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Original article

Predicting The Fragility Of Renal Calculi In Response To Shock Wave Lithotripsy Through Their Radiographic Appearance

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ABSTRACT

Objectives: To evaluate the radiological characteristics of renal stones on plain X-ray film of the kidneys, ureters and bladder (KUB) area as predictors of stone fragility during shock wave lithotripsy (SWL).

Patients and Methods: This prospective study included 336 patients who had a single renal pelvic stone ≤20 mm and were managed by SWL at 3 different centers. The patients were classified according to the radiological appearance of the stone on KUB film in terms of homogeneity, smoothness of the outline, and radiodensity in comparison to the last rib. The primary endpoint was the stone-free rate (SFR) within 3 months post-SWL. Multivariate regression analysis was used to compare the results.

Results: The overall SFR was 71.43%. SFR was significantly higher in heterogeneous compared with homogenous stones (86% vs. 53%; $p<0.01$) and in rough compared with smooth surface calculi (77% vs. 61%, $p<0.01$). SFRs for stones with density less than, similar to or higher than that of the last rib were 82%, 69% and 56%, respectively ($p<0.01$). Multivariate analysis showed a positive proportional relationship between stone fragility (SWL outcome) and one or more favorable radiological criteria.

Conclusion: The radiological characteristics of renal calculi could predict their fragility after SWL. Stones which were heterogeneous, rough, or less dense than the last rib on KUB film were more likely to disintegrate during SWL.

Key Words: Shock wave lithotripsy, renal calculi, radiography, urolithiasis

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INTRODUCTION

Shock Wave Lithotripsy (SWL) has radically changed the management of urolithiasis since its introduction in the early 1980s. It replaced most other treatment modalities for upper urinary tract calculi as a safe, effective, reliable, non-invasive outpatient procedure. SWL is suitable as single modality for treatment of 70% of non-selected upper urinary stones and in combination with other endourologic procedures in 20% of complex upper tract stones[1]. A Kidneys Ureters and Bladder (KUB) film is often required to plan lithotripsy treatment in which the appearance of the stone (size, shape and radiodensity) is often used to predict the success of therapy[2,3]. However, compared with other stone characteristics, the relative importance of stone radiodensity in predicting treatment outcome remains to be proved.

The aim of this study was to determine pre-therapeutic criteria that would predict results in term of stone clearance after SWL.

PATIENTS AND METHODS

This multicenter prospective study included 336 patients with single renal pelvic stones ≤20 mm in the largest diameter treated at 3 different centers. SWL was done using the electromagnetic Siemens Lithostar lithotripter. The exclusion criteria were age <16 years, stone >20 mm in largest diameter, multiple calculi, radiolucent stones, morbid obesity, uncorrectable bleeding disorders, associated distal obstruction, and previous SWL failure.

Patients were evaluated with full history, clinical examination and urinalysis with culture and sensitivity when indicated [culture was obtained in 105 (31.1%) patients with pyuria]. Laboratory investigations included serum creatinine, blood sugar, full blood count, liver enzymes and coagulation profile. Electrocardiography was performed in all patients. Imaging studies included KUB, Intavenous Urography (IVU) and Abdominal Ultrasound (AUS). All patients were informed about their treatment options including success rate, the need for retreatment, the expected time needed for stone clearance, analgesia, risks and possible complications.

SWL was started at a low energy level (10 Kv) and after 100-200 shocks the energy was gradually increased in a stepwise manner to the highest level the patient could tolerate. Intravenous sedation in the form of pethidine 50 mg infusion was administered and the calculus was monitored fluoroscopically. The procedure was terminated when disintegration was satisfactory or when 4000 shock waves had been given at 14-15 Kv. Radiological characteristics of the stone were assessed on the KUB in terms of the homogeneity of its texture, smoothness of its surface, and its radiodensity in comparison to the last rib (Table 1). Stone-free rate was defined as complete clearance of the stone fragments or the presence of clinically non-obstructing fragments ≤3 mm. SWL was

Table 1: Radiological characteristics of stones

Radiological characteristic		Number	%
Texture	**Homogenous**	147	43.8
	Heterogeneous	189	56.3
Surface	**Smooth**	123	36.6
	Rough	213	63.4
Radiodensity in relation to last rib	**Less dense**	147	43.8
	Similar	108	32.1
	More dense	81	24.1
Total		**336**	**100.0**

repeated biweekly until the patients became stone-free, or for a maximum of 3 sessions if not stone-free. All the radiological parameters of stones were evaluated by a fixed team consisted of 2 authors and a radiologist to avoid inter-observer bias.

