Detection of Uric Acid Stones in the Ureter Using Low- and Conventional-dose Computed Tomography

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OBJECTIVE To determine the ability of low- and conventional-dose computed tomography (CT) in identification of uric acid stones, which are of lower density than calcium oxalate stones.

MATERIALS AND METHODS Uric acid stones (3, 5, and 7 mm) were randomly placed in human cadaveric ureters and scanned using conventional 140-mAs and low-dose 70-, 50-, 30-, 15-, 7.5-, and 5-mAs settings. A single-blinded radiologist reviewed a total of 523 scanned stone images. Sensitivity and specificity were compared among different settings and stone sizes.

RESULTS Imaging using 140-, 70-, 50-, 30-, 15-, 7.5-, and 5-mAs settings resulted in 97%, 97%, 96%, 93%, 83%, 83%, and 69% sensitivity and 92%, 92%, 91%, 89%, 88%, 91%, and 94% specificity, respectively. There was a significant difference in sensitivity between 140 mAs and 15, 7.5, and 5 mAs ($P = .011$, $P = .011$, and $P < .001$, respectively). Sensitivity for 3-, 5-, and 7-mm stones was 83%, 90%, and 93%, respectively. At ≤15 mAs, 3-mm stones had a higher rate of false negatives ($P < .001$).

CONCLUSION Both low- and conventional-dose CTs demonstrate excellent sensitivity and specificity for the detection of ureteral uric acid stones. However, low-dose CT at ≤15 mAs resulted in reduced detection of uric acid stones. UROLOGY 84: 571–574, 2014.

Noncontrast computed tomography (CT) is the radiographic modality of choice for patients with kidney stones or flank pain because of rapid image acquisition and its ability to identify alternative diagnoses.[1] Additionally, CT has been shown to effectively detect stone size and stone attenuation, measured in Hounsfield units (HUs), which are helpful characteristics when determining appropriate treatment modality.[2-4] However, CT contributes to nearly half of medical ionizing radiation exposure.[5] The proportion of annual ionizing radiation exposure secondary to medical imaging has grown from 15% in the 1980s to 48% in 2006. The average effective radiation dose of a multidetector CT of the abdomen and pelvis ranges between 8 and 16 mSv.[6-8] It is estimated that radiation exposure of 10 mSv may result in a 1/1000 lifetime risk of developing cancer in patients aged 16-69 years.[9]

Because of the concern over high radiation exposure from conventional CT, alterations in imaging protocols have been suggested.[10] One such modification is the reduction of radiation exposure by using low-dose CT (LDCT) protocols. These protocols have been shown to detect calcium oxalate stones with high sensitivity and specificity for stones of various sizes, while reducing overall radiation exposure by up to 70%-95%.[11,12] Dense calcium oxalate stones are the most common and easily detectable with relatively high HU values. In contrast, uric acid stones are less dense and maybe more difficult to detect using LDCT.[2-4] The sensitivity and specificity of LDCT compared with conventional-dose CT (CDCT) in detecting uric acid stones are yet to be determined. The purpose of this study was to prospectively evaluate stone detection at different radiation dose settings for uric acid stones.

MATERIALS AND METHODS

The ability of LDCT protocols to detect ureteral uric acid stones was tested in a prospective single-blind study. Twenty-seven stones of ≥95% purity for uric acid were obtained from Herring Laboratory (Louis C. Herring & Co., Orlando, FL). The stones were measured by greatest dimension using UltraTech Digital Calipers (General Tools and Instruments, New York, NY) and grouped as 3-, 5-, and 7-mm stones. Actual stone size was ±0.75 mm of the assigned stone size group.

The Loma Linda University School of Medicine's Department of Anatomy granted approval for the use of human anatomical specimens in accordance with institutional guidelines. Seven intact urinary systems (kidneys, ureters, and bladder) were obtained from both male and female cadavers. Stones were placed in

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Table 1. Sensitivity and specificity for LDCT (5-70 mAs) compared with CDCT (140 mAs)

mAs	mSv	Sensitivity (%)	95% CI (%)	*P* Value	Specificity (%)	95% CI (%)	*P* Value	NPV (%)	PPV (%)
140	5.7	97	91-99		92	83-96		97	92
70	2.8	97	91-99	.631	92	83-96	.760	97	93
50	2.0	96	89-99	.910	91	82-95	.935	96	91
30	1.2	93	85-97	.466	89	79-94	.746	93	89
15	0.6	83	73-90	**.011**	88	78-93	.600	83	88
7.5	0.3	83	73-90	**.011**	91	82-95	.935	84	90
5	0.2	69	58-79	**<.001**	94	87-98	.888	76	93

CDCT, conventional-dose computed tomography; CI, confidence interval; LDCT, low-dose computed tomography; NPV, negative predictive value; PPV, positive predictive value.
Values in bold are statistically significant.

random configurations determined by Microsoft Excel software (Microsoft Inc., Redmond, WA) in each of the 14 ureters. The ureter was incised at the predetermined position (proximal, middle, or distal), and the stone was placed within the lumen with a dollop of Aquasonic 100 Ultrasound Transmission Gel (Park Laboratories Inc., Fairfield, NJ) to mimic the natural stone-fluid interface. The incision was closed using an interrupted suture. The intact urinary systems were then placed into a male cadaver with a body mass index (BMI) of 27.1 kg/m^2, whose urinary system had been previously removed.

