# Stone Size Limits the Use of Hounsfield Units for Prediction of Calcium Oxalate Stone Composition

**Gregory Stewart, Lewis Johnson, Halemane Ganesh, Daniel Davenport, Woodson Smelser, Paul Crispen, and Ramakrishna Venkatesh**

**OBJECTIVE** To evaluate the role of stone size in predicting urinary calculus composition using Hounsfield units on noncontrasted computed tomography (CT) scan.

**METHODS** A retrospective review was performed for all patients who underwent ureteroscopy or percutaneous nephrolithotomy during a 1-year period, had a stone analysis performed, and had CT imaging available for review. All CT scans were reviewed by a board-certified radiologist. Variables evaluated included age, sex, body mass index, stone size, stone location, Hounsfield units (HUs), and stone composition.

**RESULTS** We identified a total of 91 patients (41 men and 50 women) with CT imaging and stone analysis available for review. Stone analysis showed 41 calcium oxalate monohydrate (CaOxMH), 13 calcium oxalate dihydrate, 29 calcium phosphate, 5 uric acid, 2 struvite, and 1 cystine stone. Average age was 46 years, and average body mass index was 32 kg/m$^2$. Measured HUs varied significantly with size for CaOxMH and calcium oxalate dihydrate stones ($P$ values <.05), but not for calcium phosphate stones ($P$ = .126). Using a CaOxMH identification value of 700-1000 HUs, 28 of 41 stone compositions (68%) would not have been correctly identified, including all 10 (100%) small (<5 mm) stones, 13 of 22 (59%) medium (5-10 mm) stones, and 5 of 9 large (>10 mm) stones (55%).

**CONCLUSION** For calcium stones, the ability of CT HUs to predict stone composition was limited, likely due to the mixed stone composition. Within a cohort of CaOxMH stone formers, measured HUs varied linearly with stone size. All stones <5 mm were below thresholds for CaOxMH composition. UROLOGY 85: 292–295, 2015. 

Prior studies have demonstrated that measurement of Hounsfield units (HUs) of urinary calculi on noncontrasted computed tomography (CT) scan can predict stone composition. Initial in vitro studies demonstrated the ability to differentiate calcium oxalate (CaOx) stones from uric acid stones.[1] More recently, it has been shown that HUs can differentiate composition by calcium subtype.[2,3]

Numerous studies have attempted to define the utility of HUs in clinical practice.[2-6] Ouzaid et al[4] recently performed a prospective trial evaluating extracorporeal shock wave lithotripsy (ESWL) efficacy and HUs on preoperative imaging. They defined an HU cutoff of <970 HU as predicting treatment success and demonstrated a 96% vs 38% success rate based on this cutoff. Conversely, Gucuk et al[5] showed that a stone density of <677 HU has been found to be a predictor of percutaneous nephrolithotomy failure.

Although stone density on noncontrast CT can help counsel patients on the most efficacious treatment modality, it is unknown to what degree preoperative knowledge of the stone composition can improve outcome. Furthermore, factors that confound the use of HUs to predict stone composition have not been well defined. We evaluated the impact of stone size and location on accurate prediction of stone composition using HUs.

## METHODS

After obtaining institutional review board approval, a retrospective review was performed for patients who underwent ureteroscopy or percutaneous nephrolithotomy during a 1-year period. Our patient database was generated by querying billing records for using current procedural terminology codes 52352, 52353, 50081, and 50080. Patients were excluded if they were aged <18 years, did not have a CT scan available at our institution for review, or if a stone analysis was not performed. Data collected included age, sex, body mass index (BMI), stone size, stone location, average HUs, and stone composition. Stone

**Financial Disclosure:** *The authors declare that they have no relevant financial interests.*

*From the Department of Urology, University of Kentucky, Lexington, KY; the Department of Radiology, University of Kentucky, Lexington, KY; and the Department of Surgery, University of Kentucky, Lexington, KY*

*Address correspondence to: Ramakrishna Venkatesh, M.D., Department of Urology, University of Kentucky, MS 283, 800 Rose Street, Lexington, KY 40536-0293. E-mail: lewis.johnson@uky.edu*

*Submitted: June 12, 2014, accepted (with revisions): October 7, 2014*

 
http://dx.doi.org/10.1016/j.urology.2014.10.006
0090-4295/15

**Table 1.** Patient characteristics by stone composition

| Patient and Stone Parameters | CaOxDH | CaOxMH | CaPhos |
|---|---|---|---|
| No. of patients | 13 | 41 | 29 |
| No. of male/female | 7/6 | 21/20 | 21/8 |
| Age, mean ± SD (y) | 41.0 ± 12.9 | 48.2 ± 13.8 | 43.3 ± 14.8 |
| BMI, mean ± SD (kg/m$^2$) | 29.5 ± 6.8 | 31.4 ± 6.7 | 32.2 ± 11.6 |
| Stone size, mean ± SD (mm) | 6.2 ± 2.8 | 7.5 ± 3.8 | 17.1 ± 12.8 |
| Location | | | |
| Distal ureter, n (%) | 3 (23) | 9 (22) | 3 (10) |
| Proximal ureter, n (%) | 8 (62) | 17 (42) | 4 (14) |
| Renal, n (%) | 2 (15) | 15 (37) | 22 (76) |

