perirenal or sub-capsular fluid collections (8-10). Available Doppler ultrasound literature is mostly focused on the potential role in evaluating ureteral obstruction, non-obstructive obstructive renal diseases and renal transplant dysfunction (2,6).

The aim of this study was to establish whether there is a correlation between RI level changes following ESWL treatment in the treated and contralateral, non-treated kidneys, depending on the ESWL treatment intensity. Results of this study will point out the safety of the ESWL in the everyday practice, and be a guide for young colleagues for what they can expect right after the treatment.

PATIENTS AND METHODS

Patients and study design

The study was conducted on 60 patients of the Urology Clinic, Clinical Center of the University of Sarajevo in the period November 2014 to December 2017. Out of the total of 60 patients, 38 were males (63%), with average age of 42.3 (ranging from 22 to 59 years). A size of kidney stones ranged from 6 to 18 mm, measured as a mean value of two longest diameters on X ray and ultrasound. Resistive index was monitored on the colour Doppler ultrasound scanner, at the level of interlobar arteries, with the mean value of three measurements for each patient within the set time intervals, before, on the first, second and seventh day following ESWL treatment.

Methods

Resistive index or Pourcelot index was calculated by using the formula: RI= (A – B)/A, where A is the peak systolic Doppler shift waveform, and B is the peak diastolic shift waveform.

Resistive index calculation in each patient was done by the investigators.

The obtained RI results concerned the examination of 60 patients, out of whom 41 were set aside when RI was observed in the function of the patient's age.

The results were taken into consideration before the treatment (0), on the first (1) day, second (2) day and on the seventh (7) day following the treatment, while the subjects were divided into groups according to their age and the number of administrated shock waves. Using this method, we monitored the RI movement in two age groups: Group 1 – patients aged < 55 (n = 29) and Group 2 –patients aged ≥ 55 (n =12).

According to the number of administrated shock waves, we also monitored RI levels in two groups of patients: group of patients who received 2000 SWs (n = 24), and group of patients who received 4000 SWs (n = 36).

In both groups, in terms of the function of both age and number of received SWs, RI levels were monitored in both the treated (ipsilateral), and non-treated (contralateral) kidneys. The resulting mean pre-treatment RI levels, depending on the subjects' age, were as follows: under 25 years of age – 0.563; under 45 years of age – 0.614; under 60 years of age – 0.637; 4% of the patients had levels higher than 0.7, which approximately corresponded to the investigation results and recommendations given by other authors and institutions worldwide (5).

Statistical analysis

For each group of patients, the average value (Mean), standard deviation (SD), standard error

of the mean (SEM), median value (MED) and percentage differences (P10, 25, 75 and 90%) were determined. Analyzing the significance of the differences in the average value of the groups was carried out using the Student t-test and where it could not be used, the statistical significance of the difference in the median value was tested using the Wilcoxon Singed Ranks test. The values of $p<0.05$ were considered significant. In order to select the appropriate test for testing the differences in RI levels between the observed groups, we tested normality in all groups. Since we had less than 50 subjects in groups, instead of the Kolmogorov-Smirnov, we used the Shapiro-Wilks test of normality.

RESULTS

The normality was confirmed in all analysed groups (Table 1), which allowed the application of t-test for testing the differences in arithmetic means.

Table 1. Tests of Normality for RI value variations following extracorporeal shock wave lithotripsy (ESWL) treatment, measuring as a function of time (measured before (-1), immediately after (+1), on the second (+2) and seventh (+7) day) in different age groups or following 2000 SWs and 4000 SWs ESWL treatment (measured before (-1) and immediately after the treatment)