Patients were evaluated after one week and then bi-weekly by history and clinical examination together with KUB and AUS to evaluate the presence of complications and to assess stone clearance. The treatment was terminated if satisfactory fragmentation was achieved. Failure of SWL was considered if the stone did not fragment well after 3 SWL sessions and/or had not cleared within 3 months from the date of the first session. The patients were then redirected for alternative stone management. Data analysis was performed using the commercially available SPSS for Windows version 17 (Chicago, IL). Descriptive data were presented as means and standard deviation. Fisher's exact test was used for comparing SFR between groups (2-tailed $p<0.05$ accepted as statistically significant). Factors with significant impact on SFR in univariate analysis were further analyzed using multivariate analysis.

RESULTS

Sixty five percent of the patients were males with a mean age of was 39 ± 4.4 (range 18 – 51) years and a mean body mass

Table 2: Stone-free rates after SWL stratified by radiological stone characteristics

Radiological characteristic		Stone-free No (%)	Residual stones No (%)	p-value
Texture	Homogenous	78 (53.1)	69 (46.9)	0.0001
	Heterogeneous	162 (85.7)	27 (14.3)	
Surface	Smooth	75 (61.0)	48 (39.0)	0.002
	Rough	165 (77.5)	48 (22.5)	
Radiodensity in relation to last rib	Less dense	120 (81.6)	27 (18.4)	0.001
	Similar	75 (69.4)	33 (30.6)	
	More dense	45 (55.6)	36 (44.4)	
Total		**240 (71.43)**	**96 (28.57)**	**NA**

index of 29.7 ± 8.4 kg/m2 and a mean stone size of 12 ± 2.3 mm. The overall SFR was 71.43%. The SFR of renal pelvic stones after SWL was stratified according to their radiological appearance (Table 2). In terms of stone texture, patients who had heterogenous calculi had a higher SFR than those with homogeneous stones (86% vs. 53%; $p<0.01$). In terms of stone surface, patients with rough stones had a higher SFR than those with smooth stones (78% vs. 61%, $p<0.01$) even after adjustment for stone size. The lower the density of the stone (compared to the last rib), the greater the SFR ($p< 0.01$) even after correction for stone size (Table 2). There was no statistical difference between groups in terms of number of shock waves required for successful clearance ($p=0.2$).

Multivariate analysis showed that both radiographic criteria (stone density, smoothness and homogeneity) as well as stone size had a prognostic impact on SWL outcome (Table 3). There was a positive proportional relationship between stone fragility and one or more favorable radiological criteria (Fig. 1). SFR approached 100% for heterogeneous, rough and less dense stones <15 mm in size. On the contrary, homogenous, smooth, highly dense and large stones had a lower SFR after SWL.

DISCUSSION

SWL is a widely accepted, noninvasive option for the treatment of urinary calculi, although contemporary success rates have a broad range (46 to 91% with efficiency quotient 0.36-0.67)[4-9]. This is due to many factors including the type of lithotripter used, accurate focusing, operator experience and the stone characteristics. Radiographic appearance, stone size, multiplicity, location and chemical composition of the calculi have a pronounced impact on the results of SWL[10]. The sensitivity and specificity of radiological parameters for prediction of treatment success were determined by some authors to be 84.2% and 80.6%, respectively[11].

There is a relationship between the composition of calculi, their radiographic appearance and SWL results. Calculi predominantly formed of calcium oxalate dihydrate (COD) have been described as rough with a density lower than or equal to that of bone, and have a favorable SWL prognosis. Conversely, calculi predominantly formed of calcium oxalate monohydrate (COM) have been described as homogenous, denser than bone, with smooth surface and unfavorable SWL prognosis. The effect of stone composition on resistance to shock waves has been characterized by its appearance on KUB films[2,12,13]. Thus, it is possible to predict, to a great extent, the chemical composition of a stone by KUB or computed tomography[12, 14].

