Preoperative Stone Attenuation Value Predicts Success After Shock Wave Lithotripsy in Children

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Abbreviations and Acronyms

CT = computerized tomography

KUB = plain x-ray of kidneys, ureters and bladder

NCCT = noncontrast CT

SSD = skin-to-stone distance

SWL = shock wave lithotripsy

Study received University of Minnesota institutional review board approval.

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Purpose: We determined whether stone attenuation can predict stone fragmentation after shock wave lithotripsy in the pediatric population. Previous studies show that preoperative attenuation in HU on noncontrast computerized tomography predicts shock wave lithotripsy success. To our knowledge study of this parameter in the pediatric population has been lacking to date.

Materials and Methods: We performed a multi-institutional review of the records of 53 pediatric patients 1 to 18 years old who underwent shock wave lithotripsy for 3.8 to 36.0 mm renal calculi. Stone size, average skin-to-stone distance and attenuation value were determined by bone windows on preoperative noncontrast computerized tomography. Success was defined as radiographically stone-free status at 2 to 12-week followup after a single lithotripsy session without the need for further sessions or ancillary procedures.

Results: After lithotripsy 33 patients (62%) were stone-free and 20 had incomplete fragmentation or required additional procedures. Mean ± SD stone attenuation in successfully treated patients vs those with incomplete fragmentation was 710 ± 294 vs 994 ± 379 HU ($p = 0.007$). Logistical regression analysis revealed that only attenuation in HU was a significant predictor of success. When patients were stratified into 2 groups (less than 1,000 and 1,000 HU or greater), the shock wave lithotripsy success rate was 77% and 33%, respectively ($p < 0.003$).

Conclusions: Stone attenuation less than 1,000 HU is a significant predictor of shock wave lithotripsy success in the pediatric population. This finding suggests that attenuation values have a similar predictive value in the pediatric population as that previously reported in the adult population.

Key Words: kidney; ureter; urinary calculi; lithotripsy; tomography, x-ray computed

Extracorporeal SWL is a primary treatment modality for kidney and proximal ureteral stones in the pediatric population.[1,2] Preoperative imaging is desirable to determine stones that are likely to be fragmented by SWL[2–7] since treatment failure is costly and typically results in additional procedures. Previous studies show that preoperative stone attenuation in HU on NCCT predicts SWL success in the adult population.[8–15] To our knowledge study of this parameter in the pediatric population has been lacking to date. We determined whether the attenuation value of in vivo stones on preoperative NCCT predicts the stone-free rate after SWL in the pediatric population.

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SSD is another parameter that can be determined on NCCT that has been evaluated as a predictor of success in patients who undergo NCCT before SWL. To date this parameter has only been studied in the adult population with studies suggesting a decreased likelihood of successful SWL outcome in patients with greater SSD.[11,14] We determined whether a similar relationship exists in the pediatric population.

METHODS

This study was approved by the University of Minnesota institutional review board. We retrospectively reviewed the medical charts of pediatric patients who underwent SWL for a single upper urinary tract stone at our 3 institutions between June 2000 and June 2009. The center in India was chosen based on an established research relationship between it and University of Minnesota faculty. For study inclusion patient medical charts contained preoperative NCCT, a SWL operative note and followup imaging within 2 to 12 weeks. Treatment was done by 3 urologists in Minneapolis, Minnesota, by 2 in Dallas, Texas, and by 1 in Belgaum, India. All calculi were fragmented under fluoroscopic guidance using a Medstone STS™ second generation electrohydraulic or a Dornier Compact S® electromagnetic lithotriptor.

Stone size, SSD and attenuation were measured in standardized fashion upon retrospective review of archived NCCT images using bone windows[7] and 2.5 mm slice reconstructions. Measurements were made by a physician blinded to SWL session outcome. Stone size was defined as the largest cross-sectional diameter measurable per stone in mm using the picture archiving and communication system viewer ImageCast ruler tool. SSD was determined using the method described by Pareek et al[11] by averaging 3 measurements made from the stone center to the skin (0, 45 and 90 degrees) on axial imaging. Stone attenuation was defined as the highest measurement at the core of each stone in HU using the region of interest tool set to a size of approximately 0.03 to 0.05 cm^2. Measurements were made at the core to minimize volume averaging at the stone edge.

