Shock Wave Lithotripsy Correlates With Stone Density on Preoperative Computerized Tomography

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Purpose: We reviewed our experience with the Dornier® Doli S lithotriptor to address 2 questions. 1) What is the stone-free rate? 2) Can a stone-free outcome be predicted by preoperative computerized tomography?

Materials and Methods: The records of 76 consecutive patients undergoing shock wave lithotripsy for solitary urinary calculi 5 to 20 mm in diameter were studied retrospectively. Pretreatment noncontrast computerized tomography was reviewed to determine Hounsfield density. The shock wave lithotripsy outcome was determined at 12 weeks on imaging and categorized as 1) stone free, 2) any residual fragments or 3) stone unchanged.

Results: Of the patients 28 (37%) were stone free, 11 (14%) had residual fragments and 37 (49%) had stones that remained unchanged on computerized tomography after a single treatment with shock wave lithotripsy using a Dornier Doli S. Stones of patients rendered stone free had a lower median density compared to stones in patients with residual fragments and unchanged stones (684 vs 1,034 and 920 HU, respectively, $p = 0.04$). The stone-free rate for stones less than 1,000 HU was 46% vs 17% for stones 1,000 HU or greater ($p = 0.01$).

Conclusions: The combined stone-free and fragmentation rate was 51%, lower than in other published reports. In patients with calculi greater than 1,000 HU shock wave lithotripsy achieved a stone-free rate of only 17%. Patients should be informed of the likelihood of treatment failure or need for auxiliary procedures if the Doli S lithotriptor is used, particularly for stones greater than 1,000 HU.

Key Words: kidney; ureter; calculi; lithotripsy; tomography, emission-computed

The Dornier Doli S lithotriptor is reported to achieve an EQ of 0.41 to 0.66.[1–3] Fuselier et al reported a stone-free outcome of 52% at 3 months based on plain radiography or ultrasonography with no computerized tomography followup.[3] More successfully Sheir et al reported a stone-free rate of 89% at 4 weeks.[2] However, the average number of shocks was 4,804 (mean 1.6 treatment sessions). Thus, the efficacy of SWL varies considerably with this machine.

As determined from standard NCCT, stone density may provide prognostic information on stone fragility and SWL success.[4–6] High resolution CT and micro CT technology can predict stone composition and internal structure.[7–11] Most studies that characterize stone attenuation on CT show that SWL success is generally greater for stones of lower vs higher attenuation. We performed a retrospective review of the records of consecutive patients undergoing SWL at our institution using the Dornier Doli S lithotriptor to determine our stone-free rate and establish whether stone attenuation, measured on a standard pretreatment NCCT, could predict stone-free outcome after SWL.

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MATERIALS AND METHODS

A retrospective review was performed of the records of consecutive patients undergoing SWL from February 2003 to February 2004 using the Dornier Doli S lithotriptor by a single surgeon. Subjects were included if they had a solitary renal or ureteral calculus 5 mm to 20 mm in diameter. Exclusion criteria included prior SWL or stone treatment for the same stone. All patients underwent pretreatment NCCT (5 mm collimation width using a LightSpeed® 4-slice multidetector helical CT scanner at 0.5 seconds per rotation, 120 kV and 100 mA). Clinical followup and imaging with NCCT, plain x-ray of the kidney, ureters and bladder or renal ultrasound were performed at 4 weeks, 3 months and thereafter.

During SWL patients received conscious sedation with intravenous remifentanil as the primary anesthetic agent, supplemented as needed with midazolam or propofol. Patients were given 2,500 shocks at power level 5 for renal stones and 3,000 shocks at power level 6 for ureteral stones. Power was ramped up steadily over approximately 200 to 400 shocks. Stones were targeted using a built-in biplanar fluoroscopic unit at regular intervals during the procedure. Patients were discharged home the same day. Where fragments were recovered, composition analysis was performed. Our laboratory report indicated stones of mixed composition by listing the components in rank order but without quantification of their presence.

Patients were categorized according to findings on followup imaging as group 1—those rendered stone free, group

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2—those with evidence of fragmentation but residual fragments of any size and group 3—those in whom the stone was unchanged. The stone-free rate, fragmentation rate (stone-free plus residual fragment groups) and failure rate (stone unchanged group) were determined. EQ was calculated for the Dornier Doli S lithotriptor using the formula, percent stone-free patients = 100% + percent with re-treatment + percent with auxiliary procedures after extracorporeal SWL.

Stone attenuation in HU was determined from a pretreatment NCCT image that represented the stone in largest diameter. Mean stone attenuation was calculated from 3 nonoverlapping regions of interest (area 0.026 cm^2 or 25 pixels) chosen for each stone. Relatively small, consistent areas of interest (25 pixels) were centrally chosen to minimize the volume averaging that occurs when measurements include the stone edge. The SD for each attenuation measurement was also determined as a measure of stone heterogeneity.

Statistical comparisons were done using the unpaired t test, ANOVA and pairwise comparisons, the Kruskal-Wallis test, the Pearson correlation and the chi-square tests. We compared stone-free rates for stones 1,000 HU or greater vs less than 1,000 HU and the OR was determined.[4] Only pure composition stones could be used for statistical analyses. Because there were only 2 uric acid and 3 cystine stones, they were combined into a single cohort. There were only 3 struvite stones, which were excluded in comparisons. Multivariate logistic regression analysis was used to determine whether stone size and stone density in HU were important factors for predicting stone-free outcome.