	Kolmogorov-Smirnov test			Shapiro-Wilk test		
	Statistic	df	Sig.*	Statistic	df	Sig.
Normality RI value variations in the group under the age of 55						
Ipsilateral (-1)	.114	29	.200*	.968	29	.505
Ipsilateral (+1)	.116	29	.200*	.969	29	.524
Ipsilateral (+2)	.124	29	.200*	.968	29	.508
Ipsilateral (+7)	.114	29	.200*	.968	29	.505
Contralateral (-1)	.114	29	.200*	.968	29	.505
Contralateral (+1)	.166	29	.040	.957	29	.284
Normality RI value variations in the group older than 55						
Ipsilateral (-1)	.231	12	.200*	.915	6	.473
Ipsilateral (+1)	.213	12	.200*	.950	6	.741
Ipsilateral (+2)	.234	12	.200*	.921	6	.514
Ipsilateral (+7)	.231	12	.200*	.915	6	.473
Contralateral (-1)	.231	12	.200*	.915	6	.473
Contralateral (+1)	.213	12	.200*	.950	6	.741
Tests of Normality RI value variations following 2000 SWs and 4000 SWs						
Treated kidney (-1)	.160	24	.200*	.941	24	.367
Treated kidney 2000	.154	24	.200*	.958	24	.621
Non-treated kidney (-1)	.160	24	.200*	.941	24	.367
Non-treated kidney 2000	.160	24	.200*	.941	24	.367
Treated kidney (-1)	.125	36	.200*	.956	36	.493
Treated kidney 4000	.139	36	.200*	.959	36	.557
Non-treated kidney (-1)	.125	36	.200*	.956	36	.493
Non-treated kidney 4000	.123	36	.200*	.949	36	.376

*Lilliefors Significance Correction; lower bound of the true significance; df , degrees of freedom; sig., significance probability

In the group of patients under 55 years a significant increase in mean RI values was found, on the first (p=0.001) and second day (p=0.007) after the treatment, whereas the increase was non-significant on the seventh day (7) after the treatment (p=0.379), in relation to pre-treatment values (0.62±0.05) (Table 2).

Table 2. Statistical indicators of resistive index (RI) value variations as a function of time, in the group of 29 patients under 55 years of age, measured before (-1), immediately after (+1), on the second (+2) and seventh (+7) day following extracorporeal shock wave lithotripsy (ESWL) treatment

	Treated (ipsilateral) kidney				Non-treated (contralateral) kidney			
	(-1)	(+1)	(+2)	(+7)	(-1)	(+1)	(+2)	(+7)
Mean	0.6228	0.6681	0.6584	0.6333	0.6122	0.6395	0.6277	0.6177
SD	0.0465	0.0503	0.0495	0.0473	0.0457	0.0489	0.0474	0.0461
SEM	0.0086	0.0093	0.0092	0.0088	0.0085	0.0091	0.0088	0.0086
MED	0.630	0.680	0.670	0.6407	0.6193	0.6552	0.640	0.6249
P10%	0.568	0.607	0.598	0.578	0.558	0.581	0.570	0.563
P25%	0.590	0.628	0.620	0.600	0.580	0.603	0.590	0.585
P75%	0.660	0.703	0.694	0.671	0.649	0.676	0.660	0.655
P90%	0.682	0.728	0.718	0.694	0.670	0.693	0.684	0.676
p		0.001	0.007	0.394		0.033	0.210	0.650

SD, standard deviation; SEM, standard error of mean; MED, median; P10%, the first decile; P25%, the first quartile; P75%, the third quartile; P90%, the ninth decile;

In the group of patients older than 55 years, the resulting increase in mean RI levels was also significant on the first and second day following the treatment (p=0.001 and p=0.005, respectively), and non-significant on the seventh day following the treatment (p=0.344), in relation to pre-treatment values (0.70±0.02) (Table 3).

Table 3. Statistical indicators of resistive index (RI) value variations as a function of time in the group of 12 patients below 55 years of age measured before (-1), immediately after (+1), on the second (+2) and seventh (+7) day following extracorporeal shock wave lithotripsy (ESWL) treatment

