Ther Adv Urol
2019, Vol. 11: 1–6
DOI: 10.1177/1756287219887661
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Hounsfield unit and its correlation with spontaneous expulsion of lower ureteric stone

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Abstract

Background: Hounsfield unit (HU) is the measure of stone density, and is utilized in the predetermination of type of stone. The purpose of this study was to identify some factors in noncontrast computed tomography (NCCT) of kidney, ureter, and bladder (KUB) that are easily extractable and can be used to determine the outcome of expectant management.

Methods: All patients 18–50 years of age who presented with flank pain and diagnosed as having lower ureteric calculi of size 5–10 mm by NCCT KUB were included in the study. HU of stone was calculated from the mean HU at three different regions of interest. We prescribed tamsulosin for 4 weeks as medical expulsive therapy. We divided the patients into two groups: group A included patients with successful expulsion of stone, and group B included patients who failed to pass stone. We compared age, gender, laterality, stone size in axial and coronal section of NCCT, HU of stone, blood urea, creatinine, and renal parenchymal thickness.

Results: A total of 180 patients with lower ureteric calculus were included in the study. The mean age of patients was 34 years, with male:female ratio of 2.3:1. Of these 180 patients, 119 (66%) successfully expelled the stone and were included in group A, with the remaining 61 (34%) forming group B. In univariate analysis, longitudinal diameter of stone ($p < 0.001$), transverse diameter of stone ($p < 0.001$) and high HU ($p < 0.001$) were significantly associated with failure of expulsion. However, in multivariate analysis only longitudinal diameter of stone ($p < 0.001$) differed significantly among groups. Differences in HU ($p = 0.179$) and transverse diameter of stone ($p = 0.108$) did not reach significance level.

Conclusions: Lower ureteric calculi are definitely amenable to conservative management. Longitudinal diameter of stone can be a useful parameter; however, HU and its derivatives cannot be used as a predictor of outcome.

Keywords: Spontaneous Expulsion of Stone, Hounsfield unit and spontaneous expulsion of stone, Factors affecting outcome of Ureteric stone, conservative management of ureteric stone

Received: 23 April 2019; revised manuscript accepted: 18 October 2019.

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Introduction

Ureteric colic is the most distressing emergency in urological practice. Lower ureteric calculus is the most common entity among all ureteric calculus conditions. Despite the availability of multiple treatment options, expectant management with alpha blockers is the preferred treatment modality for stones >6 mm of lower ureteric calculus, and its superiority as medical expulsive therapy (MET) has been proven in multiple studies.

Because MET is a broad term and includes many medications, and can be used for stones <6 mm, alpha blockers are specific and prove effective only for stones ⩾6 mm.[1–3] Nevertheless, 30% of patients fail to pass stone with expectant management.[4] These 30% of patients with distal ureteral calculi are unaware of the end result. Therefore, apart from size and location, other parameters could affect success rate and these could guide urologists in appropriate selection

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of patients for MET. Noncontrast computed tomography (NCCT) scan is the investigation of choice for ureteric colic. Hounsfield unit (HU) is a measure of stone density and is utilized in predetermination of type of stone. HU values vary from 100 to 1000, and the extent to which a stone in the ureter is compacted has been correlated using this. Furthermore, it is one of the most important predictors of outcome of shock wave lithotripsy (SWL).[5] However, literature on HU as a predictor of success of MET is limited and, hence, procedures could not be standardized owing to the small sample size of these studies.[6] The purpose of this study was to identify some factors revealed by NCCT of kidney, ureter and bladder (KUB) that are easily extractable and can be used to determine the outcome of expectant management.

Materials and methods

This was a prospective clinical study, conducted in the Department of Urology, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) from August 2016 to May 2018. Ethical committee (Human study) approval was obtained for the study (JIP/IEC/2016/27/884).

All patients between 18–50 years of age who presented with flank pain and diagnosed as lower ureteric calculi of size 5–10 mm by NCCT KUB were included in the study. We excluded patients with urinary tract infection (UTI), sepsis, pregnancy, impaired renal function, solitary kidney, and patients who wanted immediate surgical management of stone. Patients lost to follow up were also excluded from the study.

All patients screened first with ultrasound (USG) KUB subsequently underwent NCCT KUB. HU of the stone was calculated from the mean of HU at three different regions of interest. According to our protocol, we prescribed tamsulosin 0.4 mg for 4 weeks as MET and a nonsteroidal anti-inflammatory drug (NSAID) for 5 days for pain relief.

We reassessed all patients at 2 and 4 weeks. Persistent stone at 4 weeks was deemed as failure of expectant management, and these patients were planned for definitive surgical treatment. We divided the patients into two groups: group A included patients with successful expulsion of stone, and group B comprised those who failed to pass stone and required surgical intervention. We compared age, gender, laterality, stone size in axial and coronal section of NCCT, HU of stone, blood urea, creatinine, and renal parenchymal thickness.

