Percutaneous ultrasonic lithotripsy (PUL) after shock wave lithotripsy (SWL) failure

Amy E. Krambeck, MD, Kent C. Krejci, MD, David E. Patterson, MD, Andrew J. LeRoy, MD, Joseph W. Segura, MD

Department of Urology, Mayo Clinic, Rochester, Minnesota, USA

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Objective: *Shock wave lithotripsy (SWL) is an attractive initial treatment for nephrolithiasis. Unfortunately, a significant number of stones are resistant to SWL therapy and require subsequent percutaneous ultrasonic lithotripsy (PUL) for definitive treatment. Our objective was to determine if previous SWL had adverse effects on PUL success and if there were differences between the patients undergoing primary PUL and those undergoing PUL after SWL failure.*

Materials and methods: *In 2001, 108 PULs were performed at our institution, of which 40 (37%) were performed after SWL failure. Stone location, anesthesia time, stone composition and size, and complication rates were compared between patients who had PUL alone and those who underwent PUL after SWL failure. Anesthesia time was considered a reflection of technical difficulty of the case.*

Results: *Stone composition differed between the SWL failure and primary PUL groups. Cystine stones were found to be more common in the ESWL failure group and calcium oxalate monohydrate stones more common in the primary PUL group. There was not a statistically significant difference in stone size, anesthesia time or complication rates, between the PUL alone and PUL after SWL failure groups.*

Conclusion: *PUL remains a reliable and safe treatment of nephrolithiasis. Prior SWL does not affect efficacy, technical difficulty, or postoperative complications of subsequent PUL. Based on our data, prior SWL should not be considered a negative factor in PUL outcomes. Stone composition should be considered a prognostic indicator of SWL failure and alert the surgeon that primary PUL may be indicated.*

Key Words: percutaneous ultrasonic lithotripsy, shockwave lithotripsy, renal calculi, percutaneous nephrolithotomy.

Introduction

Shock wave lithotripsy (SWL) and percutaneous nephrolithotomy are common methods used in the treatment of renal lithiasis. The preferred form of percutaneous stone extraction at our institution is percutaneous ultrasonic lithotripsy (PUL). As well as being the preferred treatment for large renal calculi greater than 2 cm, PUL has historically played a significant role as salvage therapy after SWL failure. A common situation faced by tertiary care centers performing percutaneous nephrolithotomy is the treatment of patients who had failed previous shock wave therapy. Currently, little data exists on the outcomes of PUL after previous failed ESWL.

We reviewed all the PULs performed at the Mayo Clinic in 2001 (N=108) and found over 1/3 were performed after SWL failure. Our objective was to determine if previous SWL had an adverse effect on

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Address correspondence to Dr. Amy E. Krambeck, Department of Urology, Mayo Clinic, 200 First Street, SW, Rochester, MN 55901 USA

PUL success and if differences existed between the two groups, which could indicate possible risk factors for SWL failure. We also looked at stone location and attempted to determine if stones requiring PUL treatment were more prone to occur on one side of the body or the other. Stone location within the collecting system was not analyzed.

Materials and methods

After approval from the Mayo Clinic Institutional Review Board, we retrospectively reviewed the charts of all patients who underwent PUL for renal calculi at the Mayo Clinic from January 1, 2001 to December 31, 2001. Preoperative data were analyzed, including patient demographics, previous SWL treatment, and radiographic determination of stone size and location using computed tomography and/or abdominal x-rays.

Operative data were analyzed, including anesthesia time, and need for secondary procedures. Anesthesia time was considered time from anesthesia induction to time the surgeon secured the nephrostomy tube in place. This included anesthesia induction, tract dilation and lithotripsy procedure. Time necessary for anesthesia reversal and extubation was not included in the anesthesia time.

