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ORIGINAL PAPER

Can we predict the ancillary treatments after extracorporeal shockwave lithotripsy for renal and upper ureteral stones?

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Summary ***Objective:** To quantify the predictors for the ancillary treatments after extracorporeal shock wave lithotripsy (SWL) for renal and upper ureteral stones.*
***Materials and methods:** From January 2014 to January 2017, patients undergoing SWL using an electromagnetic lithotripter machine (Compact Delta; Dornier MedTech GmbH, Wessling, Germany) for renal and upper ureteral stones ≤ 20 mm were retrospectively reviewed. All patients underwent CT urography prior to SWL. The cohort was subdivided into three groups according to stone attenuation values in Hounsfield Units (HU). Group I; HU < 500 (n = 20), group II; HU 500-1000 (n = 51) and group III; HU ≥ 1000 (n = 180). The parameters included for multivariate analysis were stone size, location, multiplicity, stone attenuation value, number of shocks and stone clearance rate by 3 months. The ancillary treatments were ureteroscopy (URS), ureteral stenting and hospital readmission for pain or fever.*
***Results:** A total of 251 patients were included in the study. The overall SWL success rate was 92.4%. Mean stone size was 10.9 ± 2.1, 11.6 ± 3 and 11.4 ± 3.6 mm and mean stone attenuation values were 364 ± 125, 811 ± 154 and 1285 ± 171 HU for groups I, II and III respectively. The stone clearance rates by 3 months were 96%, 92% and 88.4% for groups I, II and III respectively. On subgroup analysis, group III required ancillary treatments in 70% of patients whereas group I, II, did not require any ancillary treatments. On multivariate analysis, stone multiplicity, stone location (lower calyceal stones) and HU were independent significant predictors for the need for ancillary treatments after SWL (p values < 0.05).*
***Conclusions:** Patients with stone attenuation value (HU) > 1000, multiple stones and/or lower calyceal stones have higher risk to necessitate ancillary treatments after SWL. These patients would likely benefit from upfront endoscopic lithotripsy for treating symptomatic renal or upper ureteral stones.*

KEY WORDS: *SWL; Urolithiasis; Fragmentation; Ancillary treatment; Lower calyceal stone.*

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INTRODUCTION

The outcome of extracorporeal *shockwave lithotripsy* (SWL) relies on several factors, including stone factors such as stone composition, size, and location, as well as the mechanism and parameters of the shockwave generator (1). Several studies have proved that stone attenuation values – measured in Hounsfield *Units* (HU) on *computed tomography* (CT) – can predict the outcome of SWL. Although the threshold values differ in various studies it has generally been accepted that higher CT attenuation values have poor outcomes in terms of success rates (2-5). However, most of these studies address only the role of CT attenuation values from the success rate standpoint and there is a paucity of literature investigating the association between preoperative stone characteristics and the need for postoperative ancillary procedures. We believe that the challenge is not only to fragment the stone, but also to reduce the risk of subsequent ancillary treatments. Ancillary treatments such as *ureteroscopy* (URS) and hospital readmission for pain or fever are frequently encountered after SWL. These ancillary treatments have put an undue burden on urological treatment waiting lists.

For small ureteral or renal calculi, SWL has a comparable efficacy when compared with *retrograde intra-renal surgery* (RIRS) (6). According to the latest guidelines, SWL should be considered as the first treatment option in patients with renal stones less than 20 mm and without unfavorable factors for SWL success (1). However, the predictors for ancillary procedures after SWL are still under investigated and eagerly awaited. Therefore, the aim of the present study was to investigate the predictors for the ancillary treatments after (SWL) for renal and upper ureteral stones.

MATERIALS AND METHODS

From January 2014 to January 2017, patients undergoing SWL using an electromagnetic lithotripter machine (*Compact Delta; Dornier MedTech GmbH, Wessling, Germany*) for renal and upper ureteral stones ≤ 20 mm were retrospectively reviewed. All patients included in the analysis underwent CT urography prior to SWL. The cohort was subdivided into three groups according to stone attenuation values (HU). Group I; HU < 500, group II; HU 500-1000 and group III; HU ≥ 1000. The param-

No conflict of interest declared.

eters included in the multivariate analysis were stone size, location, multiplicity, stone attenuation value, number of shocks and stone clearance rate by 3 months.

Ureteroscopy (URS), ureteral stenting and hospital readmission for pain or fever were considered post-SWL ancillary procedures. For each stone, the mean attenuation value was calculated from a small, non-overlapping region of interest.

The SWL procedures were all performed as previously described (3). The treatments were performed under conscious sedation using intravenous fentanyl as the primary anesthetic agent. The stones were located under fluoroscopic and/or ultrasonographic guidance, and the shock impulses were given at a frequency of 60 shocks per minutes in all patients (1 Hz). Shock impulse energy was started at level 1 (10 kv) and ramped up to 6 level (16 kv). The total number of shocks did not exceed 3000.

