Original Research Article

CT density – Is it a predictor in renal calculus clearance with extracorporeal shock wave lithotripsy

Ravi Jahagirdhar[1], N Rama Murthy[2*], G. Mallikarjun[2], T. Jagadeeshwar[3], G. Ravi Chandar[2], G. Raghavendra[4]

[1]Professor, [2]Assistant Professor, [3]Professor and Head, [4]Post Graduate Student
Department of Urology, Gandhi Medical College and Hospital, Musheerabad, India
[*]Corresponding author email: **urology.gh@gmail.com**

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Abstract

Background: Computed tomography of the kidneys, ureters and bladder (CT-KUB) is increasingly used for urinary lithiasis. Its higher sensitivity in detecting small, radiolucent calculi with the avoidance of intravenous contrast media is very beneficial and replacing the traditional intravenous urography.

Materials and methods: A Prospective study at Gandhi Hospital, Hyderabed was conducted from August 2013 to January 2016. Study Group I: calculus CT density less than 900 HU and study Group II: calculus CT density more than 900 HU.

Results: Most of the stones were located in lower calix, followed by renal pelvis in both the groups. Hematuria persisted more than 24 hours among 6 (6%) patients in group 1 while18 (22.5%) in group 2. Steinstrasse was seen in 8 patients among group 1 which was managed medically in 6 patients where as ureteric stenting required in 2 patients .Where it was 3 patients in group 2 among them 1 required ureteric stenting, which appears to be significantly low but it was not when calculated among successful fragmentation as it is secondary complication to fragmented caliculi drainage.

Conclusion: In patients with CT density <900 HU the ESWL was successful in 88%, with 58% of the patients required only one session and two or three ESWL sessions in remaining; with mean no 1.58 ESWL sessions are required. In patients CT density >900 HU, ESWL was successful in fewer than half of the patients (44%), only13% of them in a single session, and 76% requiring three sessions with failure rate of 80% in that group.

Key words

CT density, Predictor, Renal calculus, ESWL, Lithotripsy.

Introduction

Computed tomography of the kidneys, ureters and bladder (CT-KUB) is increasingly used for urinary lithiasis [1-7]. Its higher sensitivity in detecting small, radiolucent calculi with the avoidance of intravenous contrast media is very beneficial and replacing the traditional intravenous urography [8-17]. ESWL was introduced in the 1980s and represents one of the most frequently used methods to treat urinary upper tract calculi [18-24]. The outcome governing the success of ESWL is dependent on a number of factors, which include stone consistency, size, shape and location [25-37].

Aim and objectives

- To evaluate the outcomes of renal stone fragmentation and stone clearance with shock wave lithotripsy in relation to caliculi density based on hounsfield units on preprocedure CT in patients with renal stones of comparable size and clinical features.
- To compare the efficacy of shockwave lithotripsy in relation to calculi density (Hounsfield units) on CT scan with regard to the following: Renal stone fragmentation and clearance at 30 days post-procedure by radiological imaging.
- To asses post treatment failure in relation to clearance of calculi.
- To assess the number of SWL sessions required for renal stone fragmentation and stone clearance.
- To record post procedure complications in both.

Materials and methods

A Prospective study at Gandhi Hospital, Hyderabad was conducted from August 2013 to January 2016.

Inclusion criteria

Both male and female patients, patients above 16 and less than 60 years of age, single renal stone, size of stone between 5 -20 mm, and uncomplicated stone.

Exclusion criteria

Patients with multiple stones, stone located in calyceal diverticulum, patients with renal anatomical anomalies e.g.; horse shoe kidney, PUJ obstruction, infundibular stenosis, patients with medical contraindication to ESWL.

The two study groups were as follows

Study Group I: calculus CT density less than 900 HU

Study Group II: calculus CT density more than 900 HU

Study treatment protocol for ESWL

Pre-operative radiological evaluation included plain abdominal radiograph of the kidneys, ureters and bladder and NCCT at 120 kV and 100 mA on a spiral CT scanner performed by the same uro-radiologist. The density (HU) was measured from three axial NCCT slices for each stone, i.e., one at the level of the stone's maximum diameter, and one above and one below nearer to both poles of the stone. In each image, a circle was drawn inside the stone perimeter and the HU was measured, with the highest value recorded.Those patients eligible study were divided into two groups. In **group I** CT density of renal calculi is < 900 HU and in group II > 900 HU. Patients were allocated into appropriate study group according to CT density. Laboratory tests included coagulation profile and urine analysis. Before the procedure, urine cultures were obtained, and, if positive, appropriate antibiotics were prescribed for 1 week. Urine cultures were repeated to document sterile urine. After informed consent IV analgesics given and ESWL done with 90 shocks per minute to a maximum of 3000 shocks. SWL terminated when maximum shocks given or stone fragmented.