Statistical analysis

Continuous data was analyzed for normality by one-sample Kolmogorov–Smirnov test. Comparison of age, stone size, renal parenchymal thickness, HU, and the other continuous variables mentioned above in relation to the categorical variables was carried out using independent Student's t test/Mann–Whitney U test. The association of spontaneous stone expulsion with categorical variables, such as gender and laterality, was carried out using Chi-square test. Independent factors associated with simultaneous stone expulsion were explored by logistic regression analysis. All statistical analyses were performed using SPSS version 19 at 5% level of significance, and a p value <0.05 was considered significant.

Results

A total of 180 patients with lower ureteric calculus were included in the study. The mean age of patients was 34 years with male:female ratio of 2.3:1. Mean longitudinal and transverse diameter of stone was 6.9 mm and 5.9 mm, respectively. Of the 180 patients, 101 had right and 79 had left ureteric calculus. Mean HU of stone was 701. Renal function test was normal in both groups.

Of the total sample of 180 patients, 119 (66%) successfully expelled the stone and were included in group A, with the remaining 61 (34%) forming group B. Median longitudinal diameter of stone was 6 mm in group A and 8 mm in group B; transverse diameter was 5 mm and 7 mm in groups A and B, respectively. Mean HU was 636 in group A and 828 in group B. Table 1 shows a comparison of parameters between the groups. In univariate analysis, longitudinal diameter of stone ($p<0.001$), transverse diameter of stone ($p<0.001$) and high HU ($p < 0.001$) were significantly associated with failure of expulsion. However, in multivariate analysis (Table 2), only longitudinal diameter of stone ($p<0.001$) was significantly different among groups. Differences in HU ($p=0.179$) and transverse diameter of stone ($p=0.108$) did not reach significance.

Table 1. Comparison of parameters between groups A and B.

Variables	Group A	Group B	Significance
Total number of patients	119 (66%)	61 (34%)	
Mean age in years (SD)	33.50	35.51	0.151
Gender (M:F)	2.4:1	2.2:1	0.864
Male	84 (70.5%)	42 (69%)	
Female	35 (29.5%)	19 (31%)	
Laterality			1.000
Right	67 (56%)	34 (55%)	
Left	52 (44%)	27 (45%)	
Median urea in mg/dl (range)	22(11–44)	22 (11–92)	0.693
Median creatinine in mg/dl (range)	1 (0.58–1.8)	1.1 (0.74–1.7)	0.128
Renal parenchymal thickness at midpole in mm (SD)	27.17 (3.83)	26.4 (4.12)	0.226
Median longitudinal diameter of stone in mm (range)	6 (5–10)	8 (5–10)	<0.001*
Median transverse diameter of stone in mm (range)	5 (5–8.6)	7 (5–10)	<0.001*
HU (SD)	636 (169)	828 (248)	<0.001*

Group A patients passed stones spontaneously after MET; Group B patients did not pass stone spontaneously after MET.
*Statistical significance.
HU, Hounsfield unit; SD, standard deviation.

Table 2. Multivariate analysis.

Variables	Odds ratio	Confidence interval	Significance
Longitudinal diameter of stone	1.978	1.39–2.81	<0.001*
Transverse diameter of stone	1.407	0.92–2.13	0.108
HU	1.002	0.99–1.00	0.179

*Statistical significance.
HU, Hounsfield unit.

Discussion

NCCT scan has long been the investigation of choice for ureteric colic.[7] Apart from site and size, other factors that can determine the outcome of expectant management can be derived from CT images. HU has proven its importance in prediction of success in SWL and ureteroscopic lithotripsy.[8,9] In our study, we measured HU at the time of presentation and investigated its association with spontaneous expulsion. Much of the literature on MET describes studies where patients were followed for 4 weeks before declaring it as a success or failure. However, there is no specific recommended time frame reported in the literature on this. Although European Association of Urology (EAU) 2018 guidelines recommend use of MET for distal ureteric calculus of size >6 mm, nevertheless, in these cases, failure rate is around 30–40%.[4]

The main purpose of our study was to identify radiological parameters that can be used to predetermine the success rate of MET, not only to eliminate the side effects of drugs but also to bring down the time to definitive management. Alpha blockers are the most effective drugs in MET among all the available medications.

Demographic parameters have been assessed in multiple studies, and were found to be ineffective in the prediction of outcome of expectant management.[10–12] In our study, age ($p = 0.151$) and gender ($p = 0.864$) were not found to be significantly different among the groups. These findings were similar to other studies.

For a long time, transverse diameter of stone was the deciding factor in the management of lower ureteric calculus. We measured transverse diameter as well as the longitudinal diameter of stone in axial and coronal sections, respectively. In our study, transverse diameter was not significantly different among the groups. However, longitudinal diameter of stone was significantly ($p < 0.001$) different between the groups with an odds ratio of 1.98. Seung Ryeol Lee and colleagues demonstrated a mean longitudinal stone diameter of 5.1 mm in the success group and 6.79 mm in the failure group.[13] These findings were similar to our study.