	Treated (ipsilateral) kidney				Non-treated (contralateral) kidney			
	(-1)	(+1)	(+2)	(+7)	(-1)	(+1)	(+2)	(+7)
Mean	0.7033	0.7562	0.7449	0.7153	0.6914	0.7252	0.7106	0.6976
SD	0.0207	0.0262	0.0251	0.021	0.0203	0.029	0.0251	0.0205
SEM	0.0084	0.0107	0.0102	0.0086	0.0083	0.0119	0.0103	0.0084
MED	0.700	0.756	0.7441	0.7119	0.6881	0.728	0.7108	0.6943
P10%	0.685	0.730	0.720	0.697	0.6734	0.6936	0.6848	0.6795
P25%	0.693	0.740	0.730	0.704	0.6808	0.706	0.6951	0.6869
P75%	0.708	0.764	0.752	0.720	0.6955	0.7358	0.7185	0.7018
P90%	0.725	0.783	0.771	0.737	0.7127	0.754	0.7362	0.7191
p		0.001	0.005	0.344		0.025	0.177	0.609

SD, standard deviation; SEM, standard error of mean; MED, median; P10%, the first decile; P25%, the first quartile; P75%, the third quartile; P90%, the ninth decile;

RI values in the non-treated kidney on the first day after the treatment grew significantly (p=0.033), while on the second and seventh day after the treatment the growth was non-significant (p=0.21 and p=0.65, respectively) in relation to pre-treatment

values (0.61±0.05) (Table 2) in the younger group of subjects. In the group of patients older than 55 years RI values in the non-treated kidney grew significantly on the first day after the treatment (p=0.044), while on the second and seventh day after the treatment the growth was non-significant (p=0.177 and p=0.609, respectively) in relation to pre-treatment values (0.69±0.02) (Table 3).

Due to a small number of observations for patients aged >55, Wilcoxon Singed Ranks test (non-parametric test for paired samples) was used to check the results, showing the same results as the t-test except for non-treated kidney on the second day of the treatment where the difference in mean RI was significant.

Comparative mean resulting RI levels for treated kidneys, using t-test, showed a significant increase in RI levels in both groups, treated with 2000 SWs (from 0.628 to 0.669; p=0.044) or with 4000 SWs (from 0.644 to 0.695; p=0.007). In the case of non-treated kidney, we did not confirm the significant increase in RI for patients who received 2000 SWs (from 0.617 to 0.636; p=0.330) whereas patients receiving 4000 SW showed a significant increase in RI (from 0.633 to 0.669; p=0.042) (Table 4).

Table 4. Statistical indicators of resistive index (RI) value variations following 2000 SWs and 4000 SWs measured in subjects before (-1) and immediately after extracorporeal shock wave lithotripsy (ESWL) treatment

	Treated (ipsilateral) kidney				Non-treated (contralateral) kidney			
	(-1)	2000 SWs	(-1)	4000 SWs	(-1)	2000 SWs	(-1)	4000 SWs
No of patients	24	24	36	36	24	24	36	36
Mean	0.628	0.669	0.644	0.695	0.617	0.636	0.633	0.669
SD	0.053	0.057	0.053	0.057	0.052	0.054	0.052	0.055
SEM	0.0133	0.0141	0.0122	0.0131	0.0130	0.0134	0.0120	0.0127
MED	0.640	0.682	0.640	0.691	0.629	0.648	0.629	0.666
P10%	0.555	0.591	0.570	0.616	0.546	0.562	0.560	0.593
P25%	0.598	0.636	0.605	0.653	0.587	0.605	0.595	0.629
P75%	0.673	0.716	0.690	0.745	0.661	0.681	0.678	0.718
P90%	0.685	0.730	0.702	0.758	0.673	0.694	0.690	0.730
p		0.044		0.007		0.330		0.042

SD, standard deviation; SEM, standard error of mean; MED, median; P10%, the first decile; P25%, the first quartile; P75%, the third quartile; P90%, the ninth decile;