Follow up of each study patient will be done at 15 days and at 30 days following the study procedure. Follow-up assessment will be done with History, Clinical examination and KUB Radiograph and/or USG KUB after procedure at these two visits.

Definitions of study outcome measures

Treatment success and treatment failure for renal stones with SWL are defined as following for this study;

Treatment success - fragmentation of renal stone to less than 4 mm in size or stone free status at one month following the procedure.

Treatment failure - is defined as any one of the following outcomes

- The patient has any residual stone fragment present after one month post procedure or
- The patient needs any ancillary treatment for renal stones including ureteroscopy
- Percutaneous nephrolithotomy [38-50].

Results

Gender distribution of study group patients was as per **Table – 1**. Comparison of age distribution in two study groups was as per **Table – 2**. Comparison of mean Body Mass Index (BMI) in two study groups was as per **Table – 3**. Comparison of laterality of stone in two study groups was as per **Table – 4**. Location of stone in two study groups was as per **Table – 5**.

Table – 1: Gender distribution of study group patients.

Sex	**HU < 900**	**HU > 900**
Female	48 (48%)	38 (47.5%)
Male	52 (52%)	42 (52.5%)

In our study, most of the stones were located in lower calix, followed by renal pelvis in both the groups (**Table – 5**). Comparison of Stone size in two study groups was as per **Table – 6**. Comparison of number of SWL sessions required in two study groups was as per **Table – 7**. Comparison of Mean number of SWL sessions required between two study groups was as per **Table – 8**. Comparison of Treatment sucess after ESWL in two study groups was as per **Table – 9**. Comparison of Treatment failure after ESWL was as per **Table – 10**. Comparison of complications in two study groups was as per **Table – 11**.

Table – 2: Comparison of age distribution in two study groups.

Age (Years)	**HU < 900**	**HU > 900**
<40	3 (3%)	4 (5%)
40-50	61 (61%)	41 (51%)
50-60	36 (36%)	30 (38%)
>60	0 (0%)	5 (6%)

Hematuria persisted more than 24 hours among 6 (6%) patients in group 1 while18 (22.5%) in group 2. Steinstrasse seen in 8 patients among group 1 which was managed medically in 6 patients where as ureteric stenting required in 2 patients .Where it was 3 patients in group 2 among them 1 required ureteric stenting, which appears to be significantly low but it was not when caliculated among successful fragmentation as it was secondary complication to fragmented caliculi drainage (**Table – 11**). Summary of results was as per **Table – 12**.

Discussion

There is a dramatic change in the treatment of kidney stone disease over the past 30 years. This change is due in large part to the arrival of ESWL [51-58]. Before the advent of ESWL in the early 1980’s, most kidney stones were treated with open surgery [59-66]. ESWL along with the advances in ureteroscopic and percutaneous techniques has led to the virtual extinction of open surgical treatments for kidney stone disease [67-75]. Shockwave lithotripsy has been used as the most popular method for urinary stone treatment because of its non invasive nature, relative high success rate and stability [76-83].

Table – 3: Comparison of mean Body Mass Index (BMI) in two study groups.

	HU < 900	HU > 900	P value
BMI (Mean ± SD)	27.1 ± 2	27.06 ± 1.99	0.843 (NS)

Table – 4: Comparison of Laterality of Stone in two study groups.

Side of kidney	HU < 900	HU > 900	P value
Left	55 (55%)	50 (62%)	0.311 (NS)
Right	45 (45%)	30 (38%)	0.25 (NS)

Table – 5: Location of stone in two study groups.

Location	HU < 900	HU > 900	P value
Upper calix	12 (12%)	8 (10%)	0.67 (NS)
Middle calix	16 (16%)	12 (15%)	0.85 (NS)
Lower calix	42 (42%)	39 (48%)	0.37 (NS)
Renal pelvis	30 (30%)	21 (27%)	0.58 (NS)

Table – 6: Comparison of Stone size in two study groups.

Stone Size	HU < 900	HU > 900
5-9	57	46
9-15	39	32
>15	4	2

Table – 7: Comparison of number of SWL sessions required in two study groups.

No of Shock wave sessions	HU < 900	HU > 900	P value
1	58 (58%)	10 (13%)	
2	26 (26%)	9 (11%)	
3	16 (16%)	61 (76%)	0.01 (S)

Table – 8: Comparison of Mean number of SWL sessions required between two study groups.