Plain X-ray kidney-ureter-bladder (KUB) and ultrasound were performed 6 weeks post SWL. Success rate was defined as inability to detect stone on ultrasound and KUB or a residual fragment measuring less than 4 mm.

Review of literature

A PubMed-MEDLINE search was conducted for SWL contemporary literature and relevant data regarding SWL auxiliary procedures and predictors of failure. Several articles based on the same patient cohort and success rate measures were included.

Statistical analysis

Statistical analyses were performed using SPSS (*SPSS Inc., Chicago, IL, USA*) version 22. Comparison of quantitative variables was done using the paired t test (if normally distributed) or the Wilcoxon signed rank test (if not normally distributed) or Fisher's exact test for categorical variable. A multivariate logistic regression analysis was used to assess predictors of postoperative ancillary treatments. Two-tailed p-values of less than 0.05 were set for statistical significance.

Results

A total of 251 patients were included in this study, including 20 patients in group I, 51 patients in group 2 and 180 patients in group 3. The overall SWL success rate at 3 months was 92.4% including 14 patients (5.5%) who developed post SWL steinstrasse. The mean stone size was 10.9 ± 2.1, 11.6 ± 3 and 11.4 ± 3.6 mm and the mean stone attenuation values were 364 ± 125, 811 ± 154 and 1285 ± 171 HU for groups I, II and III respectively. Stone clearance rates were 96%, 92%, 88.4% for groups I, II and III respectively. SWL failure was encountered in 26 patients (10.4%), 24 patients of them (6.8%) were stone-free after second session of SWL and 2 patients (0.8%) necessitated URS. The three groups were comparable in terms of body mass index, stone size and stone location (Table 1).

On subgroup analysis, group III patients required URS and ureteral stenting in 10 cases (5.6%), and hospital readmission for persistent renal colic in 4 cases (2.2%) whereas no patients in groups I and II required ancillary treatments.

Table 1.
Patients and stone demographic data.

Parameter		Value
Mean age ± SD (years)		37.79 ± 17.7
Gender	Male	181
	Female	70
Mean BMI (Kg/M^2)		23.97 ± 3.8
Stone side, n (%)	Right	125
	Left	126
Mean stone size ± SD (mm)		11.46 ± 2.74
Multiple stones, n (%)		19 (7.57%)
Stone location, n (%)	Upper calyx	21 (8.37%)
	Middle calyx	44 (17.53%)
	Lower calyx	50 (19.92%)
	Renal pelvis	82 (32.67%)
	Upper ureter	54 (21.51%)
Associated hydronephrosis, n (%)	Mild	51 (20.32%)
	Moderate	25 (9.96%)
Mean Stone attenuation value (HU)	1115 ± 329.79	
Overall SWL success rate		92.4%
SWL onset, n (%)	Primary treatment	243 (96.8%)
	Residual stone post PCNL and RIRS	16 (6.4%)

Table 2.
Predictors for ancillary treatments using univariable and multivariate regression analysis.

Variable	Univariable		Multivariable	
	OR 95%CI	p	OR 95%CI	p
Age, years	1.04 (1.01, 1.07)	0.027	0.97 (0.89-1.71)	0.09
Stone size (mm)	0.81 (0.78-1.11)	0.082		
Stone location	1.18 (0.88-1.01)	0.01	1.1 (0.99-1.78)	0.02
Stone multiplicity	2.81(1.26-3.54)	< 0.001	1.45 (1.16-2.11)	0.01
Number of shocks per session	0.91 (0.54-1.02)	0.306		
HU (< 1000 vs. ≥ 1000)	2.75 (1.40-4.99)	0.001	3.01 (1.61-6.71)	0.01
Gender, Male/Female	0.81 (0.51-1.00)	0.351		

OR = Odds ratio; CI = Confidence interval; HU = Hounsfield unit.

Univariate analysis revealed that there was a significant correlation between age, stone location, stone multiplicity, HU and the need for ancillary procedures ($p < 0.05$) whereas no significant correlation could be detected for stone size, and gender (Table 2). On multivariate analysis, it was found that stone multiplicity, stone location and HU were independent significant predictors for the treatments after SWL (p values < 0.05) (Table 2).

Table 3 summarizes SWL contemporary series tracking the required auxiliary procedures after SWL and predictors of SWL failure (7-20).

Discussion

According to the latest guidelines, SWL remains the procedure of choice for most upper urinary tract stones ≤ 20 mm in size because of its minimally invasive nature, shorter operative time, established success rates, and minimal complications with long-term safety (1). However, SWL monotherapy is not successful in 9.4% to 26.3% of renal and upper ureteric stones (6, 21). Several studies have shown that SWL efficacy is significantly lower for stones with higher attenuation values (5-8). Nevertheless, there is

Table 3.
Contemporary published SWL series.

