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Non-Contrast Computed Tomography Scan as a Predictor of Shock-Wave Lithotripsy Outcomes for the Treatment of Renal Stones

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ABSTRACT

Purpose: We assess the value of non-contrast computed tomography (NCCT) as a possible predictor of renal stone disintegration by shock-wave lithotripsy (SWL), aiming for a better selection of patients.

Materials and Methods: Forty-five patients (27 males, 18 females) with a mean age of 39.1 ± 12.5 years were reviewed between August 2008 to September 2009. All patients had a solitary renal stone ranging in size from 5 to 25 mm. High-resolution NCCT was done and a bone window was used to measure stone attenuation values. SWL was performed with an electromagnetic lithotripter. Failure was defined as no stone fragmentation after 3 sessions. The impact of the patient's sex, age, body mass index (BMI), stone location, volume, mean attenuation value, and the skin-to-stone distance on stone disintegration was statistically evaluated. The mean follow-up period was 3 months.

Results: The overall stone-free rate at 3 months was 84.4% (38 of 45 patients); 28 patients were stone free and 10 patients had residual fragments < 4 mm. The only significant predictor of residual fragments was stone density (p < 0.001). Failure of disintegration was observed in 7 patients (15.5%). Stone density > 1000 HU and BMI > 30 were the significant independent predictors of failure (p = 0.002 and 0.001, respectively).

Conclusion: Increased stone density as detected by NCCT is a significant predictor of failure to fragment renal stones by SWL. An alternate treatment should be devised for obese patients with a stone density > 1000 HU.

INTRODUCTION

The concept of using shock waves to fragment stones was noted in 1955 [1]. Currently, shock-wave lithotripsy (SWL) is the most common mode of therapy for small renal stones [2]. Stones are first disintegrated by shock waves, and then fragments are spontaneously cleared from the urinary tract. The failure of stone disintegration results in unnecessary exposure of the renal parenchyma to shock waves and the requirement of an alternative treatment procedure, which increases medical costs. Hence, it is important to identify patients who will benefit from SWL prior to treatment by examining stone fragility.

Many studies have attempted to correlate the radiographic findings of non-contract computed tomography (NCCT) with SWL success. The main drawbacks of these studies were the use of low-resolution CT protocols in some or correlating NCCT stone characters with the stone-free rate, which is influenced by other factors such as stone site and pelvicalyceal anatomy [3].

MATERIALS AND METHODS

Forty-five patients (27 males, 18 females) with a mean age of 39.1 ± 12.5 years were reviewed between August 2008 to September 2009. Our inclusion criteria was directed toward

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Figure 1. Body mass index of the included patients.

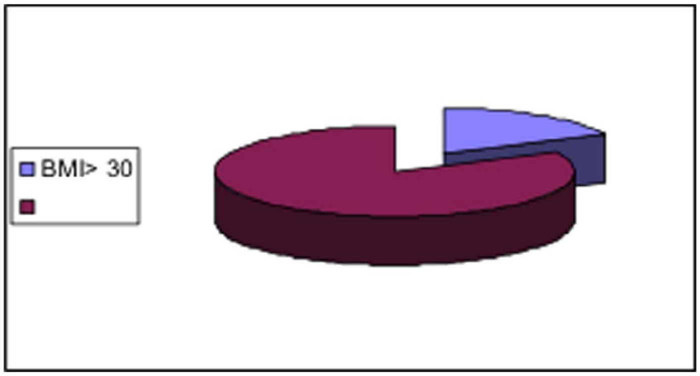

Figure 2. Normal renal CT anatomy.

