# Predicting the Impacted Ureteral Stone with Computed Tomography

**Timothy Y. Tran, Jacob N. Bamberger, Kyle A. Blum, Egor Parkhomenko, Julie Thai, Ryan A. Chandhoke, and Mantu Gupta**

**OBJECTIVE** To evaluate whether preoperative computed tomography (CT) findings could predict the presence of an impacted stone. Preoperative identification of an impacted ureteral stone may influence patient preparation and operative decisions. Factors predicting ureteral stone impaction have not been clearly identified.

**METHODS** We identified all patients from June 2014 to July 2016 that underwent ureteroscopic treatment of an impacted ureteral stone. Patients that had ureteral prestenting or previous treatment for their stone were excluded. Noncontrast CT images were reviewed to calculate stone size, stone volume, degree of hydronephrosis (0-3), and Hounsfield units (HU) of the stone as well as the ureter distal and proximal to the stone. These were compared with a control group of patients that had nonimpacted stones.

**RESULTS** Patients with impacted stones had a greater stone size, volume, HU of the ureter under the stone, HU under/above ratio, and degree of hydronephrosis on univariate analysis. Multivariate analysis demonstrated that HU under the stone was a significant predictor of ureteral stone impaction (odds ratio 1.17; 95% confidence interval 1.11-1.25). Distal ureteral density above 27 HU demonstrated a sensitivity of 85%, specificity of 85%, positive predictive value of 89%, and negative predictive value of 81% for ureteral stone impaction.

**CONCLUSION** Impacted stones are associated with ureteral density cut-off value of 27 HU or greater. Measuring this value on preoperative noncontrast CT may help predict which patients are more likely to have impacted stones. UROLOGY 130: 43−47, 2019. © 2019 Elsevier Inc.

Impacted ureteral stones remain a surgical challenge. Pathologic changes such as ureteral edema and hypertrophy as well as secretion of an adhesive fibrinous exudate have been described with stone impaction.[1,2] These changes can lead to more challenging retrograde access to the stone, greater adherence of stone fragments to the mucosa, increased risk of bleeding, perforation, stricture formation, and need for repeat operation.[3,4]

Identification of impacted stones prior to surgery can be advantageous. First, preoperative data suggesting stone impaction may help urologists better differentiate which patients should likely be referred to a stone specialist. Additionally, during consultation endourological surgeons may estimate with greater confidence the likelihood of ureteral stent placement with subsequent stone management and a higher risk of ureteral stricture. Medications can be adjusted to limit bleeding risk. Alpha blockers, which may promote ureteral relaxation and facilitate better access beyond the impaction point, can be started preoperatively as well.[5] Also, advance knowledge of stone impaction creates the opportunity for advantageous alterations to the surgical approach, such as using an antegrade approach instead of retrograde for large proximal ureteral stones.[6,7]

In this study, we compared the noncontrast computed tomography (CT) findings of patients with impacted stones to those with nonimpacted stones in order to identify factors that may predict for ureteral stone impaction.

## METHODS

After institutional review board approval, we queried our prospectively maintained database of 1151 stone formers for patients that were treated with ureteroscopic laser lithotripsy for ureteral stones between June 2014 and July 2016. At the time of the surgery, a single surgeon determined whether or not a stone was impacted, based upon the intraoperative findings. Stone impaction was determined by a single surgeon using a 10 point Likert Scale. Guidelines for the scale are as follows. Stones were classified as nonimpacted if rated between 1 (mobile/rolling stone, zero edema) and 5 (stone stuck in ureter, mild edema, and can be dislodged with light pressure/irrigation). Stones rated between 6 (stone stuck in ureter, moderate edema, requires moderate pressure/irrigation to dislodge) and 10 (stone embedded within ureteral tissue, guidewire and contrast unable to pass,

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*From the Department of Urology, Icahn School of Medicine at Mount Sinai, New York, NY; the Division of Urology, Providence VA Medical Center, Providence, RI; the Urology Service, Memorial Sloan Kettering Cancer Center, New York, NY; and the Department of Urology, Boston University School of Medicine, Boston, MA*

*Address correspondence to: Jacob N. Bamberger, B.S., Department of Urology, Icahn School of Medicine at Mount Sinai, 425 W 59th St, 4th Floor, New York, NY 10019. E-mail: jacob.bamberger@mssm.org*



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unable to dislodge, requires in situ treatment, and/or tissue stuck onto stone) were considered impacted.