Mean no SWL session	Group 1	Group 2	P value
Mean no	1.58	2.6	<0.01 (S)

Table – 9: Comparison of Treatment sucess after ESWL in two study groups.

ESWL post treatment	Group 1	Group 2	P value
Overall success rate	88 (88%)	35 (44%)	0.01 (S)
Stone-free	69 (69%)	24 (30.3%)	0.01 (S)
Fragments <4 mm	19 (10%)	11 (13.7%)	0.44 (NS)

Table – 10: Comparison of Treatment failure after ESWL.

Treatment failure	**Group 1**	**Group 2**	**P value**
Failure rate	12 (12%)	55 (68.7%)	0.01 (S)

Table – 11: Comparison of complications in two study groups.

Complications	**Group 1**	**Group 2**	**P value**
Hematuria >24 hours	6 (6%)	18 (22.5%)	< 0.01 (S)
Steinstrasse	8 (8%)	3 (3.75%)	0.32 (NS)
Fever	2 (2%)	1 (1.25%)	0.69 (NS)

Table – 12: Summary of results and observations.

Study group		**Group 1 (HU < 900)**	**Group 2 (HU > 900)**	**Total**	**P value**
No. patients enrolled (%)		100 (56%)	80 (44%)	180	
No. sex (%)					
	Female	48 (48%)	38 (48%)	86	
	Male	52 (52%)	42 (52%)	94	
Age (Mean±sd)		49.08 ± 5	49.9 ± 5.9		0.305(NS)
BMI (Mean±sd)		27.1 ± 2	27.06 ± 1.99		0.843 (NS)
No. side (%)					
Left		55 (55%)	50 (62%)	105(58%)	0.311 (NS)
Right		46 (46%)	30 (38%)	76 (42%)	0.25 (NS)
No. Location (%)					
Upper calix		12 (12%)	8 (10%)	20 (11%)	0.67 (NS)
Middle calix		16 (16%)	12 (15%)	28 (15%)	0.85 (NS)
Lower calix		42 (42%)	39 (48%)	81 (45%)	0.37 (NS)
Renal pelvis		30 (30%)	21 (27%)	51 (29%)	0.58 (NS)
Mean Stone size		12.09± 1.64	11.84±1.27		
No of SWL sessions required					
1		58 (58%)	10 (13%)		
2		26 (26%)	9 (11%)		
3		16 (16%)	61 (76%)		
Mean no sessions required		1.58	2.6		0.01 (S)
Treatment success after ESWL (Immediate and post 1 month)		88 (88%)	35 (44%)		0.01 (S)
Stone-free		69 (69%)	24 (30%)		0.01 (S)
Fragments<4 mm		19 (19%)	11(13.7%)		0.44 (NS)
Treatment failure after completed seesions		12 (12%)	55 (68.7%)		0.01(S)
Hematuria >24 hrs		6(6%)	18(22.5%)		0.01 (S)
Steinstressae		8(8%)	3 (3.75%)		0.32 (NS)
Fever		2 (2%)	1 (1.25%)		0.69 (NS)

Patients with HU < 900 were allotted to group I and patients with HU > 900 were allotted to group II. Out of 180 patients, 100 patients (56%) were enrolled for group I (< 900 HU) and 80 patients were in group II (>900 HU). In our study, mean age of patients in group 1 was 49.08 (±5) and in group 2 was 49.9 ± (5.9) as per **Table – 13**.

Out of 100 patients in group 1(HU less than 900) in our study, 52 (52%) were males and 48 (48%) were females. In group 2 (hu >900), 42 (52%) were males and 38 (48%) were females. In a study by Narmada P Gupta, et al., 108 patients who underwent lithotripsy 77 (71.3%) were males and 31 (28.3%) were females (**Table – 14**).

Table – 13: Number and Age of patients in study groups.

Studies	HU	No of patients	Mean patient age
Narmada P Gupta, et al. [52]	< 750	51	
	>750	57	
Idir Ouzaid, et al. [82]	<970	38	48
	>970	12	48
Sultan M Sultan, et al. [81]	<500	41	
	>500 - < 1000	44	
	>1000	13	
Amar M Massoud, et al. [80]	<500	81	39.9
	>500 -< 1000	141	38.5
	>1000	83	40.3
Our study	< 900	100	49.08
	>900	80	49.9

Table – 14: Sex distribution of patients.