Postoperative data were analyzed including surgical complications, the need for repeat PUL, and stone weight and composition. Postoperative complications included: ureteropelvic junction injury and edema, bleeding, obstructing blood clots, sepsis, and residual stones. Standard postoperative care consisted of a 22 French nephrostomy tube and an open ended 6 French ureteral catheter placed at time of procedure. All patients received nephrostograms on postoperative day number one to evaluate stone clearance. The ureteral catheter was pulled and the nephrostomy tube then clamped if there was no evidence of residual stones. Once the patient tolerated nephrostomy tube clamping without flank pain the nephrostomy tube was removed and the patient dismissed home. Those patients with residual stones underwent repeat PUL to achieve stone free status. Indwelling ureteral stents were not used.

Differences in the features of the primary PUL group and SWL failure group were compared using Kruskal-Wallis, chi square, Fisher's Exact tests. P-values <0.05 were considered statistically significant. Statistical analysis was performed using the SAS software package (SAS Institute, Cary, NC, USA).

Results

One hundred and nine PUL procedures were performed at the Mayo Clinic in the year 2001. One patient was excluded from the study. This patient required PUL for removal of a calcified ureteral stent and therefore not considered in our cohort. A total of 63 female and 45 male patients were treated with PUL at the Mayo Clinic during the 2001 calendar year. Forty patients (37%) had failed prior SWL treatment within the last 6 months. The patients were then categorized into two groups: those that had failed a previous SWL and those that were treated primarily with PUL. See Table 1 for patient demographics. Average age of the patients with primary PUL was 56.6 years, and the average age of the patients with prior SWL failure was 46.9 years (p value <0.0032).

TABLE 1. **Study demographics**

	Primary PUL N=68 (63%)	**SWL failure N=40 (37%)**	**Total N=108**	**p value**
Gender				0.501
Female	38 (55.9%)	25 (62.5%)	63 (58.3%)	
Male	30 (44.1%)	15 (37.5%)	45 (41.7%)	
Age				0.003
Mean (SD)	56.6 (15.74)	46.9 (16.61)	53.0 (16.67)	
Median	58.0	46.0	55.0	
Range	11.0-83.0	21.0-80.0	11.0-83.0	
Side				0.171
Left	35 (51.5%)	26 (65%)	61 (56.5%)	
Right	33 (48.5%)	14 (35%)	47 (43.5%)	

TABLE 2. **Stone weight and radiographic size**

	Primary PUL N=68 (63%)	SWL failure N=40 (37%)	Total N=108	p value
Stone weight				0.256
N	59	36	95	
Mean (SD)	1.9 (3.02)	1.6 (2.67)	1.8 (2.88)	
Median	0.9	0.5	0.8	
Range	0.0-15.0	0.0-13.9	0.0-15.0	
Stone size				0.548
<=2 cm	35 (51.4%)	17 (42.5%)	52 (48.2%)	
2.1-3 cm	8 (11.8%)	4 (10%)	12 (11.1%)	
>3 cm	25 (36.8%)	19 (47.5%)	44 (40.7%)	
Of those >3 cm				
Partial staghorn	9 (13.2%)	10 (25%)	19 (17.6%)	
Complete staghorn	10 (14.7%)	5 (12.5%)	15 (13.9%)	

Radiographic stone size was divided into six categories: <2 cm, 2.1-3 cm, and > 3 cm. The stones greater than 3 cm were also subdivided into partial and complete staghorn calculi. If there were multiple fragments, the size of the largest fragment was used in analysis. Table 2 compares the radiographic stone size of each group. There was no statistically significant difference in stone size between the primary PUL and SWL failure group.

Stones were classified into one of the following groups based on a greater than 50% mineral composition: calcium phosphate, magnesium ammonia phosphate, uric acid, calcium oxalate dihidrate, calcium oxalate monohydrate, and cystine. Eleven individuals treated did not have stone analysis performed. One stone unit did not have a mineral composition greater than or equal to fifty percent. See Table 3 for stone composition data. A statistical significance was noted between the two groups in regard to stone composition. The SWL failure group had a higher percentage of cystine stones as compared to the primary PUL group (p value 0.0328). There was also a statistical significance between the two groups for calcium oxalate monohydrate, with the primary PUL group having a higher percentage of calcium oxalate monohydrate stones than the SWL failure group (p value 0.0325).

