Original Article

A prospective observational study on the predictability of Triple-D score versus Quadruple-D score in the success rate of extracorporeal shock wave lithotripsy of renal stones 1–2 cm in diameter

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Abstract

Introduction: The aim of the study is to evaluate the clinical efficacy of Triple-D scoring system versus Quadruple-D scoring system for assessing stone-free rate (SFR) in individuals with renal stones measuring 1–2 cm in diameter after extracorporeal shock wave lithotripsy (ESWL).

Materials and Methods: The study was conducted on 120 patients who presented to a tertiary care center in eastern India. Systemic random sampling technique was applied with a sampling interval of 2. Triple-D scoring system comprising of three computed tomography based metrics – stone dimension (volume), stone density (Hounsfield unit), and skin-to-stone distance (SSD) was done before ESWL. Stone location was included as an additional parameter to formulate Quadruple-D scoring system where an extra score was given for stones in the non-lower polar region. Stone-free status was assessed by plain abdominal radiography 3 weeks after ESWL.

Results: In the study population, stone dimension, stone density, and stone location were positive predictors of SFR after ESWL whereas age, sex, and body mass index of the patients, laterality of the stone and SSD were not. The area under the curve of Triple-D and Quadruple-D scoring systems were 0.598 and 0.674.

Conclusion: Triple-D scoring system has been successfully validated as the SFR showed a parallel increase with every positive component. The Quadruple-D scoring system with a simple addition of stone location can further facilitate the validation of Triple-D scoring by increasing SFR, keeping the calculation simple and easy to use. These findings support the incorporation of Quadruple-D scoring system over Triple-D scoring system.

Keywords: Computed tomography, extracorporeal shock wave lithotripsy, Hounsfield unit, predictability, stone-free status

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INTRODUCTION

There are numerous factors which affect the stone-free rate (SFR) after extracorporeal shock wave lithotripsy (ESWL) such as the stone location and size,[1-3] composition,[4,5] Hounsfield unit (HU) as determined by computed tomography (CT),[6] intrarenal anatomy,[1,3] skin-to-stone distance (SSD),[7,8] and body mass index (BMI).[9] Triple-D scoring system was proposed by Tran *et al*.[10] Ichiyanagi O *et al*. proposed Quadruple-D scoring system as an extension of Triple-D scoring system. The aim of this study is to evaluate the clinical efficacy of Triple-D versus Quadruple-D scoring system for assessing SFR in individuals with renal stones measuring 1–2 cm in diameter after ESWL.

MATERIALS AND METHODS

In routine urological practice, renal and ureteral stones are very commonly encountered pathologies after urinary tract infection and disease of prostate. Endourological procedures such as percutaneous nephrolithotomy (PCNL) and ureteroscopy (URS) are now the preferred treatment modalities for renal stones. However, ESWL still remains a recommended treatment option for solitary renal stones of <2 cm in dimension.[1,11]

A prospective observational study was conducted from April, 2019 to July, 2020 on 120 patients who presented to the outpatient department of a tertiary urology care center in eastern India. The sample size was calculated using the formula for descriptive study.

One hundred and twenty participants were selected for the study using systemic random sampling technique with a sampling interval of 2 (two).

The study was conducted as per guidelines laid down by the Declaration of Helsinki. The study protocol was approved by the institutional ethical committee. Inclusion criteria were (1) age more than 18 years, (2) urine culture-negative patients, (3) patient receiving ESWL for the first time for the targeted stone and (4) patient with no anatomical urinary tract abnormalities. The exclusion criteria were (1) distal urinary tract obstruction, (2) unavailable CT images before ESWL, (3) pregnant patients, (4) staghorn stones, (5) calyceal diverticular stones, (6) coagulopathy, (7) urinary tract infection, and (8) endourological/open procedures before ESWL.