patients who had a single renal stone of 0.5 to 2.5 cm in the longest dimension (as measured from excretory urography films) and had no contraindications to SWL. High-resolution NCCT of the kidneys was performed for all patients on the same day as the SWL session with a helical CT scanner (GE Prospeed). The images were obtained using high-quality mode at 200 mA, 250 KV, and 2 mm collimation. Body mass index (BMI) was calculated by dividing the weight (kg) by the square of height (m) (Figure 1). The post-scan bone-window protocol was used to measure stone attenuation value (stone density) and volume. For stone density measurement, 3 axial planes were defined for each stone: 1 near the upper end, 1 in the middle, and 1 near the lower end. In each plane, a region of interest smaller than the stone was drawn, the CT attenuation value in Hounsfield units (HU) was measured, and the mean value of the 3 planes was calculated (Figure 2). The skin-to-stone distance (SSD) was calculated by measuring 3 distances from the stone to the skin at 0o, 45o, and 90o using radiographic callipers, and the average of these values was calculated to represent SSD for each stone.

SWL was performed with the electromagnetic (Lithostar) lithotripter. A total of 3 000 shocks were delivered during each session or until the stone was completely fragmented. Patients were evaluated 2 weeks after each session using kidney, ureter, and bladder (KUB) film and a renal ultrasound to assess fragmentation and the presence of renal dilatation. Repeat treatment was carried out if inadequate fragmentation of the stone was observed. If there was no breakage of the stone after 3 sessions, the case was considered a disintegration failure. Patients were evaluated 3 months after the last lithotripsy session by KUB. The procedure was considered successful if patients showed complete clearance of the stone fragments or had small residual gravels < 4 mm. Patients with non-infected, asymptomatic residual gravels < 4 mm were scheduled for regular follow-up every 6 months.

Statistical Analysis

The effect of patient characteristics (sex, age, BMI) and calculus characteristics (laterality, location, volume, stone density, SSD) on stone disintegration by SWL was examined. Both univariate (Chi-square or t-test) and multivariate (logistic regression) analyses were performed to determine significant independent factors. Pearson correlation tests were used to determine the correlation between stone density and the number of shock waves needed until complete stone fragmentation. Statistical analyses were performed using SPSS software.

RESULTS

The 45 patients included were 27 males and 18 females. Their mean age was 39.1 ± 12.5 years, and their mean BMI was 25.8 ± 4.09 kg m^2. The mean stone volume was 1.476 ± 0.441 mm^3, and the mean stone density was 670.7 ± 180.4 HU. Failure of disintegration was observed in 4 patients (9%). According to univariate analyses, higher BMI, stone density >1 000 HU, longer SSD, and larger stone volume were significant predictors of disintegration failure. According to multivariate analyses, the significant independent factors were BMI and stone density >1 000 HU. The success rate of SWL at 3 months was 84.4% (38 of 45 patients): 28 patients were stone free and 10 patients had residual fragments < 4 mm. There was a significant correlation between mean stone density and the number of shock waves needed for complete stone disintegration ($r = 0.002$). Among these patients, the only significant predictor of residual fragments was stone density. The mean attenuation value in stone-free patients was 670.7 ± 180.4 HU, and the mean attenuation value for patients with residual fragments was 1523.1 ± 205.1 HU ($p < 0.002$) (Table 1).

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Table 1. Correlation between mean HU and ESWL outcome.

Mean HU	ESWL Outcome		
	stone free	significant residuals	no response
	670.7 ± 180.4	1151.3 ± 267.4	1523 ± 205.1
p value	0.002 (significant)		

DISCUSSION

Disintegration is the first step in the treatment of renal stones by SWL. The magnitude of response of a calculus to disintegration (stone fragility) should be considered before using SWL. It is often not possible to predict whether or not a given stone is amenable to fragmentation by shock waves before starting treatment; however, there are many factors that affect stone fragility such as size and composition [4].

