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Original Research Article

THE ROLE OF SHEAR WAVE ELASTOGRAPHY IN RENAL CALCULUS AND ITS PREDICTIVENESS OF SUCCESS OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY USED IN THE TREATMENT OF RENAL CALCULUS

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ABSTRACT

Background: Extracorporeal Shock Wave Lithotripsy (ESWL) is a non-invasive treatment for renal calculi, but its success varies based on stone characteristics, especially hardness. Shear Wave Elastography (SWE), an ultrasound-based modality, offers a radiation-free, quantitative method for assessing tissue stiffness and may predict ESWL outcomes. **Aim:** To evaluate the role of SWE in predicting ESWL success and its correlation with Hounsfield Unit (HU) values from computed tomography (CT).

Materials and Methods: This study included 43 adults with solitary renal calculi (5–15 mm) treated with ESWL. SWE values were obtained using a Mindray Resona i9 US before ESWL, and stone density was measured using CT (HU values). Post-ESWL outcomes were assessed using CT, and success was classified as stone-free or residual fragments <4 mm. Statistical comparisons and logistic regression analyses were performed.

Results: The mean SWE was 10.57 ± 5.56 kPa. The mean SWE and HU values were significantly lower in the success group (7.3 ± 2.8 kPa and 728.9 ± 304) than in the failure group (14.5 ± 5.6 kPa and 1117 ± 353) ($p < 0.001$). SWE showed a moderate positive correlation with HU ($r = 0.55$, $p = 0.0002$). Stones >10 mm were more frequent in the failure group. Multivariate logistic regression identified SWE >10 kPa as an independent negative predictor of ESWL success (Adjusted OR = 0.11, $p = 0.005$), while age and gender were not significant predictors.

Conclusion: SWE correlates with CT-derived HU values and effectively predicts ESWL outcomes. As a radiation-free and cost-effective tool, SWE may serve as a valuable adjunct or alternative to CT for evaluating renal stone hardness, particularly in radiation-sensitive populations.

Keywords: Shear wave elastography, Extracorporeal shock wave lithotripsy, Renal calculi, Hounsfield unit, Stone hardness.

INTRODUCTION

Renal calculi are a common urological disorder with an increasing prevalence worldwide, affecting up to 15% of the population. The incidence of this condition has increased in recent decades due to lifestyle modifications such as dietary changes, sedentary habits, and obesity.[1] Kidney stones result from urine supersaturation with certain solutes, leading to crystal formation and aggregation. Common types include calcium oxalate, uric acid, struvite, and cystine stones, with calcium-based stones being the most prevalent.[2]

Extracorporeal Shock Wave Lithotripsy (ESWL) is a non-invasive technique that uses focused acoustic pulses to fragment renal stones and is typically the first-line treatment for renal and proximal ureteral calculi less than 2 cm.3 Its effectiveness is variable and depends on several factors, such as stone size, composition, location, patient BMI, anatomy of the urinary tract, skin-to-stone distance, and equipment used. Among these, stone hardness is particularly crucial, and assessing it before treatment can improve therapeutic decisions.[4]

Currently, non-contrast computed tomography (CT) is the standard imaging technique for evaluating renal stones. CT provides information on stone size, location, and density through Hounsfield Unit (HU) measurements, which indirectly reflect the stone's composition and hardness.[5] Ultrasound (US) is an alternative imaging tool that avoids ionising radiation and is readily available and cost-effective. However, it cannot traditionally assess stone hardness.[6] Shear Wave Elastography (SWE), an emerging US-based technique, quantifies tissue stiffness by measuring shear wave velocity. It has already been established in liver fibrosis and breast lesion evaluation, and recent studies suggest its utility in assessing renal tissue and, potentially, renal calculi.[7]

SWE offers the advantage of being operator-independent and reproducible. It provides real-time quantitative data that can be easily integrated into clinical assessments. Unlike CT, SWE poses no radiation hazard and can be safely repeated for follow-up examinations. It may be particularly useful in populations where radiation exposure is a concern, such as children, pregnant women, and patients with recurrent stones.[8] Therefore, this study aimed to evaluate the effectiveness of SWE in predicting ESWL outcomes and examine its correlation with HU values obtained from CT imaging. If SWE is found to be a reliable predictor, it could pave the way for broader implementation in urolithiasis assessment.