Before ESWL, plain abdominal radiography and helical non-contrast CT (NCCT) scan of the kidney, ureter, and bladder region (KUB) were done for evaluation of the renal stones. The coagulation profile and urine culture sensitivity were also done. Ellipsoid stone volume (SV) was measured using the formula SV = $\pi/6 \times$ (anteroposterior × transverse × craniocaudal diameters) in millimeters.[10,12,13] Stone density was measured in HU. SSD was calculated as the average distance from the body surface to a targeted stone at 0°, 45°, and 90° on NCCT.[7]

Triple-D score was calculated as the sum of the number of components matching the cutoffs of <150 mm^3 for SV, <600 HU for stone density, and <12 cm for SSD as described by Tran *et al*.[10] Quadruple-D scoring system was defined as Triple-D score combined with the stone location (i.e., distribution). The location was allocated 0 point if the stone was placed at the lower calyx and 1 point if the stone was located at other sites.[14] The score would range from 0 (worst) to 3 (best) points and 0 (worst) to 4 (best) points in Triple-D and Quadruple-D scoring system, respectively [Tables 1 and 2].

Electromagnetic shockwave lithotripter, Dornier Compact Sigma, manufactured by Dornier MedTech systems GmbH was used. ESWL was performed with a gradual ramping up of shockwave energy at a fixed frequency rate of 60 shocks/min. The patients underwent just a single ESWL session as part of this study. Plain abdominal radiography of KUB was done 3 weeks after ESWL to assess the stone-free status [Figure 1].

Statistics

IBM SPSS statistics 26.0 developed by IBM, New York, USA was used to do all the statistical analysis. Student's

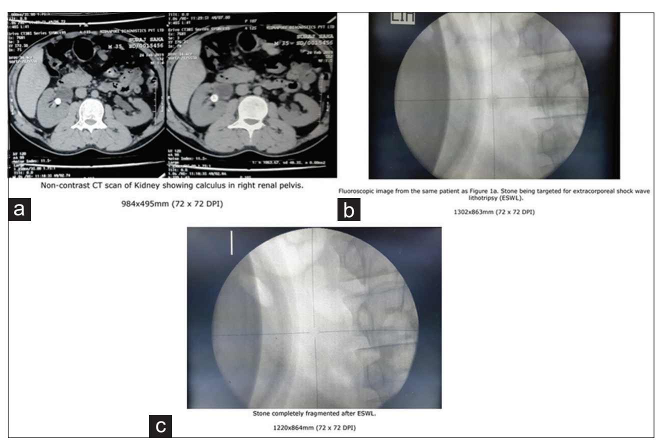

Figure 1: (a) Non-contrast computed tomography scan of kidney showing calculus in the right renal pelvis. (b) Fluoroscopic image from the same patient as (a). Stone being targeted by extracorporeal wave lithotripsy (ESWL). (c) Stone completely fragmented after extracorporeal shock wave lithotripsy

Table 1: Triple-D scoring system

Parameters	Score 1	Cutoff value	Score 0
Dimensions (mm^3)	<150	150	≥150
Density (HU)	< 600	600	≥ 600
Skin-stone distance (cm)	<12	12	≥ 12

Table 2: Quadruple-D scoring system

Parameters	Score 1	Cutoff value	Score 0
Dimensions (mm^3)	<150	150	≥150
Density (HU)	<600	600	≥600
Skin-stone distance (cm)	<12	12	≥12
Lower pole distribution	No		Yes

HU: Hounsfield unit

t- test or Mann–Whitney *U*-test was used to compare continuous variables. Their correlations were assessed using Pearson's correlation analysis. Fisher's exact test and Chi-square test were used to analyze the cross charts between two categories. All *P* values were based on two-sided statistical analysis. $P < 0.05$ was considered statistically significant.

RESULTS

The study population of 120 patients was divided into two groups after fulfilling the inclusion and exclusion criteria.

- Group A: Had stone-free status 3 weeks after ESWL
- Group B: Had residual stone 3 weeks after ESWL.

The age, sex, BMI, laterality of the stone, and SSD were not statistically significant for the prediction of stone-free status.