No statistically significant intra-operative complications were identified in either the SWL failure group or the primary PUL group. Anesthesia time averaged 95.0 minutes in the primary PUL group. For the SWL failure group the average anesthesia time was

TABLE 3. **Stone composition, based on > 50% mineral composition***

	Primary PUL N=59 (61%)	SWL failure N=37 (39%)	Total N=96	p value
Mineral				0.022
Calcium phosphate	18 (30.5%)	16 (43.2%)	34 (35.4%)	
Magnesium ammonia phosphate	2 (3.4%)	2 (5.4%)	4 (4.2%)	
Uric acid	12 (20.3%)	3 (8.1%)	15 (15.6%)	
Calcium oxalate dihidrate	3 (5.1%)	4 (10.8%)	7 (7.3%)	
Cystine	1 (1.7%)	5 (13.5%)	6 (6.3%)	
Calcium oxalate monohydrate	23 (39%)	7 (18.9%)	30 (31.3%)	

* The stone composition was not analyzed for 11 patients, and one patient did not have any minerals accounting for ≥ 50% of stone composition

TABLE 4. **Anesthesia time (minutes)**

	Primary PUL N=68 (63%)	SWL failure N=40 (37%)	Total N=108	p value
Anesthesia time (minutes)				0.788
Mean (SD)	95.0 (28.1)	96.8 (28.1)	95.6 (27.7)	
Median	90.0	90.0	90.0	
Range	35.0-170.0	60.0-180.0	35.0-180.0	

96.8 minutes Table 4. No statistical difference (p value 0.7881) existed between the groups regarding these variables.

Thirty-seven patients (54.4%) in the primary PUL group and 65% of in the SWL failure group experienced no postoperative complications. Those postoperative complications that did occur are represented in Table 5. A statistical significance between the two groups in regards to postoperative complications could not be established (p value 0.573). No statistical significance was noted between the two groups in regards to residual stones (p value 0.573) or number of PUL procedures required (p value 0.3535).

Discussion

Approximately 10%-20% of all kidney stones may cause enough patient discomfort to warrant surgical intervention.[1] Asymptomatic renal calculi <5 mm in diameter in unobstructed non-infected kidneys do not require removal, unless this is necessary for professional reasons (pilot, professional driver, etc.).[2] Larger symptomatic stones may be managed with minimally invasive techniques such as SWL, percutaneous nephrostolithotomy (PCNL), and ureteroscopy. Open surgery once the corner stone of nephrolithiasis management is now only necessary in less than 1% of cases.[3] Improved radiologic imaging equipment, endourological devices and shockwave lithotripsy have revolutionized patient care, allowing efficient stone removal with a significant reduction in postoperative pain and convalescence compared to the open alternatives.[1]

Issues pertinent to any discussion of renal calculi treatment are stone location, composition, and size.[4] In general, non-cystine stones <2 cm in size in non-

TABLE 5. **Postoperative complications**

	Primary PUL N=68 (63%)	SWL failure N=40 (37%)	Total N=108	p value
Postoperative complications				
UPJ edema	2 (2.9%)	0 (0%)	2 (1.9%)	
UPJ injury/tear	4 (5.9%)	1 (2.5%)	5 (4.6%)	
Bleeding	3 (4.4%)	0 (0%)	3 (2.8%)	
Obstructive clots	1 (1.5%)	1 (2.5%)	2 (1.9%)	
Sepsis	1 (1.5%)	0 (0%)	1 (0.9%)	
Postoperative ileus	1 (1.5%)	0 (0%)	1 (0.9%)	
Postoperative fever	0 (0%)	1 (2.5%)	1 (0.9%)	
Residual stone only	19 (27.9%)	11 (27.5%)	30 (27.8%)	
None	37 (54.4%)	26 (65%)	63 (58.3%)	
Residual Stones after first PUL procedure				0.573
No	44 (64.7%)	28 (70%)	72 (66.7%)	
Yes	24 (35.3%)	12 (30%)	36 (33.3%)	
PUL procedure				0.597
1	46 (67.6%)	29 (72.5%)	75 (69.4%)	
2 or 3	22 (32.4%)	11 (27.5%)	33 (30.6%)	