Patients were separated into 2 groups: those with impacted stones, and those with nonimpacted stones. Patients were excluded if preoperative noncontrast CT imaging was not available for review or if a stone was located at the ureterovesical junction since the Hounsfield units (HU) of the ureter distal to the stone could not be reliably calculated. Patients with preoperative nephrostomy tube or ureteral stent were excluded.

Clinical data including demographics, preoperative imaging, and laboratory values were reviewed. Creatinine was measured as part of standard preoperative laboratory work and remeasured at 1-month follow-up. The time (days) between initial presentation of stone in the clinic and the extraction procedure, as well as when the CT scan was administered and extraction procedure were recorded. Noncontrast CT images were reviewed by a blinded investigator for calculation of stone size, stone volume, degree of hydronephrosis, HU density of the stone as well as HU density of the ureter proximal and distal to the stone. Following initial data analysis, measurements of HU density of the ureter proximal and distal to the stone was repeated by a second blinded investigator. Inter-rater reliability was analyzed using intraclass correlation coefficient with a 0.7 cut-off value.

The degree of preoperative hydronephrosis was assigned a value of 0-3 based upon the following scale: 0 = no hydronephrosis (no dilation of the renal pelvis or calyces); 1 = mild hydronephrosis (dilation of the renal pelvis without changes to the renal calyces); 2 = moderate hydronephrosis (rounding of the calyces and flattening of the renal papillae); and 3 = severe hydronephrosis (obliteration of the calyces and papillae with cortical thinning).

HU of a stone was measured by drawing a region of interest over a stone and recording the mean HU density. HU density of the ureter under and above the stone was measured at a 4-8 times magnification in the coronal view with an abdominal window, drawing a region of interest within the ureter. Care was taken to avoid any coning of the ureteral stone and overlapping tissues (Fig. 1). The coronal view was selected for this measurement as it facilitates identification of the ureter proximal and distal to the stone.

Stone volume was measured using the length and width in the axial view under 8 times magnification and the height was measured in the coronal view at 8 times magnification. The largest value from height, width, or length was used to determine the final stone size in millimeters (mm). The stone length, width, and height measurements were used in the ellipsoid formula, $V = \left(\frac{\pi}{6}\right)lwh$, to determine the final stone volume (mm$^3$). The final results were verified by a separate investigator who was blinded to the identity of patients with impacted and nonimpacted stones.

Demographic data, CT imaging, postoperative and preoperative laboratories, and intraoperative factors were used for comparison between the impacted and nonimpacted stone groups. Statistical analysis was performed using student *t*tests and logistic regression with SPSS statistical software v.25 (IBM Analytics, Armonk, NY). Cut-off values for HU density of the ureter were determined based upon identification of cutoffs that had greatest sensitivity and specificity for impacted stones.

## RESULTS

Of the 1151 patients in our database, 47 patients were identified that had impacted ureteral stones. These patients were compared with 47 consecutive control patients that had ureteroscopy for ureteral stones that were found to be not impacted.

Comparison of the 2 groups revealed no differences in age, gender, or body mass index (Table 1). On univariate analysis, patients with impacted stones were noted to have greater stone size (8.48 mm vs 7.01 mm, $P$ = .026) and stone volume (130 mm$^3$ vs 63 mm$^3$, $P$ = .018). No significant difference in mean time between first clinical presentation of ureteral stones and day of extraction procedure was noted between the control group, 24 days, and impacted group, 14.5 days ($P$ = .33). Additionally, differences in mean time between CT scan and date of surgery was also found to be nonsignificant, with means of 25 days vs 25.6 days for the control and impacted groups, respectively ($P$ = .93).