Table 3: Multivariate analysis of factors affecting stone-free rate after SWL

Variables		Stone free Mean ± SD/ No (%)	Residuals Mean ± SD/ No (%)	p-value
Age (yrs)		39.1 ± 7.8	43.0 ± 5.7	0.79
Mean stone size (mm)		10.5 ± 1.7	11.7 ± 2.1	0.01
Fluoroscopy time (min)		2.2 ± 1.2	2.4 ± 1.3	0.18
Energy Used		6.7 ± 0.9	6.9 ± 1.2	0.09
Total number of shocks		3893 ± 51	3978 ± 193	0.21
Sex	Male	132 (25.9)	56 (74.1)	0.10
	Female	108 (19.0)	40 (81.0)	
Laterality	Left	142 (29.0)	55 (71.0)	0.001
	Right	98 (16.4)	41 (83.6)	
Radiological characteristic	Homogenous	78 (53.1)	69 (46.9)	0.01
	Heterogeneous	162 (85.7)	27 (14.3)	
	Smooth	75 (61.0)	48 (39.0)	0.03
	Rough	165 (77.5)	48 (22.5)	
	Less dense	120(81.6)	27 (18.4)	
	Similar	75(69.4)	33 (30.6)	0.01
	More dense	45(55.6)	36 (44.4)	

Stone composition is an independent variable that may be useful to predict SWL success. The concept that renal stones of different types have variable susceptibility to shock waves has been appreciated since SWL came into common use, and this was termed "stone fragility". If stone fragility could be predicted before treatment, stones that would not break easily by SWL could be treated by other methods. Stone fragility is related to stone composition: uric acid stone require the fewest shock waves to break, while cystine stones are least fragile[15].

In line with the present study, others have found that stones up to 15 mm in diameter that are more radio-dense than bone are difficult to break whereas those less dense are more likely to break with SWL[16]. Spiral CT scan has been used to predict stone fragility. Stone density >1000 HU indicates less fragility with poor results after SWL, while density <600 HU predicts for successful SWL, independent of stone size and location[5, 17]. Clearance rates following SWL with stone attenuation values <500 HU are as high as 98%, with 500-1000 HU 67% and >1000 HU only 54%[17]. Stones with attenuation >1000 HU should receive a greater number of shock waves or be treated with another modality (e.g. ureteroscopy or percutaneous nephrolithotomy) to save cost and renal damage from excess inefficient shock waves[17].

Stone fragility in response to SWL shows marked variability and even knowledge of major stone composition does not allow adequate prediction of its fragility to SWL. The CT attenuation value of kidney stones is affected by several factors such as the size of the stone, its composition, the energy of the CT machine and the slice thickness (collimation) used to image the stone[18].

Mattelaer and colleagues observed that high radio-density stones needed an average