Aim

To determine the overall mean SWE value in patients with renal stones and to assess the correlation between SWE and HU values, specifically comparing their mean values between the ESWL success and failure groups.

MATERIALS AND METHODS

An experimental study without controls involving 43 patients with single renal calculi measuring 5–15 mm in diameter was conducted at the Barnard Institute of Radiology, Madras Medical College, and Rajiv Gandhi Government General Hospital, Chennai, from March 2023 to March 2024. Ethical approval was obtained from the Institute Ethical Committee, and written informed consent was obtained from all participants.

Inclusion Criteria

Patients were adults aged 18 years or older with a single primary renal calculus measuring 5-15 mm located in the upper/mid/lower calyx, pelvis, or PUJ.

Exclusion Criteria

Patients who were pregnant, those with anatomic kidney variations (e.g. single or ectopic kidney), obese patients (BMI > 30), individuals with bleeding diathesis, and psychologically unstable/non-cooperative patients were excluded.

Method

For each patient, after the initial CT evaluation, the exact location, size, and HU value of the renal stone were recorded. A Mindray Resona i9 ultrasound machine was used to perform 2D(SWE) on the calculus. Patients were instructed to hold their breath for 5-10 seconds while a Region of Interest (ROI) was placed on the calculus to obtain three SWE values, which were then averaged. Post-ESWL, patients underwent a follow-up CT scan the next day to determine the procedure's outcome, with success defined as no detectable stone or clinically insignificant residual fragments (< 4 mm), and failure as detectable stone or significant residual fragments (> 4 mm).

Statistical Analysis

Data are expressed as the mean ± standard deviation for continuous variables and as frequency and percentage for categorical variables. Comparisons of continuous data between groups were conducted using the independent-samples t-test, while categorical variables were analysed using Pearson's chi-square test. A two-tailed p-test ($p < 0.05$) was considered significant. All statistical analyses were performed using IBM SPSS software (version 25).

RESULTS

In our study, the median age was 44 years, and the mean age was 43.6 years. Males comprised 55% of the cohort. The average stone size was 10.9 mm (range: 5.6–15 mm), with a mean SWE value of 10.5 kPa and a mean Hounsfield Unit (HU) of 900. Stones were more commonly located on the left side (58%), and nearly half (48%) were found in the lower pole, followed by the pelvis (25%), mid-pole (18%), and upper pole (6%) (Table 1).

Table 1: Demographic and stone profile in the study population

Parameter	Min – Max	Median	Mean	Range
Age (years)	19 – 72	44	43.6	53
Gender	Males – 24 (55%), Females – 19 (45%)	—	—	—
Stone Size (mm)	5.6 – 15	10.7	10.9	9.4
SWE (kPa)	3.4 – 28	9.1	10.5	24.6
Hounsfield Unit (HU)	190 – 1602	900	900	1412

Side of Stone	Right – 18 (41%), Left – 25 (58%)	—	—	—
Stone Localization	Pelvis – 11(25%), Upper pole – 3(6%), Mid pole – 8(18%), Lower pole – 21(48%)	—	—	—

The mean age of patients with successful outcomes is 41.5 years, while those in the failure group had a mean age of 46 years. Males predominated in the success group (70%), whereas females predominated in the failure group (64%). Stones in the failure group were larger on average (11.5 mm vs. 10.4 mm), with significantly higher SWE (14.5 ± 5.6 kPa) and HU values (1117 ± 353) than those in the success group (7.3 ± 2.8 kPa and 728.9 ± 304, respectively). Left-sided stones were more frequent in the success group, and most stones in both groups were located in the lower pole (Table 2).