obstructed systems are best managed by SWL. Stones between 2-3 cm in size can be managed by either SWL following placement of stents or by primary percutaneous nephrolithotomy. Stones >3 cm in size are best treated by primary percutaneous nephrolithotomy.[2] The presence of staghorn calculi mandates complete stone removal and therefore percutaneous nephrolithotomy or open surgery is preferred. Unfortunately, the wide availability of SWL often makes it the first line treatment of renal calculi with disregard to the above guidelines.

Nearly 40% of percutaneous procedures are performed as salvage therapy after failed SWL at our institution. Many of these patients are referred after multiple failed prior SWL treatments, which is a common situation faced by tertiary care centers. Factors that have been shown to be associated with poor SWL outcomes are: multiple stones, calculi requiring multiple sessions of high voltage SWL, stones formed secondary to SWL treatment of stones in other locations, stones within the renal parenchyma, large stone size, composition and calculi occurring in kidneys previously treated by percutaneous nephrolithotomy.[2] Although, SWL is minimally invasive, there are potential significant complications such as flank pain, inflammation, urinary tract infections, transient hematuria, skin ecchymoses, pyuria, pancreatitis, formation of intrarenal hematomas, development of hypertension, and disorder of renal function. Functional impairment of adjacent organs (liver, prostate, gallbladder) has also been noted secondary to SWL.[5-10] Steinstrasse may commonly occur in stones >2 cm leading to significant morbidity.[2] The multiple stone fragments formed by SWL are also thought to make subsequent surgical eradication of the entire stone burden difficult and time consuming. These properties of SWL led us to question what effect would prior SWL have on the outcome of subsequent PULs.

Current indications for the use of PCNL in our practice are as follows: large staghorn calculi or a stone burden > 2 cm, cystine stones, calyceal diverticular calculi, impacted ureteral pelvic junction or upper ureteric calculi, and renal calculi in association with UPJ obstruction when antegrade pyelolysis is being performed. PCNL is highly effective at achieving a stone free status, with success rates of 100%, 89%, and 94 % for stones <1 cm, 1-2 cm, and > 2 cm respectively.[2] This is dramatic compared to SWL results of 74%, 56%, and 33 % respectively for the same stone sizes.[11]

Our analysis of patients undergoing PUL showed no adverse outcomes after prior SWL treatment. Anesthesia time used as a reflection of procedure difficulty was not significantly prolonged by prior SWL treatment. Residual retained stone fragments after initial PUL and need for subsequent PUL procedures was not increased nor decreased by prior SWL treatment. In addition, adverse outcomes such as postoperative bleeding, sepsis, ureteropelvic injury, or edema were not significantly increased after prior SWL. This information could aid physicians in patient education and operative planning. However, it should be emphasized that these data does not advocate the use of SWL as a primary treatment with disregard to current treatment guidelines.

Another goal of our study was to identify stones that were likely to fail SWL treatment. This data would potentially decrease medical expenses incurred from duplicate procedures. It has long been known calcium oxalate monohydrate and cystine stones are considered “hard stones” and may not fragment easily using SWL. These stones frequently require subsequent intracorporeal treatments. Our data supports these statements with regards to cystine stones only. We found that patients who failed prior SWL were more likely to have cystine stones. However, we did not note the same finding with regards to calcium oxalate monohydrate stones. On the contrary it was noted that patients who underwent primary PUL were more likely to have stones composed of calcium oxalate monohydrate as compared to SWL failure group. This finding may reflect our practice bias, which favors PUL as a primary therapy over SWL for known calcium oxalate monohydrate stones.