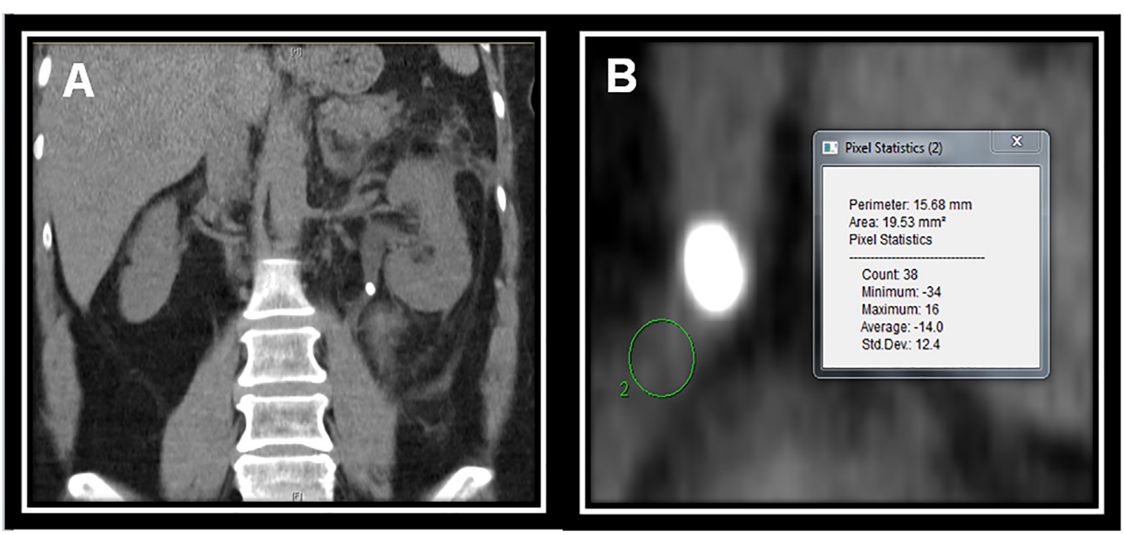


**Figure 1.** (**A**) The proximal ureteral calculus is demonstrated in coronal section. (**B**) An elliptical region of interest is drawn over the ureter distal to the calculus. Average Hounsfield unit density is calculated by the imaging software. Maximal (8×) magnification is used to facilitate accurate demarcation of ureteral borders. Care is taken not to include the retroperitoneal fat or calculus in the region of interest. (Color version available online.)

**Table 1.** Comparison of Clinical and demographic factors between patients with impacted and nonimpacted stones

| | Control $n = 47$ | Impacted $n = 47$ | $P$ Value |
|---|---|---|---|
| Mean Age | 54 | 56 | .385 |
| Female, $n$ | 28 (61%) | 26 (55%) | .370 |
| Body mass index, kg/m$^2$ | 29.0 | 28.2 | .607 |
| Stone size, mm | 7.01 | 8.48 | .026* |
| Stone volume, mm$^3$ | 63 | 130 | .018* |
| HU of stone | 855 | 820 | .628 |
| HU under stone | 19.3 | 34.9 | .001* |
| HU above stone | 14.0 | 11.4 | .138 |
| HU under/above | 2.19 | 4.97 | .009* |
| Degree of hydronephrosis | 1.22 | 1.66 | .006* |

HU, Hounsfield units.
* Denotes Significance

Impacted stones had a significantly greater HU density of the ureter under the stone (34.9 HU vs 19.3 HU, $P = .001$) and ratio of HU density under and above the stone (4.97 HU vs 2.19 HU, $P = .009$). The average degree of preoperative hydronephrosis was noted to be higher among patients with impacted stones than those with nonimpacted stones (1.66 vs 1.22, $P = .006$). Intraclass correlation coefficient values for HU above, HU under, and HU under/above were 0.991, 0.961, and 0.955, respectively.