Sixty-nine (57.5%) patients in the study population had stones at the pelviureteric junction, 14 (11.66%) patients had stones at the renal pelvis, 22 (18.33%) had stones in the lower calyx, 12 (10%) in middle calyx, and 3 (2.5%) in upper calyx, respectively. Fifty (65.78%) patients of Group A and 19 (43.18%) patients in Group B had stones at the pelviureteric junction, 10 (13.15%) patients in Group A and 4 (9.09%) patients in Group B had stones at the renal pelvis, 7 (9.20%) patients in Group A and 15 (34.09%) patients in Group B had stones in lower calyx, 7 (9.20%) patients in Group A and 5 (11.36%) patients in Group B had stones in middle calyx, and 2 (2.63%) patients in Group A and 1 (2.22%) patient in Group B had stones in upper calyx, respectively. Using the Fisher's exact probability test, *P* value is 0.014 (<0.05). Difference in the two groups with respect to stone location is statistically significant, making stone location an important predictor of success of ESWL.

The mean ± standard deviation (SD) (in mm^3) ellipsoid SV is 396.44 ± 163.23 and 395.81 ± 227.52 in Groups A and B, respectively. Using the independent samples *t*-test, *P* value is 0.049 (<0.05). Hence, the differences in the SV in the two groups were statistically significant and an important predictor of success of ESWL.

The mean ± SD (in HU) stone density was 724.28 ± 210.90 and 814.56 ± 190.63 in Groups A and B, respectively. Using the Student's *t*-test, *P* value is 0.001 (<0.05). The difference in the stone density between the groups was statistically significant and a positive predictor of ESWL success.

The mean ± SD (Score) Triple-D score was 1.18 ± 0.58 and 0.93 ± 0.545 in Groups A and B, respectively. The *P* value is 0.026 (<0.05) using the Mann–Whitney *U*-test, so the difference in the Triple-D score in both the groups is statistically significant. The mean ± SD (score) Quadruple-D score was 2.09 ± 0.65 and 1.54 ± 0.79 in Groups A and B, respectively. Using the Mann–Whitney *U*-test, the *P* value is < 0.001 (<0.05), so the difference in the Quadruple-D score in both the groups is statistically significant. Triple-D and Quadruple-D scores can thus be used as important clinical assessment tools to predict the success rate of ESWL [Table 3].

The area under the curve (AUC) of the Triple-D scoring system was 0.598 with 95% confidence interval of 0.493–0.703. The Triple-D score of 0, 1, 2, and 3 points showed SFRs of 38.46%, 63.52%, 75%, and 100%, respectively. The AUC of Quadruple-D scoring system was 0.674 with 95% confidence interval of 0.57–0.77 ($P = 0.01$). The Quadruple-D score of 0,1,2,3 and 4 points showed SFRs of 0%, 45.83%, 68.05%, 82.35% and 100%, respectively (Cochran–Armitage test, $P = 0.001$). This shows that Quadruple-D scoring system is a better predictor of SFR after ESWL than Triple-D [Figures 2 and 3].

DISCUSSION

In our study, we see that Triple-D score and lower pole location are independent predictors of SFR after ESWL for 1–2 cm renal stones. The SFR improved with increasing Triple-D and Quadruple-D score. The Quadruple-D score may be even more relevant than Triple-D score in making the clinical decision before choosing ESWL as a treatment modality.

The receiver operating characteristic curve analysis revealed a low AUC of 0.598 in Triple-D score and 0.674 in Quadruple-D score for SFR prediction. In a similar study by Ichiniyag O *et al.*, the AUC of Triple-D score was 0.596 and AUC of Quadruple-D score was 0.651. This may be because the SSD parameter, a component of

Table 3: Comparison of the study population 3 weeks after extracorporeal shock wave lithotripsy