Table 2: Baseline characteristics of patients based on ESWL outcome

Parameter	Success (n = 24)	Failure (n = 19)
Age (years)	Mean: 41.5 Median: 43	Mean: 46 Median: 44
Gender	Male: 17 (70%) Female: 7 (30%)	Male: 7 (36%) Female: 12 (64%)
Stone Size (mm)	Mean: 10.4 Median: 10.6	Mean: 11.5 Median: 11.7
SWE (kPa)	7.3 ± 2.8 Median: 7.2	14.5 ± 5.6 Median: 15.5
HU (CT)	728.9 ± 304 Median: 710	1117 ± 353 Median: 1200
Side of Stone	Right: 8 (33%) Left: 16 (67%)	Right: 10 (52%) Left: 9 (48%)
Stone Location	Pelvis: 5 (21%) Upper pole: 2 (8%) Mid pole: 5 (21%) Lower pole: 12 (50%)	Pelvis: 6 (32%) Upper pole: 1 (5%) Mid pole: 3 (15%) Lower pole: 9 (48%)

The overall mean SWE value for all patients was 10.57 ± 5.56 kPa. The mean SWE in the success group was significantly lower (7.3 ± 2.8 kPa) than that in the failure group (14.5 ± 5.) with (p = 0.0001). Similarly, the mean HU values were significantly lower in successful cases (728.9 ± 304) than in failed cases (1117 ± 353) (p=0.0004). Pearson's correlation analysis showed a moderate positive correlation between SWE and HU values (r = 0.55, p = 0.0002) (Table 3).

Table 3: Comparison of SWE and HU values between ESWL groups

Analysis Objective	Group/Value	Mean ± SD	P-value
Overall mean SWE value	All patients	10.57 ± 5.56	—
Comparison of SWE between ESWL success and failure groups	Success	7.3 ± 2.8	0.0001
	Failure	14.5 ± 5.6	
Comparison of HU between ESWL success and failure groups	Success	728.9 ± 304	0.0004
	Failure	1117 ± 353	
Correlation between SWE and HU	Pearson correlation coefficient (r)	r = 0.55	0.0002

Univariate and multivariate logistic regression analyses revealed that SWE >10 kPa was a significant negative predictor of ESWL success (Adjusted OR 0.11; 95% CI: 0.024–0.51; p = 0.05). Gender and age did not significantly affect the outcomes after adjustment. Patients with stones >10 mm had lower odds of success, although this finding was not significant (Table 4).

Table 4: Logistic regression of age, gender, stone size, and SWE in predicting ESWL success

Variable	Category	Total n (%)	Success n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	P-value
Age (years)	≤30	8 (19%)	7 (29%)	Reference	Reference	—
	>30	35 (81%)	17 (71%)	0.13 (0.014–1.21)	0.23 (0.022–2.55)	0.23
Gender	Male	24 (55%)	17 (70%)	Reference	Reference	—
	Female	19 (45%)	7 (30%)	0.24 (0.06–0.86)	0.35 (0.07–1.62)	0.18
Stone Size (mm)	≤10	16 (37%)	10 (42%)	Reference	—	—
	>10	27 (63%)	14 (58%)	0.81 (0.23–2.81)	—	—
SWE Value (kPa)	≤10	22 (51%)	18 (75%)	Reference	Reference	—
	>10	21 (49%)	6 (25%)	0.08 (0.021–0.37)	0.11 (0.024–0.51)	0.05

SWE >10 kPa remained a significant independent predictor of ESWL failure (OR = 0.1129; 95% CI: 0.0248–0.5144; p = 0.005). Neither gender (OR = 0.3511; p = 0.18) nor age >30 years (OR = 0.2394; p = 0.236) showed significant differences (Table 5).