No differences in pre- or postoperative creatinine, stone density or HU above the stone were noted between the 2 groups. Patients above a cut-off value of 27 HU of the ureter distal to the stone were noted to have impacted stones with a sensitivity of 85.1%, specificity of 84.9%, positive predictive value of 85.1%, and negative predictive value of 84.1% (Table 2). Using a logistic regression model and adjusting for the degree of hydronephrosis and stone size, patients with higher HU under the stone had an independently higher likelihood of being impacted (odds ratio = 1.17; 95% confidence interval 1.1-1.25; $P = .001$) (Table 2). Additionally, there were no significant differences between impacted patients and nonimpacted patients relative to postoperative parameters including: postoperative hydronephrosis, stone free rates, readmission, second surgery within 6 months of initial surgery, infection, stone recurrence within 6 months of initial surgery, nor rates of stricture.

## DISCUSSION

With miniaturization of ureteroscopes, increased surgeon experience and improved stone fragmentation and retrieval devices, retrograde treatment of ureteral stones has become a relatively straightforward procedure. However, treatment of impacted ureteral stones continues to pose a noteworthy challenge for the urologist. A CROES database report of 2650 patients undergoing ureteroscopic treatment of impacted stones demonstrated lower stone-free rates and higher rates of bleeding, ureteral avulsion, and ureteral perforation.[8]

**Table 2.** Multivariate regression with stone size, Hounsfield units distal to the stone and degree of hydronephrosis

| | OR (95% CI) | $P$ Value |
|---|---|---|
| Stone size, mm | 1.12 (0.93-1.36) | .24 |
| HU under stone | 1.17 (1.11-1.25) | .001* |
| Degree of hydronephrosis | 1.14 (0.54-2.41) | .73 |

CI, confidence interval; HU, Hounsfield units; OR, odds ratio.
* Denotes Significance

Impacted stones are associated with distinct pathologic changes within the ureter. These include increased edema, tissue hypertrophy (with polyp formation) and mucosal secretion of adhesive exudate that increases stone adherence to the ureteral wall.[9] As a result, surgeons may encounter challenges in accessing the stone, more bleeding from the mucosa, difficulty freeing the stone from the area of impaction as well as a greater chance of ureteral perforation.[3,10] Following these cases, patients are more likely to require a postoperative stent for ureteral drainage while the impaction-related inflammation resolves.

Preoperative knowledge of an impacted stone provides clinical benefits across the field of urology. Stone impaction is associated with an increased likelihood of ureteral stent placement, ureteral perforation and stricture, as well as need for reoperation.[8] If a urologist notes preoperative CT features suggesting stone impaction they may choose to refer this potentially complex case to a stone specialist. For cases that necessitate surgical intervention, this information may inform preoperative counseling with respect to likelihood of potential complications, and facilitate more accurate estimations of stent duration. In turn, a strengthened understanding of postoperative expectations from the patient may help them better manage and schedule their daily lives following operation.

Also, while ureteroscopy appears safe for patients on antiplatelet medications and anticoagulants,[11,12] surgeons may be more inclined to hold these agents to limit the increased bleeding that is associated with an impacted stone. Lastly, preoperative administration of alpha blockers can be considered, as they are noted to promote ureteral relaxation and subsequently more successful retrograde access to a ureteral stone and/or placement of a ureteral access sheath, which allows continues flow and fragment passage.[5]

Operative planning can be influenced as well. For retrograde ureteroscopy, surgeons may alter their approach to establishing access to the ureter. The presence of an inflamed, edematous ureter raises the chances of submucosal wire passage or perforation.[13] While PTFE-Nitinol wires are commonly used as safety wires, a hydrophilic-coated guidewire may be selected instead. In addition, urologists may choose an antegrade approach for large proximal ureteral stones to manage the chance of procedure failure and/or avoid traversing the area of impaction. Moufid et al noted a significantly higher stone-free rate (95.4 vs 54.5%, $P = .01$) and lower perforation rate (0% s 9.1%) with a percutaneous antegrade approach.[7] Long et al reported a series of 163 patients who underwent mini-percutaneous nephrolithotomy (16-French tract) for impacted upper ureteral stones. Their findings included a 95.7% stone-free rate, no ureteral perforations and no postoperative strictures with follow-up of at least 6 months.[6]