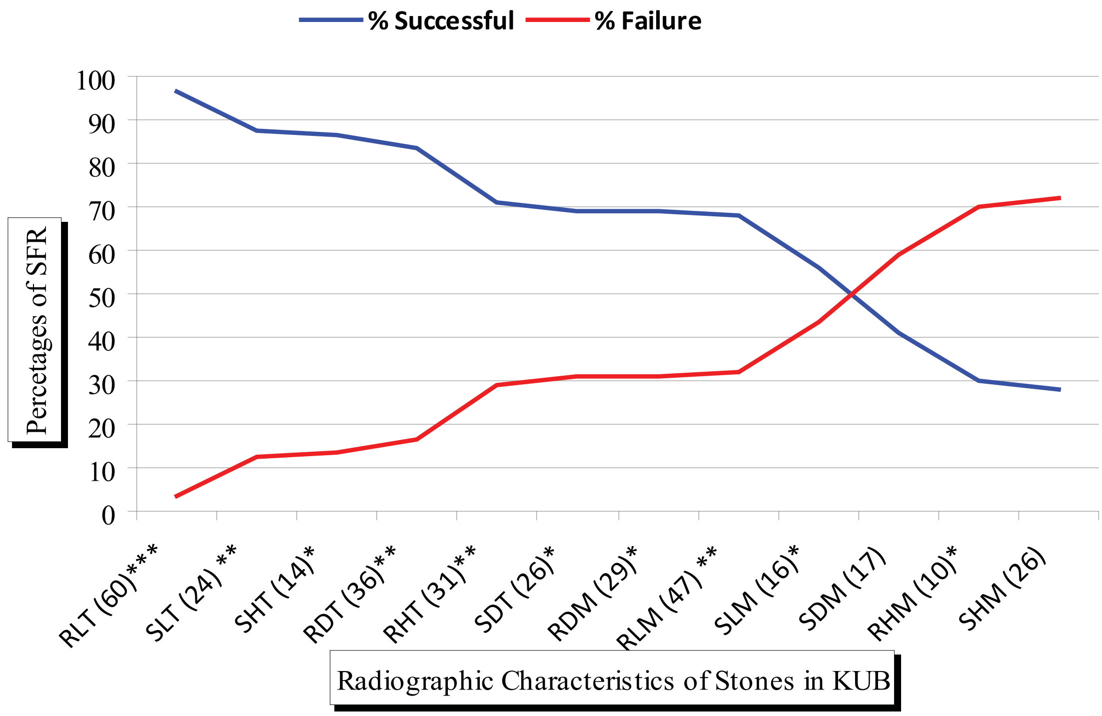

Fig. 1: R = Rough, S = Smooth, L = Less dense, D = Similar density to rib, H = Hyperdense, T = Heterogeneous, M= Homogenous
* One favourable radiological criterion, ** Two favourable radiological criteria,
*** Three favourable radiological criteria.

of 1.7 times more shock waves than low radio-density stones of the same size to attain comparable stone free rates[19]. CT attenuation values at small collimation (1-3 mm) have greater ability to predict stone composition in vitro, but this remains to be verified in clinical practice[20]. Uric acid calculi may be differentiated from calcium stones based on their HU, but this distinction can also be made by characteristic radiodensity of that stone type on the KUB film plus urinary pH[3].

Recently, Arshadi and colleagues assessed the accuracy of radiological characteristics in estimating the success rate of SWL in patients with kidney calculi and concluded that calculus density compared with the adjacent bone, and calculus shape could predict the success rate of SWL[11]. These findings support the results in the present series. Bon et al reported that dense, smooth calculi larger than 15 mm and located in the lower calyx were characterized by unfavorable prognosis for SWL[21]. They reported that the SFR was 79.4% for rough, less dense calculi and 33.6% for smooth or denser calculi. SWL success rate was 65% for COD stones which are rough and less dense versus 41% for COM stones which are homogenous and of higher density[21].

The present study showed that the overall SFRs were 82%, 69% and 56% for stones with density lower than, similar to or greater than bone density, respectively. Aeberli et al found no correlation between stone radiodensity and disintegration, but their results were not stratified according to stone size and location[22]. Krishnamurthy et al found that stone radiodensity alone did not predict the SWL outcome for stones <10 mm in the renal pelvis. However, with increased stone size >10 mm, this parameter was useful and could be used in combination with other stone parameters to select appropriate therapy[23].

CONCLUSIONS

The efficacy of SWL in the management of renal stones is related to the radiological characteristics of the stone which reflect its composition and fragility, such as homogeneity, smoothness and radiodensity in relation to the last rib. Stones which are non- homogenous, rough or less dense than the last rib on KUB films are more efficiently disintegrated by SWL.

REFERENCES

1. Fuchs GJ. Interventional urinary stone management. J.Urol. 1994; Mar;151(3):668-9.

2. Grasso M, Loisides P, Beaghler M, Bagley D. The case for primary endoscopic management of upper urinary tract calculi: I. A critical review of 121 extracorporeal shock-wave lithotripsy failures. Urology. 1995; Mar;45(3):363-71.

3. Dretler SP, Polykoff G. Calcium oxalate stone morphology: Fine tuning our therapeutic distinctions. J.Urol. 1996; Mar;155(3):828-33.

4. Abe T, Akakura K, Kawaguchi M, Ueda T, Ichikawa T, Ito H, et al. Outcomes of shockwave lithotripsy for upper urinary-tract stones: A large-scale study at a single institution. J.Endourol. 2005; Sep;19(7):768-73.

5. Perks AE, Schuler TD, Lee J, Ghiculete D, Chung DG, D’A Honey RJ, et al. Stone attenuation and skin-to-stone distance on computed tomography predicts for stone fragmentation by shock wave lithotripsy. Urology. 2008;72(4):765-9.