BMI, body mass index; CaOxDH, calcium oxalate dihydrate; CaOxMH, calcium oxalate monohydrate; CaPhos, calcium phosphate; SD, standard deviation.

analysis was performed by ARUP Laboratories using infrared spectroscopy (University of Utah, Salt Lake City, UT). At our institution, stone composition of mixed stones is routinely reported by percentage of each stone composition. Stones were assigned to each composition category based on what constituted the majority (>50%) of the stone component. Stones were classified as CaOx monohydrate (CaOxMH), CaOx dihydrate (CaOxDH), calcium phosphate (CaPhos), uric acid, struvite, or cystine.

All CT scans were retrospectively reviewed on a picture archiving and communication system system by 1 board-certified radiologist who was blinded to other clinical variables including stone composition. HUs and size of the renal and ureteral calculi were measured at their greatest transverse dimension. This was measured in the region of interest (ROI) at the center of the stone. The mean and median of the ROI including standard deviations (SDs) within the ROI for each stone were evaluated. When multiple stones were present, the largest stone was selected. Stone location was characterized as within the kidney, proximal ureter, or distal ureter. Stones above the iliac vessels but below the ureteropelvic junction were classified as proximal ureteral stones. Stones between the iliac vessels and ureterovesical junction were classified as distal.

The ability to accurately predict stone composition based on HU was then examined for CaOxMH stones. We selected a cutoff value of 700-1000 HU for CaOxMH stones based on previously published data.[2] If the stone was measured to be <700 or >1000 HU on CT but was found to be CaOxMH based on stone analysis, it was considered nonpredictive. If the stone was measured to be between 700 and 1000 HU on CT scan and stone analysis confirmed that it was a CaOxMH stone, it was considered predictive.

The Pearson correlation was used to analyze HU and stone size, and multivariate linear regression was used to adjust for demographic and clinical parameters. Significance was set at $P$ <.05 for all analyses. SPSS statistical software, version 19 (IBM Corporation, Armonk, NY), was used for all calculations.

## RESULTS

A total of 165 patients were identified as having undergone ureteroscopy or percutaneous nephrolithotomy during a 1-year period in 2009. Ninety-one of these patients had CT images available for review and a stone analysis. Of the 91 patients included in the analysis, 41 were men and 50 were women. Mean age was 46 years (range, 20-76 years). Mean BMI was 32 kg/m$^2$ (range, 19-70 kg/m$^2$). Sixty-five patients underwent ureteroscopy with lithotripsy or stone removal, and 26 patients underwent percutaneous nephrostolithotomy. Patient characteristics based on stone type are presented in Table 1.

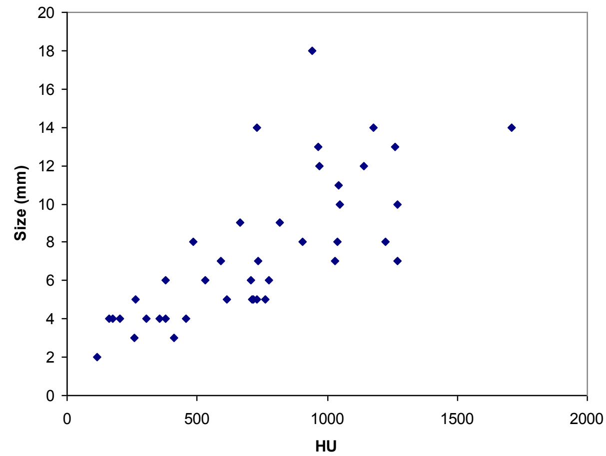


**Figure 1.** Distribution of stone size and Hounsfield unit (HU) measurements in 41 calcium oxalate monohydrate stones in kidney and ureter. (Color version available online.)

Measured HU varied with stone size only for CaOxMH and CaOxDH stones (Pearson correlation = 0.74 for both; $P$ value <.01). For CaOxMH stones, mean (±SD) stone size was 7.5 ± 3.8 mm, and average HU were 732 ± 375. Fifteen were located within the kidney (37%), 17 in the proximal ureter (41%), and 9 in the distal ureter (22%). Figure 1 demonstrates that HU increases linearly with stone size for CaOxMH stones (n = 41; R = 0.74; $P$ <.01). On multivariate analysis, measured HUs of CaOxMH stones varied with stone size independent of stone location, BMI, age, and gender (adjusted coefficient, B = 59 HU per mm stone size; $P$ <.001). CaPhos stones did not show a correlation between size and HU overall; however, in the ureter, it may be trending so (Fig. 2), but our sample size was too small to be sure. The number of struvite and uric acid stones was too small to draw any correlation between stone composition, size, and HUs.

In our cohort, within the HU range of 700-1000 units, CaOx and CaPhos stones could not be differentiated from each other based on HUs (Supplementary Table 1). The mean and median of HUs including the SDs within the