In general, stones composed of uric acid are broken up easily by shock waves, whereas stones of calcium oxalate monohydrate (COM), brushite, or cystine are difficult to break. Few stones are composed of a single material, however, and the variability of stone fragility within the same class is dramatic [5]. Moreover, because there is marked overlap between attenuation values of different stone classes, stone composition cannot be accurately predicted before the retrieved stones are analyzed. Nakada et al. was only able to differentiate between uric acid and COM stones using peak attenuation measurements [6], whereas Sheir et al. could only differentiate between pure stone classes [7]. Knowing stone composition before treatment is difficult and may not be sufficient to predict the response to SWL. Therefore, as was done in the present study, pre-SWL radiographic examinations should focus on those radiological stone characteristics that influence SWL outcome rather than on stone composition.

Many radiological methods and parameters have been evaluated for their ability to predict stone fragility. For example, Bon et al. found that smooth, uniform calculi that appeared denser than bone on KUB responded poorly to SWL [4]. Mandhani et al. concluded from their study using dual X-ray absorptiometry that patients with high stone-mineral content should not be treated with SWL. NCCT has proven to be the most sensitive and accurate imaging modality for the diagnosis of urolithiasis [8]. It is superior to both KUB and intravenous urograms in its ability to detect radiolucent and small stones without interference with colonic gas shadows and, also, because it can precisely localize the site of the stone without the need for iodinated contrast. Thus an increasing number of hospitals have accepted NCCT as the preferred imaging modality for the assessment of urinary stones [9].

Regarding stone characteristics, NCCT is more accurate than KUB in determining stone burden (number and volume), and the measurement of stone attenuation value is more accurate in the determination of stone density [10]. Moreover, the internal structure of renal calculi can be identified with high-resolution NCCT protocols using a bone window and narrow slide width. In this series, we used a bone window for a more accurate estimation of the stone size and the attenuation values of the upper, middle, and lower part of each stone.

Many studies had investigated the effect of various stone characteristics detected by NCCT on the success of SWL [9]. The most extensively studied character was the CT stone attenuation value (stone density), with high-density stones requiring more shock waves for fragmentation. Joseph et al. found a positive correlation between the number of shock waves required to treat a stone and its CT attenuation value [3]. In our study, we found a significant correlation between stone attenuation value and a number of shock waves needed for stone disintegration. Regarding the effect of stone density on the rate of residual fragments after SWL, Pareek et al. found that the mean stone attenuation values were significantly higher in patients with residual stones [11]. In our series, we reproduced these results using high-resolution CT protocols since we observed that the stone attenuation value was a significant predictor of the rate of residual fragments.

Recent studies have used high-resolution CT protocols to predict the outcome of SWL. For example, Gupta et al. concluded that the worst outcome was in patients with a calculus density > 750 HU and a stone diameter of > 1.1 cm; 77% of those patients needed more than 3 sessions of SWL and the clearance rate was 60% [12]. Wang et al. concluded that stone density > 900 HU and a volume > 700 mm^3 were significant predictors of SWL failure [13]. Comparable results were observed in the present study in which larger stone volume and higher stone density were significant predictors of the need for more than 3 sessions, and a stone density > 1000 HU was a significant predictor for disintegration failure. The differences in the cut-off values that predicted extracorporeal SWL failure may be due to different inclusion criteria, the use of different CT protocols, or the measurement of different end points (e.g., the failure of disintegration, the need for multiple sessions, or the rate of residual stones) in these studies

Therefore, further studies with a large number of patients and a standardized CT protocol are needed to clarify this point. The other significant predictor of disintegration failure in our study was higher BMI. The same was reported by Pareek et al. who observed a significant negative impact of higher BMI on the stone-free rate after SWL [11]. SWL failure in obese patients may be explained by hampered targeting of the stone or dampened

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shock waves. In contrast to Pareek et al., we found that SSD was a significant predictor of failure based on univariate (but not multivariate) analysis. Additional studies in this area are needed to provide conclusive data.

CONCLUSION

Based on this prospective study, we conclude that obesity and a high-stone CT attenuation value are significant predictors of failure to fragment renal stones by SWL. Therefore, an alternative treatment should be devised for obese patients with a stone density > 1000 HU.

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