Previous studies have evaluated the utility of various parameters in predicting challenging ureteroscopic cases. Krambeck et al evaluated 154 renal units in 120 patients undergoing elective ureteroscopy for renal stones. Factors that predicted successful treatment were >50% opacification of the ureter on 10-minute delayed images, wider ureteropelvic junction (5 mm vs 4 mm), previous ipsilateral stent and stone surgery.[14]

Tran et al reviewed 247 patients that underwent ureteroscopy after presenting to the emergency room with intractable renal colic from a ureteral stone.[15] Their treatment failure rate was 18% and 95% of the failures were due to inability to access the stone. Predictors of failure included an elevated HU density of the ureter distal to the stone. While the authors postulated that higher periureteral density may be reflective of lower stone free rates, the study failed to analyze the parameter's efficacy in predicting stone impaction specifically. Also, the study did not assess specific intraoperative factors correlated with stone impaction.

Lastly, Legemate et al reviewed a worldwide ureteroscopy database that included 2650 patients with impacted stones.[8] Here, they noted that female gender, ASA Score >1, larger stone size, positive preoperative culture and prior ipsilateral treatment were associated with stone impaction.

In this series, we found several factors to be predictive of impacted stones on univariate analysis. These included stone size, stone volume, distal ureteral density, and degree of preoperative hydronephrosis. Stone size (and volume) are known to be associated with degree of hydronephrosis.[16,17] This raised the question as to whether distal ureteral density was just related to stone size. However, on multivariate analysis only distal ureteral density remained a significant predictor of stone impaction (odds ratio 1.17, 95% confidence interval 1.1-1.25, $P$ = .001).

Sensitivity and specificity analysis established a cut-off value for the density of the ureter distal to the stone to be 27 HU. This cutoff demonstrated a sensitivity and specificity of 85%, as well as positive predictive value of 89% and negative predictive value of 81%. As noted previously, it is possible that a higher density ureter may reflect greater tissue edema and inflammation, which correlates with the endoscopic findings of an impacted stone.

It is reasonable to consider why metrics are needed to predict an impacted stone. Previously, an impacted stone has been defined as one where antegrade or retrograde contrast does not readily pass.[17] Because this is typically discovered at the time of surgery, however, using this definition precludes the opportunity for consideration of alternative approaches and medication adjustments. Other series have defined an impacted stone as one that has not progressed distally for over 2 months.[3] This has been challenged, however, given that endoscopic findings characteristic of impacted stones are known to develop in fewer than 2 months.[4]

Advantages to this study include endoscopic confirmation of stone impaction by a single surgeon, which facilitates consistent definition. In addition, evaluation of radiographs with a blinded reviewer limits bias in the measurement of the CT-related factors.

This study is limited by its retrospective nature. External and/or prospective validation of measuring distal ureteral density will be required to confirm its utility. An additional limitation is that many patients with distal ureteral stones were excluded due to inability to clearly measure the HU density of the ureter distal to the stone. As such, the utility of this metric may be restricted to proximal and midureteral stones.

Despite these limitations, this study is unique as it reveals HU distal to the stone as a novel predictor of stone impaction that may facilitate improved outcomes by preoperative identification of patients with impacted stones.

## CONCLUSION

Impacted stones are associated with a greater distal ureteral density with a cut-off value of 27 HU on noncontrast CT. Preoperative knowledge of stone impaction may affect patient preparation for surgery and influence the operative approach.