Studies	HU	Male	Female
Narmada P Gupta, et al. [52]	< 750 + >750	77	31
Idir Ouzaid, et al.[82]	<970 + >970	33	17
Amar M Massoud, et al. [80]	<500	53	28
	>500 -< 1000	82	59
	>1000	49	34
Our study	< 900	52	48
	>900	42	38

Amar M Massoud, et al [80]. had mean age of patients 39.9 (range 21-60) in group < 500 HU with 53 (65%) male patients and 28 (35%) female patients. In group 500-1000 HU, mean age of patients was 38.5 (range 20-60), males were 82 (58%) were males and 59 (42%) were females in group > 1000 HU mean age was 40.3 (range 20-63), males were 49 (59%) and females were 34 (41%). In our study mean body mass index (BMI) of patients in group 1 was 27.1 ± 2 and in group 2 27.06 ± 1.99. Other studies by Idir Ouzaid, et al [82]. was 25.7±5.2 in group 1 and 24.5 ±4.4 in group 2 and Amar M Massoud [80], et al. were 26.2 , 26.5 and 27.2 in respective groups (**Table – 15**).

In Group 1, fifty five patients (55%) were having stone on left side and 45 (45%) on right side, while as in group 2, fifty patients (62%) had stone on left side while as 30 (38%) had on right side (**Table – 16**).

Table – 15: Body Mass Index (BMI).

Studies	HU	BMI	P Value
Idir Ouzaid, et al.[82]	<970	25.7±5.2	NS
	>970	24.5±4.4	
Amar M Massoud, et al. [80]	<500	26.2±3.2	NS
	>500 -< 1000	26.5±3.4	
	>1000	27.2±3.6	
Our study	< 900	27.1 ± 2	0.843 (NS)
	>900	27.06 ± 1.99	

Table – 16: Right versus Left Renal Stone (Laterality).

Studies	HU	Left side	Right side
Idir ouzaid et al [82]	<970	19 (50%)	19 (50%)
	>970	5 (47.7%)	7 (58.3%)
Our study	< 900	55 (55%)	45 (45%)
	>900	50 (62%)	30 (38%)

In our study location of calculus in group 1 (HU< 900), 12 (12%) stones were in upper calyx, 16 (16%) stones in middle calyx, 42 (42%) in lower calyx and 30 (30%) in renal pelvis. In group 2, 8 (10%) stones were in upper calyx, 12 (15%) in middle calyx, 39 (48%) in lower calyx and 21 (27%) in renal pelvis.

In both groups lower calyceal stone was more common (**Table – 17**).

In our study patients were divided into three categories according to the stone size. In Group 1, 56 patients were having stone size 5-9 mm with mean size of 7.2 mm, 40 patients were having stone size in the range of 9.1-15 mm with a mean size of 11.8 mm and 4 patients were having stone size in the range of 15.1-20 mm with a mean size of 17.5 mm. Overall mean stone size in group was 12.16 mm. In Group 2, 46 patients were having stone size 5-9 mm with mean size of 6.9 mm, 32 patients were having stone size in the range of 9.1-15 mm with a mean size of 12.02 mm and 2 patients were having stone size in the range of 15.1-20 mm with a mean size of 16.5 mm. Overall mean stone size in group 2 was 11.8 mm (**Table – 18**).

Narmada P Gupta, et al [52]. concluded that the worst outcome was in patients with a SAV(stone attenuation value) >750 HU and a stone diameter < 1.1 cm, as 67% of those patients needed more than three sessions of ESWL, and the clearance rate was 60% (**Table – 19**). In Amar M Massoud [80], et al. study for the effect of the SAV on the results of ESWL. All patients with a SAV <500 HU were stone-free after one session, irrespective of the size and location of the stone.

In patients with SAVs of 501–1000 HU the ESWL was successful in 95.7%, with about half of the patients needing two or three ESWL sessions; on average about two sessions are required. In patients with a SAV >1000 HU, ESWL was successful in fewer than half of the patients (44.6%), none of them in a single session, with 16 of the 37 successful cases (43%) requiring three sessions.

In our study the overall number of stone-free patients after ESWL for calculi with HU < 900 was 88/100 (69% stone free and 19% having fragments <4 mm at 1 month post treatment) in 12 patients (12%) ESWL failed, which is consistent with previous studies reporting a failure rate of 5–20% (**Table – 20**).

Table – 17: Comparison of location of stone.