Its is well known that HU of stone is one of the important determinant factor of outcome of shock wave lithotripsy. The success rate decreases once it reaches the value of 1000HU.

Correlation of HU with stone composition has been attempted. In some studies, successful differentiation of Ca oxalate from cystine and uric acid stones was possible on this basis.[14] Its use in decision making for expectant management had been tried in multiple studies but none of these had a fruitful outcome.[6,10] Indeed, we could not find any association of stone composition with HU.

There are many recent studies on the use of NCCT in predicting stone composition in adult patients. In these studies, parameters such as core HU, periphery HU, mean HU, HUD (HU Density), absolute HU difference, and relative HU were used as HU value derivatives.

Altan and colleagues suggested that median HUD was significantly different between calcium oxalate and cystine stones.[14] However, no difference was seen between cystine and struvite stones in terms of HU parameters. To distinguish these groups, mean spot urine pH values were compared, and were found to be higher in struvite than in cystine stones.

Erturhan and colleagues demonstrated that stones with high HU are very compacted, and the rate of expulsion of such stones was slow in their study.[6] However, they concluded that HU and HU density cannot predict the outcome of expulsive therapy in ureteric calculi. These findings were also similar to our study.

Before starting our study, we hypothesized that stone density does not affect stone passage. In group B, the mean HU was 828, which was higher than that of group A; however, in multivariate analysis, the difference was not statistically significant. So, our null hypothesis was correct and suggested there could be some other parameters that need to be focused on in future research.

The effect of alpha blockers on stone expulsion has been studied and is well documented. Dellabella and colleagues concluded that tamsulosin, which is used as a spasmolytic drug for ureteric colic due to juxtavesical calculi, increased stone expulsion rate and decreased expulsion time, the need for hospitalization, and endoscopic procedures, and provided good control of colicky pain.[4]

Similarly, Kumar and colleagues compared tadalafil, tamsulosin, and silodosin in the management of lower ureteric calculi, and concluded that Tadalafil was as effective as tamsulosin, while silodosin was the most potent of the three drugs.[1]

In another study where MET was studied using calcium channel blockers with steroids, Saita and colleagues demonstrated that nifedipine, along with prednisolone, promotes the passage of ureteric stones.[15] These findings suggest that it is ureteric inflammation, rather than the type of stone, that is associated with failure of expulsion.

The list of drugs used in MET is never ending. Solakhan and colleagues studied the effect of mirabegron, a beta 3 agonist, and concluded that mirabegron is efficient, safe, and a new treatment modality with a lower side-effect profile for distal ureteral stones.[16]

Sfoungaristos and colleagues demonstrated in their study that smaller size, higher serum white blood cell (WBC) count, and the presence of ureteral jet were statistically significant predictors for spontaneous stone passage.[12] Total WBC count was found to be the most significant predictor, followed by the size of the calculus.

Stone surface as a predictor of conservative management of ureteric calculi was studied by Ibrahim and colleagues,[17] who found that the stones with irregular surface have better chances of spontaneous passage than those with smooth surface. The hypothesis behind this assumption was laid down by Rose and Gillenwater, who opined that, unlike stones with a smooth surface, those with an irregular surface seldom become completely impacted, and urine finds its way around the surface to the distal ureter, ensuring better flushing of the ureter and helping progression of the stone. Also, the irregular surface may stimulate peristalsis by causing more irritation to the ureteric wall, and that complete obstruction by stones will cause overdistension of the proximal ureter, leading to peristaltic inhibition after initial stimulation of the smooth muscle.[18]

The effect of various drugs on ureteral peristalsis was studied using ureteral pressure transducer catheters based on *in vitro* studies by Davenport and colleagues with the aim of providing further information regarding the use of these drugs in the promotion of stone passage. It was found that diclofenac and nifedipine produced inconsistent ureteric pressure responses, but had little effect on contraction frequency, while tamsulosin significantly reduced ureteric pressure, but had no effect on contraction frequency. It was concluded that all three drugs allowed peristalsis to continue and the reduction in pressure generation seen with tamsulosin may be the essential factor in the promotion of stone passage.[19]

Interval to stone passage was studied by Miller and colleagues.[20] It was concluded that the time to pass a ureteric stone is highly variable, and dependent on stone size, location, and side. Degree of pain, patient gender, and age had no bearing on the time to stone passage. It was suggested that the ureteral stones, 95% of which are 2–4 mm in size, pass spontaneously, but passage may take as long as 40 days. Intervention may be required in 50% of ureteral calculi >5 mm.

Conclusion

To conclude, lower ureteric calculi are definitely amenable to conservative management, whereby surgical intervention can be obviated in carefully selected cases. HU and its derivatives cannot be used as predictors of outcome. Other indicators, such as longitudinal diameter of stone, of successful spontaneous stone expulsion should be carefully assessed before assigning a patient to conservative management.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and publication of this article: This study was not funded by any agency.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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