DISCUSSION

The results of the presented study have shown that in the group of patients who received 2000 SWs, RI levels grew significantly, as well as in the group who received 4000 SWs during the treatment. According to most recent information, these changes of RI values following ESWL are a result of cellular infiltration and edema formed around peripheral branches of the renal artery, because of swelling of perivascular tissue so vascular resistance thus may grow too (14-18). RI levels in the non-treated contralateral kidney in the first group of patients who received 2000 SWs did not show any significant changes, while in the other group with 4000 SWs the RI levels grew significantly. In patients under 55 years of age, RI increase was significant on the first and second day after the treatment, whereas it was non-significant on the seventh day, while in patients older than 55 years of age the RI increase practically stood in the same relation to the set temporal determinants, but the significance was more pronounced. RI levels in the contralateral kidney in both age groups showed a significant increase only on the first day after the treatment, while the RI levels on day two and day seven were decreasing. Additionally, the mentioned results in most part confirm the results from other authors' studies. The literature review shows reports addressing the relationship between the ESWL and RI variations after treatment. Knapp et al. found a positive linear correlation between the RI increase following ESWL treatment and the patients age, and concluded that patients older than 65 fall within the risk group for the ESWL treatment due to possibility of elasticity loss in renal tissue and intrarenal blood vessels (10,11). Aoki et al. reported that RI levels measured in interlobar arteries in the region around kidney stone before, 30 min and 7 days after ESWL, showed a significant increase after 30 min (from 0.656±0.053 to 0.682±0.053), but eventually return to their pre-treatment levels over a period of seven days (18). A significant RI increase on the contralateral kidney was verified only in patients older than 65, but the changes were of a reversible character over a limited seven-day period of time (18). Nazaroglu et al. found a temporary RI increase three hours after ESWL in both ipsilateral and contralateral kidneys, with the increase being most pronounced in the region near the stone, whereas the lowest increase was reported in the contralateral kidney. After seven days, RI levels returned to normal (1). Beduk et al. reported there was no significant difference in RI levels in renal blood vessels before and after ESWL

treatment by Dornier MPL 9000; the levels were evaluated 24 hours after the treatment (14). Kataoka et al. reported about a significant RI increase in 23 monitored patient's right after Dornier MPL 9000 treatment and found no RI change on contralateral kidney blood vessels (15).

Color Doppler sonography has proven that a non-invasive renal vascular function assessment method may be efficient, and may be used to measure blood flow speed in renal circulation within small parenchymal arteries (15). In our study no significant RI differences between the treated and contralateral kidneys, regardless of patients' age. Post-ESWL RI was elevated by more than 0.7 in more than a half of the elderly patients, which indicates pathological changes. This phenomenon may be attributed to the loss of renal tissue elasticity and intrarenal vascular sclerosis. We assume that the same amount of energy is not that well tolerated by elderly individuals as is the case with younger patients. The differences in results noticed in the works of the foregoing authors depend on numerous factors, including the time of measuring RI, the type of lithotripter used, SW generator power, focal size, quantity of delivered energy, number of delivered SWs and pre-treatment renal function. The discrepancy between the RI monitoring results may be attributed to the different RI measuring techniques. The differences in RI variation reports may be a reflex of pathological changes at each measuring point. The difference in lithotripters may also affect RI changes. Electrohydraulic and electromagnetic lithotripters more often result in acute sub-capsular hematomas and fibrosis when compared to piezoelectric ones (16-18). Characteristic differences include wider aperture and smaller focal zone. Contralateral non-treated kidneys show significant pre- and post-lithotripsy RI changes in elderly patients. Other studies report of non-significant RI changes in the contralateral, non-treated kidney (17).

Ultrasound has long been a primary diagnostic method in discovering pathologic changes in kidneys. Colour Doppler ultrasound, as a method that provides information on blood flow in kidneys and renal arteries, and non-invasive assessment of vascular resistance, to obtain information on ESWL effect on renal vasculature in both treated as well as non-treated kidneys by measuring RI levels (10-13).

Based on study results, there is a correlation between RI changes and the degree and localization of changes in vascular elements of the kidney, where RI changes are directly correlated with the number of administered shock waves and the administered energy. Post-ESWL treatment changes are existent and reversible over a period of one week after the treatment.