Table 5: Multivariable logistic regression output for predicting ESWL success

Variable	Odds Ratio (OR)	Std. Error	Z	P-value	95% Confidence Interval
SWE >10 kPa	0.1129	0.0874	-2.82	0.005	0.0248 – 0.5144
Gender	0.3511	0.2742	-1.34	0.18	0.0760 – 1.6226
Age >30 years	0.2394	0.2891	-1.18	0.236	0.0225 – 2.5519
_Constant	21.3754	25.888	2.53	0.011	1.9907 – 229.5168

DISCUSSION

In our study, the mean age of successful outcomes is 41.5 years vs. 46 years in the failure group. This is similar to a study by Tubsaeng et al., in which failure of ESWL was observed more in patients aged > 40 years. Their success rate for patients aged ≤ 40 years was 78.2%, which decreased for older patients. A study by Wagenius et al. found that younger age was a significant predictor of successful ESWL, a finding that has been shown previously in other studies.

Our study found that the stones in the failure group were larger on average (11.5 mm vs. 10.4 mm). This is consistent with the results of the study by Shinde et al., where univariate analysis showed a significant difference, with a higher success rate for stones < 10 mm (83.8%) vs. > 10 mm (64.3%).

In our study, a significant difference was observed in the HU values between the ESWL success and failure groups. The mean HU in the success group was 728.9 ± 304, whereas the failure group had a significantly higher mean HU of 1117 ± 353 ($p = 0.0004$). Similarly, El-Assmy et al., reported that HU >1000 was predictive of ESWL failure. Ouzaid et al., identified cut-offs of 970 HU, above which only 38% of patients were stone-free compared to 96% below this threshold. Similarly, other studies have categorised patients into HU-based groups: <500, 500–1000, and >1000, showing corresponding success rates of 100%, 95.7%, and 44.6%, respectively. Our data closely align with these findings, as our success group averaged below these critical cut-offs and the failure group.

In our study, the mean SWE value in the success group was 7.3 ± 2.8 kPa, compared to 14.5 ± 5.6 kPa in the failure group ($p = 0.0001$). These results suggest that lower SWE values correlate with successful ESWL outcomes, likely because softer stones are more amenable to fragmentation. This finding is similar to the conclusions of Abdelaziz et al., who demonstrated that SWE can be used to quantify stone stiffness and predict ESWL outcomes. In their study, SWE values ≥15.5 kPa and HU >894 were significantly associated with treatment failure.

Logistic regression analysis in our study showed that SWE >10 kPa was associated with significantly reduced odds of ESWL success (Adjusted OR = 0.11, $p = 0.05$), confirming its utility as a predictive tool. In contrast, neither age (Adjusted OR = 0.23, $p = 0.236$) nor gender (Adjusted OR = 0.35, $p = 0.18$) was a significant predictor of outcome. This is consistent with a study by Koçakgöl et al., who concluded that stone-specific factors outweigh patient demographics in determining ESWL efficacy.

Our study explored the correlation between SWE and HU values and found a moderate positive correlation ($r = 0.55$, $p = 0.0002$) between these two parameters. This positive correlation suggests that as the stone density (measured in HU) increases, so does its stiffness (measured by SWE). This finding is consistent with other emerging research that has begun to explore this relationship, indicating that SWE can serve as a reliable support for HU in assessing stone hardness. For example, Samir et al., reported a significant correlation between stone density measured using HU and SWE, concluding that SWE could be used as an alternative to HU in decision-making before SWL. Similarly, Demir et al., found a correlation between SWE and HU values in their pilot study, further supporting the potential interchangeability of these measurements for predicting ESWL success.

Limitations

Our study was limited by its small sample size and the exclusion of patients with obesity or anatomical variations, which may have affected its generalisability. SWE values can be operator- and equipment-dependent, despite efforts to standardise measurements.

CONCLUSION

Our study highlights the potential of SWE as a reliable, noninvasive tool for predicting the success of ESWL in patients with renal calculi. SWE values showed a significant correlation with CT(HU), reflecting stone hardness, and SWE >10 kPa was an independent predictor of ESWL failure. Given its radiation-free, cost-effective, and reproducible nature, SWE can serve as a valuable adjunct or alternative to CT, particularly in radiation-sensitive populations. Further large-scale studies are needed to validate and standardise its clinical use for urolithiasis assessment.

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