Studies	HU	Upper calyx	Middle calyx	Lower calyx	Renal pelvis + Upper ureter
Idir ouzaid, et al. [82]	<970	8 (21%)		6 (15.7%)	24 (63.2%)
	>970	4 (33.3%)		3 (25%)	5 (41.7%)
Amar M Massoud, et al. [80]	<500	13 (16%)	12 (15%)	16 (20%)	28+12 (50%)
	>500 -< 1000	23 (16%)	12 (9%)	27 (19%)	62+17 (56%)
	>1000	9 (11%)	6 (7%)	30 (36%)	38 (46%)
Our study	< 900	12 (12%)	16 (16%)	42 (42%)	30 (30%)
	>900	8 (10%)	12 (15%)	39 (48%)	21 (27%)

Table – 18: Comparison of mean stone size.

Studies	HU	Mean stone size (mm)
Idir ouzaid, et al. [82]	<970	10.8
	>970	9.1
Amar M Massoud, et al. [80]	<500	22.5
	>500 -< 1000	17.5
	>1000	18.6
Our study	< 900	12.16
	>900	11.8

Table – 19: Comparison of mean number of ESWL sessions required.

Studies	HU	Mean no of sessions
Narmada P Gupta, et al. [52]	< 750	< 3 (83%) > 3 (17%)
	>750	< 3 (33%) > 3 (67%)
Amar M Massoud, et al. [80]	<500	1
	>500 -< 1000	2.5
	>1000	3.6
Our study	< 900	1.58
	>900	2.6

In group 2 (> HU 900) treatment success is 35/80 (44%) and failure was 55/80 (56%). Mean no of SWL sessions required for group 1 was 1.58 and group 2 is 2.6 which is clinically significant. Our study is consistent with previous studies and confirmed the results of previous studies.

In our study, post treatment complications recorded were hematuria persisted > 24 hours, steinstrasse and fever. Hematuria > 24 hours seen in 6% in group 1 and 22.5% in group 2 which was significant. It may be implied for more no of sessions and shockwaves required to fragment for group 2 and there is no significant difference seen in other complications (**Table – 21**).

Steinstrasse seen in 8 patients among group 1 which was managed medically in 6 patients where as ureteric stenting required in 2 patients .Where it is 3 patients in group 2 among them 1 required ureteric stenting, which appears to be significantly low but it is not when caliculated among successful fragmentation as it is secondary complication to fragmented caliculi drainage [83-92].

Table – 20: One Month post treatment results.

Studies	HU	Success rate	Failure rate
		Stone free+ fragments < 4mm	**Uncleared + Fragments > 4 mm**
Narmada P Gupta, et al. [52]	< 750	37 (90%)	4 (10%)
	>750	19 (70%)	8 (30%)
Idir Ouzaid, et al. [82]	<970	31 (97%)	1 (3%)
	>970	7 (39%)	11 (61%)
Sultan M Sultan, et al. [81]	<500	41 (100%)	0
	>500 - < 1000	44 (95.7%)	2 (4.6%)
	>1000	0	13 (100%)
Amar M Massoud, et al. [80]	<500	81 (100%)	0
	>500 -< 1000	135 (95%)	6 (5%)
	>1000	37 (45%)	46 (55%)
Our study	< 900	88 (88%)	12 (12%)
	>900	35 (44%)	55 (66%)

Table - 21: Complications.

Complications	Group 1	Group 2	P value
Hematuria >24 hours	6 (6%)	18 (22.5%)	0.001 (S)
Steinstrasse	8 (8%)	3 (3.75%)	0.32 (NS)
Fever	2 (2%)	2 (1.25%)	0.69 (NS)

Conclusion

Shock wave lithotripsy is a highly effective treatment for the removal of kidney stones <20 mm. Stone attenuation value (HU) obtained by NCCT correlated with stone fragility. The higher the attenuation value of stones, the greater the number of shockwaves needed for fragmentation. Stone attenuation not only correlated with the numbers of shockwaves required, but also associated with the sessions of shockwave treatment needed. The mean stone attenuation of those with in the stone-free group was significantly lower than that for those with in the residual stone group. Hence stone attenuation on pre-treatment NCCT can predict the stone-free rate after SWL. In patients with CT density <900 HU the ESWL was successful in 88%, with 58% of the patients required only one session and two or three ESWL sessions in remaining; with mean no 1.58 ESWL sessions are required. In patients CT density >900 HU, ESWL was successful in fewer than half of the patients (44%), only13% of them in a single session, and 76% requiring three sessions with failure rate of 80% in that group. In patients with a CT density >900 HU, ESWL should not be considered or offered to patients as a first treatment. As failure would be expected in more than half, together with the need for many sessions, this will increase the treatment-related morbidity with little cost benefit. Therefore, we recommend treating them with other methods rather than ESWL.

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