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TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

REFERENCES

1. Nazaroglu H, Akay AF, Bükte Y, Sahin H, Akkus Z, Bilici A. Effects of extracorporeal shock-wave lithotripsy on intrarenal resistive index. Scand J Urol Nephrol 2003; 37:408-12.
2. Juan YS, Huang CH, Wang CJ, Chou YH, Chuang SM, Li CC, Shen JT, Wu WJ. Predictive role of renal resistance indices in the extracorporeal shock-wave lithotripsy outcome of ureteral stones. Scand J Urol Nephrol 2008; 42:364-8.
3. McAteer JA, Evan AP. The Acute and long-term adverse effects of shock wave lithotripsy. Semin Nephrol 2008; 28:200-13.
4. Zhu S, Cocks FH, Preminger GM, Zhong P. The role of stress waves and cavitation in stone comminution in shock wave lithotripsy. Ultrasound Med Biol 2002 28:661–71.
5. Krambeck AE, Gettman MT, Rohlinger AL, Lohse CM, Patterson DE, Segura JW. Diabetes mellitus and hypertension associated with shock wave lithotripsy of renal and proximal ureteral stones at 19 years of followup. J Urol 2006; 175:1742–47.
6. Evan AP, Willis LR, Connors B, Gordon ReedBA, McAteer JA, Lingeman EJ. Shock wave lithotripsy-induced renal injury. Am J Kid Dis 1991; 17:445–50.
7. Morris JA, Husmann DA, Wilson WT, Preminger GM. Temporal effects of shock wave lithotripsy. J Urol 1991; 145:881–3.
8. Madbouly K, El-Tiraifi AM, Seida M, El-Faqih SR, Atassi R, Talic RF. Slow versus fast shock wave lithotripsy rate for urolithiasis: a prospective randomized study. J Urol 2005; 173:127–30.

9. Eisenmenger W, Du XX, Tang C, Zhao S, Wang Y, Rong F, Dai D, Guan M, Qi A. The first clinical results of "wide focus and low pressure" ESWL. Ultrasound Med Biol 2002; 28:769–74.
10. Knapp PM, Kulb TB, Lingeman JE, Newman DM, Mertz JH, Mosbaugh PG, Steele RE. Extracorporeal shock wave lithotripsy-induced perirenal hematomas. J Urol 1988; 139:700-3.
11. Knapp R. Frauscher F. Helweg G, Judmaier W, Strasser H, Bartsch G, zur Nedden D. Blood pressure changes after extracorporeal shock wave nephrolithotripsy: prediction by intrarenal resistive index. Eur Radiol 1996; 6:665-9.
12. Chaussy C, Schmiedt E, Jocham D, Brendel W, Forssmann B, Walther V. First clinical experience with extracorporeally induced destruction of kidney stones by shock waves. J Urol 1982; 127:417–20.
13. Tomomasa H, Kaneko S, Ogawa K, Satoh S, Muramatsu H, Satoh M, Umeda T, Okada E, Iizumi T. Results of extracorporeal shock wave lithotripsy for the treatment of upper urinary tract stones. Hinyokika Kiyo 2007; 53:771–6.
14. Bedük Y, Erden I, Gögüs O, Sarica K, Aytac S, Karalezli G. Evaluation of renal morphology and vascular function by color flow Doppler sonography immediately after extracorporeal shock wave lithotripsy. J Endourol 1993; 7:457–60.
15. Hocaoglu E, Inci E, Aydin S, Cesme DH, Kalfazade N. Is quantitative diffusion-weighted MRI a valuable technique for the detection of changes in kidneys after extracorporeal shock wave lithotripsy? Int Braz J Urol 2015; 41: 139–146.
16. Janetschek G, Frauscher F, Knapp R, Höfle G, Peschel R, Bartsch G. New onset hypertension after extracorporeal shock wave lithotripsy: age related incidence and prediction by intrarenal resistive index. J Urol 1997; 158:346–51.
17. Labanaris AP, Kühn R, Schott GE, Zugor V. Perirenal hematomas induced by extracorporeal shock wave lithotripsy (ESWL). Therapeutic management. ScientificWorldJournal 2007; 7:1563–66.
18. Aoki Y, Ishitoya S, Okubo K, Okada T, Maekawa S, Maeda H, Arai Y. Changes in resistive index following extracorporeal shock wave lithotripsy. Int J Urol 1999; 6:483–92.