Parameters	Mean±SD			*P*
	Overall (*n*=120), *n* (%)	Group A (*n*=76), (stone free), *n* (%)	Group B (*n*=44) (residual stone), *n* (%)	
Age (years)	40.335±9.77	34.90±9.11	45.77±10.43	0.453*
Sex				
Male	75 (62.50)	47 (61.84)	28 (63.63)	0.845**
Female	45 (37.50)	29 (38.15)	16 (36.36)	
BMI (kg/m^2)	24.62±1.06	24.36±1.12	24.89±1.00	0.327*
Laterality				
Left	67 (55.83)	43 (56.57)	24 (54.54)	0.829**
Right	53 (44.16)	33 (43.42)	20 (45.45)	
Stone location				
Upper calyx	3 (2.5)	2 (2.63)	1 (2.22)	0.014***
Middle calyx	12 (10)	7 (9.20)	5 (11.36)	
Lower calyx	22 (18.33)	7 (9.20)	15 (34.09)	
Renal pelvis	14 (11.66)	10 (13.15)	4 (9.09)	
PUJ	69 (57.5)	50 (65.78)	19 (43.18)	
Stone volume	396.12±195.37	396.44±163.23	395.81±227.52	0.049*
Mean CT attenuation (HU)	769.42±200.76	724.28±210.90	814.56±190.63	0.001*
SSD (cm)	11.59±0.9	11.39±0.94	11.79±0.86	0.422*
Triple-D score				
Total	1.055±0.56	1.18±0.58	0.93±0.545	0.026****
Score 0	13 (10.83)	5 (6.57)	8 (18.18)	
Score 1	85 (70.83)	54 (71.05)	31 (70.45)	
Score 2	20 (16.66)	15 (19.73)	5 (11.36)	
Score 3	2 (1.66)	2 (2.63)	0	
Quadruple-D score				
Total	1.81±0.72	2.09±0.65	1.54±0.79	<0.001****
Score 0	5 (4.16)	0	5 (11.36)	
Score 1	24 (20)	11 (14.47)	13 (29.54)	
Score 2	72 (60)	49 (64.47)	23 (52.27)	
Score 3	17 (14.16)	14 (18.42)	3 (6.81)	
Score 4	2 (1.66)	2 (2.63)	0	

*Independent samples *t*-test, **Chi-square test, ***Fisher's exact probability test, ****Mann-Whitney *U*-test. SSD: Skin-to-stone distance, PUJ: Pelviureteric junction, HU: Hounsfield unit, BMI: Body mass index, CT: Computed tomography, SD: Standard deviation

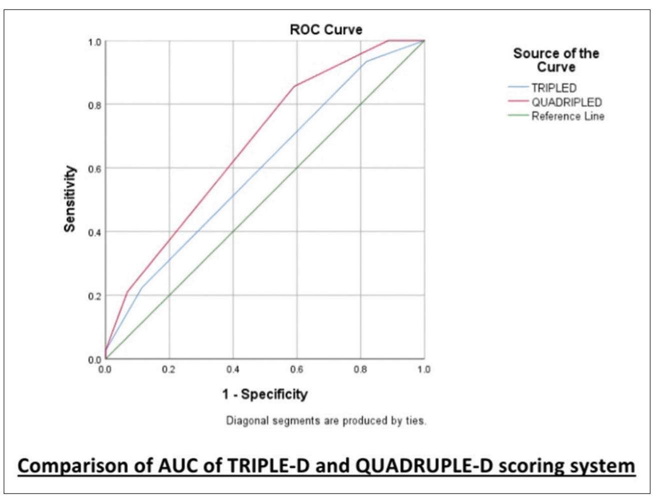

Figure 2: Comparison of receiver operating characteristic curve of Triple-D and Quadruple-D scoring system. Area under curve is 0.598 in Triple-D; 95% confidence interval of 0.493–0.703; area under curve is 0.674 in Quadruple-D; 95% confidence interval 0.57–0.77