### References


1. Morgentaler A, Bridge SS, Dretler SP. Management of the impacted ureteral calculus. *J Urol*. 1990;143:263–266. https://doi.org/10.1016/s0022-5347(17)39928-7.
2. Yamaguchi K, Minei S, Yamazaki T, Kaya H, Okada K. Characterization of ureteral lesions associated with impacted stones. *Int J Urol*. 1999;6:281–285. https://doi.org/10.1097/01.ju.0000100960.08768.81.
3. Roberts WW, Cadeddu JA, Micali S, Kavoussi LR, Moore RG. Ureteral stricture formation after removal of impacted calculi. *J Urol*. Mar 1998;159:723–726. https://doi.org/10.1097/00005392-199803000-00023.
4. Mugiya S, Ito T, Maruyama S, Hadano S, Nagae H. Endoscopic features of impacted ureteral stones. *J Urol*. 2004;171:89–91. https://doi.org/10.1097/01.ju.0000100960.08768.81.
5. Ahmed AF, Maarouf A, Shalaby E, et al. Semi-rigid ureteroscopy for proximal ureteral stones: does adjunctive tamsulosin therapy increase the chance of success? *Urol Int*. 2016:e1137. https://doi.org/10.1016/s1569-9056(16)61138-7.
6. Long Q, Guo J, Xu Z, et al. Experience of mini-percutaneous nephrolithotomy in the treatment of large impacted proximal ureteral stones. *Urol Int*. 2013;90:384–388. https://doi.org/10.1159/000343668.
7. Moufid K, Abbaka N, Touiti D, et al. Large impacted upper ureteral calculi: a comparative study between retrograde ureterolithotripsy and percutaneous antegrade ureterolithotripsy in the modified lateral position. *Urol Ann*. 2013;5:140–146. https://doi.org/10.4103/0974-7796.115729.
8. Legemate JD, Wijnstok NJ, Matsuda T, et al. Characteristics and outcomes of ureteroscopic treatment in 2650 patients with impacted ureteral stones. *World J Urol*. 2017;35:1497–1506. https://doi.org/10.1007/s00345-017-2028-2.
9. Brito AH, Mitre AI, Srougi M. Ureteroscopic pneumatic lithotripsy of impacted ureteral calculi. *Int Braz J Urol*. 2006;32:295–299. https://doi.org/10.1590/s1677-55382006000300006.
10. Oliver R, Wells H, Traxer O, et al. Ureteric stents on extraction strings: a systematic review of literature. *Urolithiasis*. 2018;46:129–136. https://doi.org/10.1007/s00240-016-0898-1.
11. Westerman ME, Scales JA, Sharma V, et al. The effect of anticoagulation on bleeding-related complications following ureteroscopy. *Urology*. 2017;100:45–52.
12. Westerman ME, Sharma V, Scales J, et al. The effect of antiplatelet agents on bleeding-related complications after ureteroscopy. *J Endourol*. 2016;30:1073–1078. https://doi.org/10.1016/j.urology.2016.09.034.
13. El Darawany H, Barakat A, Madi MA, et al. Latrogenic submucosal tunnel in the ureter: a rare complication during advancement of the

guide wire. *Ann Saudi Med*. 2016;36:112–115. https://doi.org/10.5144/0256-4947.2016.112.

14. Viers BR, Viers LD, Hull NC, et al. The difficult ureter: clinical and radiographic characteristics associated with upper urinary tract access at the time of ureteroscopic stone treatment. *Urology*. 2015;86:878–884. https://doi.org/10.1016/j.urology.2015.08.007.
15. Tran TY, Hernandez Bustos N, Kambadakone A, Eisner B, Pareek G. Emergency ureteral stone treatment score predicts outcomes of ureteroscopic intervention in acute obstructive uropathy secondary to urolithiasis. *J Endourol*. 2017;31:829–834. https://doi.org/10.1089/end.2017.0043.
16. Hiller N, Berkovitz N, Lubashevsky N, Salaima S, Simanovsky N. The relationship between ureteral stone characteristics and secondary signs in renal colic. *Clin Imaging*. 2012;36:768–772. https://doi.org/10.1016/j.clinimag.2012.01.018.
17. Deliveliotis C, Chrisofos M, Albanis S, et al. Management and follow-up of impacted ureteral stones. *Urol Int*. 2003;70:269–272. http://doi.org/10.1159/000070133.