Our own practice is to treat known cystine stone formers with PUL, not SWL. Only one of our cystine stone patients had not been previously treated with SWL. This reflects the fact cystinuria is a rare disease and the majority of our patients are referred from other facilities after treatment failure.

This addresses a difficult diagnostic situation in new stone formers. If a patient is a known calcium oxalate monohydrate or cystine stone former they have a high probability of failing SWL and requiring subsequent PUL salvage. From a financial and time perspective it would be beneficial for these patients to proceed directly to PUL treatment and bypass multiple SWL failures. Currently, this is only possible if the patient has undergone prior stone analysis or has a known medical history. Attempts have been made by clinicians in the past to predict stone composition by radiographic appearance, but results have been disappointing. A panel study consisting of two urologists, two nephrologists, and two radiologists attempted to determine stone composition based on radiographic appearance alone. Correct diagnosis of stone composition occurred less than fifty percent of the time.[12] This high percentage of predictive error further reinforces the need for development of reliable ways to identify stone composition prior to initiation of therapy. There has been a surge of investigation in the area of computed tomography to determine preoperative stone composition. To date, Hounsfield (HU) unit measurements can only accurately identify uric acid stones.[13] In addition, a recent group has suggested that stones with greater than 500 HU are less likely to be stone free post SWL than those with less than 500 HU.[14] However, study sizes are small and further investigation is still needed.

Interestingly, our study did not note a difference in stone size between the SWL failure group and the primary PUL group. As stated earlier, SWL has decreasing efficacy in stones greater than 2 cm. However, some advocates have suggested using SWL as an initial treatment of even staghorn calculi.[15] As evident by our data SWL is being used in the treatment of large renal calculi. One would expect the SWL failure group to have smaller stones than the PUL group due to SWL fragmentation and the accepted practice of limiting SWL to stones less than 2.5 cm. This data reinforces the concept of SWL failure secondary to stone size and composition.

The size of all stone fragments in the SWL failure group prior to initiating PUL were not measured. In each group only the size of the largest fragment was recorded. Since the SWL failure group had more stone fragments than the primary PUL group one would assume the surgical procedure would be more time consuming or have a higher failure rate as compared to the primary PUL group. However, our data did not reflect this hypothesis.

The study also revealed a disparity in age between the two groups. The age of the patients with primary PUL was 12 years older on average than those that had a prior failed SWL. These results might be explained by larger stones noted in older populations, however we are not fully able to account for this finding. We also noted an equal distribution between genders. In most stone series the male to female ratio is two to one.[16] There is no obvious explanation for the female preponderance noted in this series. This study does not represent a true cross-section of the population, since most patients were referred for particularly difficult or large stones. This may account for the disparity.

The review observed that patients with prior failed SWL had more left sided stones than right. Due to small sample size this was not deemed statistically significant. In 1985 a retrospective review of 1000 percutaneous nephrolithotomies noted of the stones requiring percutaneous intervention 543 were in the left kidney and 457 in the right.[17] This was the first statistically significant display of stone laterality. However, this does not explain this laterality being present only in the SWL failure group. Further investigation into this issue is needed.

We do recognize our small sample size and lack of long-term follow up as weakness of this study. However, results demonstrate that during 1 calendar year PUL was safely instituted after SWL without intraoperative and immediate postoperative complications. It correlates well with known data regarding stone composition and the effectiveness of noninvasive treatment.

Conclusion

Prior SWL was not determined to be a negative factor in PUL outcomes despite its potential complications and damaging effects. This information will assist urologists in percutaneous procedure planning in post SWL patients. However, we do not advocate inappropriate use of SWL as an initial therapy with disregard of stone size, location, or composition. Prior studies have demonstrated these qualities to be important for SWL success. This study also supports the known fact that "hard stones", such as cystine stones have poorer outcomes with SWL and are better treated with PUL, further reinforce the need for research in the area of pretreatment stone composition determination. By determining preoperatively which stones are likely to fragment with SWL and which will fail we will decrease costs incurred by unnecessary procedures. □

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