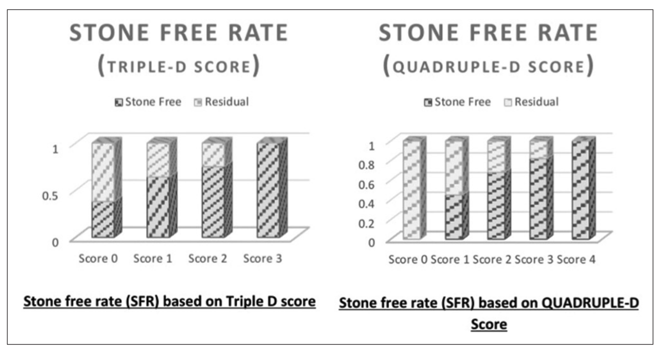

Figure 3: Triple-D and Quadruple-D scores in relation to stone-free rate

both Triple-D and Quadruple-D scores, is not a statistically significant factor for discriminating stone-free or residual stones after ESWL. Contrary to our study, SSD and BMI, which are clinical indicators of obesity, have been reported as significant predictors of ESWL outcome in multivariate analysis.[15,16] SSD and BMI were not related to the SWL outcomes in the present study possibly because the study population comprised of mostly underprivileged and low socioeconomic status patients (mean BMI of 24.62 ± 1.06 kg/m^2), reflecting the racial background different from previous similar studies.[7,15-17]

Lower polar location of renal stones is a significant factor related to poor SFR after ESWL. An obtuse infundibular-pelvic angle, long lower calyx (<1 cm), and narrow infundibulum (<5 mm) are depicted as unfavorable factors for ESWL success.[1] However, these details were not incorporated in Quadruple-D score for ease of use in clinical practice. Increased stone burden, lower polar location, and increased SSD, all decrease success rate of ESWL and URS but has limited influence on PCNL outcomes.[3] Hence, for 1–2 cm renal calculi, stone and anatomical factors must be carefully examined when considering ESWL as the treatment modality. In a similar study, Ozgor *et al*. revealed the importance of stone location in addition to Triple-D score for predicting ESWL success in their multivariate analysis.[13]

In our study, age is not a significant predictor of ESWL success rate. Contrary to this observation, age was reported as an independent predictor of ESWL outcome in multivariate analyses.[14,15,18] In another prospective study,[16] age and ESWL success rate reached a statistical significance in a univariate but not in multivariate analysis. Hence, age is not considered a parameter of Triple-D and Quadruple-D study. There are also other studies where age was not considered as having any significant impact on ESWL outcome.[15,19-21]

In a study correlating the age with ESWL efficacy,[22] it was seen that renal stones were difficult to fragment with ESWL in older patients than young patients. There is also a higher probability of renal hematoma after ESWL, which increased with age. Hence, age might have a negative impact on SFR.

Many other nomograms exist for prediction of the successful outcome after ESWL,[2,10,15,21,23,24] but they are often too complex to calculate in clinical settings even though these have excellent outcomes. In a nomogram by Kim *et al*., manual scoring system was formulated using four to six variables on graphical chart in a CT-dependent or independent manner. Beside the four variables, sex, stone location, number, and maximal diameter, hydronephrosis grade and stone CT attenuation are included in the CT dependent nomogram.[24] This nomogram including Triple-D as well as Quadruple – D scoring system is practical and easy to use and remains externally validated.

There are limitations in the present study. The infundibulo pelvis angle, infundibular length and width of lower calyx, and hydronephrosis were not assessed. Other limitations include relatively small number of patients. It is not clear how to extrapolate Triple-D and Quadruple-D score for ureteral stones. Further studies are needed to confirm the validity of the present findings.

CONCLUSION

In Indian patients with renal stones between 1 and 2 cm, Triple-D scoring system has been successfully validated as the SFR showed a parallel increase with every positive component of Triple-D scoring system. The Quadruple-D scoring system with a simple addition of stone location (non-lower polar vs. lower polar) can further facilitate the validation of Triple-D scoring by increasing SFR, keeping the calculation simple and easy to use.

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Conflicts of interest

There are no conflicts of interest.

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