Series	Study design	N	Ancillary treatment	Success rate	Predictors of failure
Garrido-abad et al. (7)	Retrospective	270	N/A	68.8%	- Stone size > 9.3 mm - Stone volume > 237 - SAV > 951, SSD 133 mm - BMI > 26.9
Nakasato et al. (8)	Retrospective	260	N/A	76.5%	- HU > 815 - Stone location
Massoud et al. (9)	Prospective	305	- Stienstrusse in 3.6% - Conservative in 2.6%		- BMI > 30 - Lower calyceal stone
			- URS in 10.8%	83%	- SAV > 956.5
Abdelaziz et al. (10)	Retrospective	89	N/A	68.5%	- HU > 800 - SSD > 11.2 ± 2.6 cm
Quzaid et al. (11)	Prospective	50	N/A	52%	- HU > 970
Park et al. (12)	Retrospective	43	N/A	69.7%	- SSD > 92.03 ± 14.51 mm
Olive et al. (13)	Retrospective	98	- Cystoscopy + ureteric stents in 40.6%	56.3%	- Obesity - BMI > 35
Bandi et al. (14)	Retrospective	94	N/A	62%	- Stone volume > 500 microL.
Talas et al. (15)	Retrospective	198	N/A	61%	- In lower calyceal stones - IP angle and infundibular width
Al-ansari et al. (16)	Retrospective	427	- Post-ESWL - Auxiliary procedures were required in 8.4%	78%	- Stone size, location and number - Radiological renal features and congenital renal anomalies.
Ghoneim et al. (17)	Retrospective	205	N/A	68.8%	- IP Angle more than 70 degrees - Infundibular length of > 50 mm
Wang et al. (18)	Prospective	89	N/A	52.5%	- Stone burden > 700 mm^3 - Stone density of > 900 HU
Abdel-khalek et al. (19)	Retrospective	2954	- Static steinstrassae in 4.9%. - Auxiliary - Procedures in 4%	86.7%	- Patient age, stone size, location and number - Radiological renal features and congenital renal anomalies
Sumino et al. (20)	Retrospective	63	N/A	54%	- Higher infundibular Length-to-diameter ratio - Diameter and number of minor calices

a paucity of literature investigating the association between preoperative stone characteristics and the need of postoperative ancillary procedures. Therefore, the aim of the present study was to investigate the predictors for the ancillary treatments after (SWL) for renal and upper ureteral stones. It was found that overall SWL success rate at 3 months was 92.4%. After 3 months follow-up, the stone-free rates were 96%, 92%, and 88.4% for groups I, II, and III respectively. On subgroup analysis, group III (HU > 1000) required URS and ureteral stenting in 5.6% of patients, and hospital readmission for persistent renal colic in 2.2% whereas groups I and II did not require any ancillary treatments. These results are consistent with current medical literature, indicating that SWL is associated with significantly higher retreatment rates compared with RIRS and PCNL (21). On multivariate analysis, it was found that stone multiplicity, stone location and HU > 1000 were independent significant predictors for the treatments after SWL (p values < 0.05; Table 2). Interestingly, when we analyzed stone location cases, we found that most of the lower calyceal stone were associated with SWL failure and required ancillary treatments.
It was reported that several factors such as obesity, stone density, stone composition and unfavorable lower pole anatomy would also affect stone clearance rates (22).
These results may change our clinical practice in the following manner; for those patients with multiple stones, a 1-2 cm lower calcyeal stone or stone attenuation value > 1000 HU and who are anxious about the increased complication rates of RIRS and PCNL and do not mind retreatment or multiple procedures, SWL could be considered an acceptable first management option. Favorable lower pole anatomy [infundibular-pelvic angle (> 30°), short calyx (< 10 mm), and wide infundibulum (> 5 mm)] should also be considered in the treatment algorithm (22). Most patients, who fail primary SWL treatment, are best suited to be treated with endoscopic treatments (RIRS or PCNL) due to its high stone-free rate, significantly lower operative and fluoroscopy time.
However, patients with challenging lower pole calyceal anatomy, PCNL would be the first option.
Our study had some limitations including, first the retrospective nature resulting in some missing data such as stone to skin distance, infundibulo-pelvic angle.
However, these variables are sufficiently reported in medical literature. Secondly, there exists a selection bias which explains the high heterogeneity between groups. Finally, the interpretation of our findings may be affected by these confounders. Nevertheless, this is one of the rare studies investigating the predictors for the ancillary treatments after SWL.

Conclusions

Our study suggests that patients with stone attenuation value (HU) > 1000, multiple stones and/or lower calyceal stones have higher risk to necessitate ancillary treatments after SWL. Those patients could be offered an endoscopic lithotripsy as a first line therapy for treating symptomatic renal or upper ureteral stones. Future prospective studies are definitely warranted.

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