RESULTS

Table 1 lists demographics and treatment outcomes for 76 consecutive patients with a mean followup of 195 days. Overall at 3 months of followup 28 patients (37%) were stone free, 11 (14%) had residual fragments and 37 (49%) had stones that remained unchanged after a single SWL treatment. The overall fragmentation rate, including stone-free and fragmented stones, was 51%. There was no statistical difference in stone diameter, the percent of patients with stones 10 mm or greater, or stone location among the groups. The EQ was 0.25, including 37% for stone-free status, 16% for SWL re-treatment and 33% for auxiliary procedures. When comparing results at 1 vs 3 months of followup, 1 of 12 patients (8%) who had residual fragments at 1 month subsequently passed the fragments spontaneously and became stone free at 3 months. In 37 patients with no evidence of fragmentation at 1 month no significant change was seen at 3 months unless they had undergone adjunctive therapy in the interim (p = 0.08). Secondary procedures were required in 5 patients (45%) with residual fragments, including ureteroscopy in 2, percutaneous nephrolithotomy in 1, SWL in 1 and other in 1, and in 21 (57%) with stones that remained unchanged, including ureteroscopy in 10, percutaneous nephrolithotomy in 5, SWL in 5 and nephrectomy in 1.

TABLE 1. *Demographics in 76 patients*

	Stone Free	Fragments	No Change	p Value
No. pts (%)	28 (37)	11 (14)	37 (49)	—
Mean ± SD age	49 ± 13	56 ± 18	56 ± 13	0.11
No. stone side (%):				
Rt	14 (50)	5 (45)	16 (43)	0.82
Lt	14 (50)	6 (55)	21 (57)	
Mean ± SD stone diameter (mm)	8 ± 4	9 ± 3	9 ± 4	0.79
No. stones 10 mm or greater (%)*	6 (21)	4 (36)	10 (27)	0.76
No. stone location (%):				
Kidney (not lower pole)	11 (39)	5 (45)	17 (46)	
Kidney (lower pole)	2 (7)	4 (36)	12 (32)	0.08
Proximal ureter	11 (39)	2 (18)	7 (19)	
Distal ureter	4 (14)	0	1 (3)	
No. ureteral stent (%)	1 (4)	4 (36)	6 (16)	0.03

* Rate of 26%.

TABLE 2. *Stone density in 76 patients in outcome groups*

	Stone Free	Fragments	No Change	p Value
No. pts (%)	28 (37)	11 (14)	37 (49)	—
Preop stone size (mm)	8.0 ± 3.6	8.5 ± 2.7	8.6 ± 4.0	0.79
Median preop stone density (HU)	684	1034	920	0.04
Mean ± SD stone density measurements variance*	72 ± 44	68 ± 57	60 ± 26	0.49
No. pts 1,000 HU or greater (%)	4 (15)	6 (50)	15 (41)	0.04
Preop stone density in median 1,000 HU or greater subset	1,234	1,300	1,203	0.45

* When measuring stone density in HU on CT using a picture archiving communication and storage station, a SD is calculated for the measured area of interest that contains several pixels or voxels, and we used a standardized area of interest of 0.026 cm^2, equivalent to 25 pixels.

Median preoperative stone attenuation was significantly lower in the stone-free, residual fragments and unchanged stone groups (684, 1,034 and 920 HU, respectively, p = 0.04, table 2). Only 4 of 28 patients (14%) rendered stone free had a stone density of 1,000 HU or greater vs 6 of 11 (55%) with residual fragments and 15 of 37 (41%) with stones unchanged (p = 0.02, table 2). Conversely 24 of 52 patients (46%) with stones less than 1,000 HU were stone free following SWL vs 4 of 24 (17%) with stones 1,000 HU or greater (p = 0.01). Stones less than 1,000 HU had a smaller mean ± SD diameter than stones 1,000 HU or greater (8 ± 3 vs 10 ± 4 mm, p = 0.01). Stone size correlated with stone attenuation (Pearson correlation 0.371, p = 0.001, see figure). Stone composition was available for 58 of 76 patients (76%), including 45 pure composition stones, and it did not differ among the groups (p = 0.43). When comparing stone attenuation across compositions, combined uric acid/cystine stones were 587 ± 247 HU, calcium oxalate dihydrate stones were 772 ± 251 HU, brushite stones were 934 ± 322 HU and calcium oxalate monohydrate stones were 962 ± 308 HU (p = 0.04). Pairwise comparisons were significant only between uric acid/cystine vs calcium oxalate monohydrate and uric acid/cystine vs brushite.

Univariate analysis identified that mean stone density, lack of a ureteral stent and stone location were associated with stone-free outcome (p <0.05). In 16 patients who had stents or nephrostomy tubes all were placed at a prior visit. However, on multivariate analysis stone density was the only independent predictor of stone-free outcome. For every 100 HU increase in stone density patients treated with SWL had significantly lower odds of becoming stone free (OR 0.78, 95% CI 0.649–0.933, p = 0.01). Stone size was not predictive of stone-free outcome (OR 1.29, 95% CI 0.266–6.283, p = 0.75.) Due to small numbers for other variables only HU and stone size could be tested on multivariate analysis.