6. White W, Klein F. Five-year clinical experience with the Dornier Delta lithotriptor. Urology. 2006; Jul;68(1):28-32.

7. Coz F, Orvieto M, Bustos M, Lyng R, Stein C, Hinrichs A, et al. Extracorporeal shockwave lithotripsy of 2000 urinary calculi with the modulith SL-20: Success and failure according to size and location of stones. J.Endourol. 2000; Apr;14(3):239-46.

8. Albala DM, Assimos DG, Clayman RV, Denstedt JD, Grasso M, Gutierrez Aceves J, et al. Lower pole I: A prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy for lower pole nephrolithiasis-initial results. J.Urol. 2001; Dec;166(6):2072-80.

9. Pace KT, Ghiculete D, Harju M, Honey RJ. Shock wave lithotripsy at 60 or 120 shocks per minute: A randomized, double-blind trial. J.Urol. 2005; Aug;174(2):595-9.

10. Ackermann DK, Fuhrimann R, Pfluger D, Studer UE, Zingg EJ. Prognosis after extracorporeal shock wave lithotripsy of radiopaque renal calculi: A multivariate analysis. Eur.Urol. 1994;25(2):105-9.

11. Arshadi H, Dianat SS, Ganjehei L. Accuracy of radiological features for predicting extracorporeal shock wave lithotripsy success for treatment of kidney calculi. Urol.J. 2009;6(2):88-91.

12. Cohen NP, Parkhouse H, Scott ML, Bowsher WG, Crocker P, Whitfield HN. Prediction of response to lithotripsy--the use of scanning electron microscopy and X-ray energy dispersive spectroscopy. Br.J.Urol. 1992; Nov;70(5):469-73.

13. Dretler SP. Stone fragility--a new therapeutic distinction. J.Urol. 1988; May;139(5):1124-7.

14. Bhatta KM, Prien EL,Jr, Dretler SP. Cystine calculi--rough and smooth: A new clinical distinction. J.Urol. 1989; Oct;142(4):937-40.

15. Williams JC,Jr, Saw KC, Paterson RF, Hatt EK, McAteer JA, Lingeman JE. Variability of renal stone fragility in shock wave lithotripsy. Urology. 2003; Jun;61(6):1092,6; discussion 1097.

16. Chaussy C, Fuchs G, Kahn R, Hunter P, Goodfriend R. Transurethral ultrasonic ureterolithotripsy using a solid-wire probe. Urology. 1987; May;29(5):531-2.

17. Joseph P, Mandal AK, Singh SK, Mandal P, Sankhwar SN, Sharma SK. Computerized tomography attenuation value of renal calculus: Can it predict successful fragmentation of the calculus by extracorporeal shock wave lithotripsy? A preliminary study. J.Urol. 2002; May;167(5):1968-71.

18. Saw KC, McAteer JA, Fineberg NS, Monga AG, Chua GT, Lingeman JE, et al. Calcium stone fragility is predicted by helical CT attenuation values. J.Endourol. 2000; Aug;14(6):471-4.

19. Mattelaer P, Schroder T, Fischer N, Jakse G. In situ extracorporeal shockwave lithotripsy of distal ureteral stones: Parameters for therapeutic success. Urol.Int. 1994;53(2):87-91.

20. Saw KC, McAteer JA, Monga AG, Chua GT, Lingeman JE, Williams JC,Jr. Helical CT of urinary calculi: Effect of stone composition, stone size and scan collimation. AJR Am.J.Roentgenol. 2000; Aug;175(2):329-32.

21. Bon D, Dore B, Irani J, Marroncle M, Aubert J. Radiographic prognostic criteria for extracorporeal shock-wave lithotripsy: A study of 485 patients. Urology. 1996; Oct;48(4):556,60; discussion 560-1.

22. Aeberli D, Muller S, Schmutz R, Schmid HP. Predictive value of radiological criteria for disintegration rates of extracorporeal shock wave lithotripsy. Urol.Int. 2001;66(3):127-30.

23. Krishnamurthy MS, Ferucci PG, Sankey N, Chandhoke PS. Is stone radiodensity a useful parameter for predicting outcome of extracorporeal shockwave lithotripsy for stones < or = 2 cm? Int.Braz J.Urol. 2005; Jan-Feb;31(1):3,8; discussion 9.