The male cadaver was loaded into the gantry with the arms raised above the head to reduce noise artifact and mimic patient positioning during routine imaging. A laser guide was used to zero the CT scanner at the top of the midline incision. Initial scout images, before insertion of urinary systems, were obtained to ensure the absence of distracting calcifications or clips. CT imaging was performed using a GE LightSpeed VCT 64-slice tomographic scanner (GE Healthcare, Waukesha, WI), with constant settings of 120 kVp, collimation 0.625 mm, 2.5-mm axial slices (iterative reconstruction), 0.5-second gantry rotation time, and a pitch of 1.375. Each abdomen and pelvis scan was performed using a CDCT setting of 140 mAs and LDCT settings of 70, 50, 30, 15, 7.5, and 5 mAs. After imaging, the stones were serially rearranged to achieve a total of 76 random configurations. There were 182, 169, and 172 images of 3-, 5-, and 7-mm stones, respectively. This resulted in a total of 523 scanned stone images.

The CT images were then axially reconstructed with a 2.5-mm section width, randomly sequenced, and reviewed for stone detection by a single radiologist (J.C.S.), a board-certified abdominal imaging specialist with 11 years of experience. The radiologist was blinded to stone number, size, laterality, ureteral position, and CT setting. Sensitivity and specificity were compared among different settings using the Wilson score method. The study was powered at 81% to detect a mean difference of 10%. The ability to detect stones of different sizes was analyzed using the Fisher exact test. All significance levels were set to <.05.

RESULTS

Overall sensitivity and specificity were 89% (confidence interval [CI], 85%-91%) and 91% (CI, 88%-93%), respectively. Compared with the 140-mAs setting of CDCT, LDCT settings of 15, 7.5, and 5 mAs showed significantly less sensitivity (P = .011, P = .011, and P <.001, respectively; Table 1). There were no significant differences seen in specificity. Sensitivity, specificity, and positive and negative predictive values are summarized in Table 1. Estimated effective dose for the tested protocols ranged from 5.7 mSv for CDCT at 140 mAs to 0.2 mSv for the 5 mAs LDCT (Table 1). The Fisher exact test determined that the proportion of false negatives was significantly different among the 3- (31 of 182; 17.0%), 5- (17 of 169; 10.1%), and 7-mm (12 of 172; 7.0%) stone groups (P = .011; CI, 0.008-0.013), with the 3-mm group exhibiting the highest rate of false negative results. Overall sensitivities across stone sizes are shown in Figure 1. As illustrated in Figure 2, false negative rates for 3-mm stones were higher in doses <30 mAs (P <.001), whereas 5- and 7-mm stones had significantly higher false negative rates only at 5 mAs (P = .012 and P = .002, respectively).

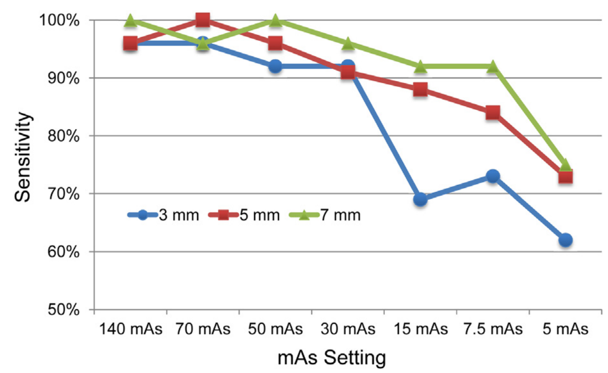

Figure 1. Sensitivity for each group of stone sizes at each mAs setting. (Color version available online.)

When looking specifically at each stone size group at settings of 140, 70, 50, 30, 15, 7.5, and 5 mAs, sensitivities were 96%, 96%, 92%, 92%, 69%, 73%, and 62% for 3-mm stones, 96%, 100%, 96%, 91%, 88%, 84%, and 73% for 5-mm stones, and 100%, 96%, 100%, 96%, 92%, 92%, and 75%, for 7-mm stones. Because of the randomization involved within the study design, specificity could not be determined for each stone size group. The average attenuation value for all stones was 371 HU (range, 157-625 HU).

COMMENT

CT remains the gold standard for imaging urolithiasis.[1] Despite the many merits of CDCT, the high radiation exposure remains its Achilles' heel. There is currently no known safe lower threshold of radiation exposure. The linear nonthreshold dose-response model used by the