The outcome of each single session SWL was categorized as stone-free, incomplete fragmentation or unchanged on 2 week to 3-month followup imaging by CT, ultrasound or KUB. Success was defined as radiographically stone-free status after a single SWL session without the need for further sessions or ancillary procedures, including ureteroscopy. In addition to attenuation, the SSD, stone size, number of shocks, and patient gender and age were evaluated as success predictors. The 2-tailed unpaired Student t or Fisher exact test was used for univariate analysis with Minitab®, version 15 and $p < 0.05$ considered statistically significant. Multivariate binary logistical regression analysis was done on parameters found to be significant on univariate analysis. Attenuation subanalysis included stratification at 1,000 HU to evaluate success.

RESULTS

Using the study criteria we identified 53 study candidates, including 30 boys (57%) and 23 girls (43%). A total of 48 stones were located in the kidney and 5 were in the proximal ureter. Mean patient age at SWL was 10.3 ± 4.6 years (range 1 to 18). Mean stone size was 10.6 ± 6.8 mm (range 3.8 to 36.0), mean attenuation was 817 ± 354 HU, mean SSD was 6.0 ± 2.6 cm in 39 patients and a mean of 2,255 ± 848 shocks was delivered in 40. After single session SWL 17 boys and 16 girls (33 patients or 62%) were stone-free on followup imaging at a mean of 49 days without the need for further SWL sessions or ancillary procedures. Treatment failed in 13 boys and 7 girls (20 patients or 48%), including 16 (30%) with incomplete fragmentation on followup imaging and 4 (8%) with stones that were considered unchanged, of whom 2 (4%) required percutaneous nephrolithotomy (overall vs stone-free Fisher's exact test $p = 0.40$). Six patients with incomplete fragmentation required further ureteroscopy with basketing and 2 required ureteroscopy with laser lithotripsy. No patient needed ureteral stenting. The only complication of SWL in the 53 patients was renal subcapsular hematoma in 1.

On univariate analysis stone attenuation, stone size and SSD were statistically significant predictors of success. In successful vs failed cases mean stone attenuation was 710 ± 294 vs 994 ± 379 HU ($p = 0.007$, fig. 1), stone size was 8.8 ± 5.9 vs 13.4 ± 8.0 mm ($p < 0.03$) and SSD was 7.0 ± 2.9 vs 5.2 ± 1.5 cm ($p = 0.02$). Figure 2, *A* shows SSD in study patients. Of these parameters multivariate logistical regression analysis revealed that only attenuation in HU was a significant predictor of success (for each 100 HU OR 0.81, 95% CI 0.67 to 0.99, $p = 0.04$). There was no statistically significant difference when comparing gender, age or number of shocks delivered (table 1). Outcomes did not differ significantly by institution or machine. Stone composition

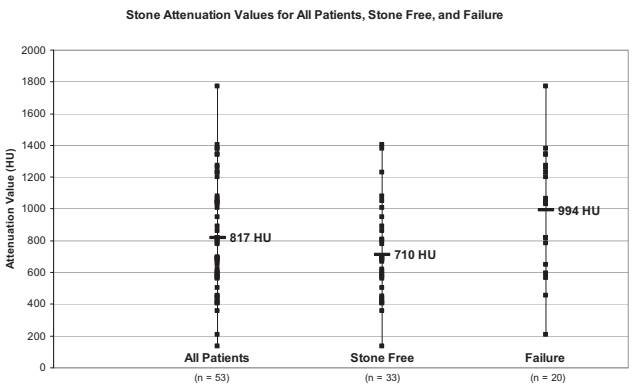

Figure 1. Mean stone attenuation in patients with treatment success vs failure was 710 ± 294 vs 994 ± 379 HU ($p = 0.007$).