Identification of Uric Acid stones with Dual Energy CT

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Authors: R. Salvador Izquierdo, M. P. Luque, B. Paño Brufau, A. Ciudin, L. Buñesch, R. Castañeda, M. C. Sebastia, C. Nicolau; Barcelona/ES
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Aims and objectives

This prospective study sought to assess dual-energy computed tomography's (DECT) performance in in vivo identification of uric acid stones in a usual clinical setting.

Urinary stones are a common condition that affect up to 12% of males and 6% of females through life span with frequent recurrence. Treatment of urinary stones depends on symptoms, size and localization and treatment options vary from medical treatment to invasive treatments. Uric acid stones account for 6 to 10% of urinary stones and can be medically dissolved with urine alkalization (1).

Correct and confident identification of uric acid stones may prompt adequate treatment and avoid unnecessary invasive approaches.

Unenhanced CT is an effective imaging modality for the assessment of urinary stones. However, single-energy CT does not have the ability to reliably differentiate between different calculus material (2,3). DECT has proved to differentiate uric acid stones from other urinary stones in in vitro models(4-6). Uric acid stone tend to have higher attenuation values in low-energy images whereas other type of urinary stones have typically higher density values in high-energy images.

We wished to assess DECT performance in our clinical context.
Methods and materials

We assessed 65 stones in 63 consecutive patients scanned with DECT for urinary stones between December 2010 and October 2013 with available urinary stone for ex vivo analysis. Patients were scanned for suspected renal colic or before treatment of a known kidney or ureteral stone.

DECT was performed in a double-source double-energy second-generation scanner (Somatom Definition Flash, Siemens, Fochheim, Germany) using a clinical 80/Sn140 kV protocol with a tin filter for the high-energy X-ray tube. Imaging parameters were as follows: 32 × 0.6 mm collimation, 319 and 123 quality reference mAs for the 80 kV and 140 kV tubes, respectively, 0.5 s rotation time, and spiral mode with pitch = 0.7. Automatic exposure control was used. Dual-energy images were reconstructed using a kernel B30f, with a 300-mm field of view, image thickness of 2.0 mm and 1 mm interval.

An experienced radiologist with at least 4 years of full-time dedication to uroradiology identified and studied the images for each retrieved stone with specific software and with manually drawn regions of interest. A specific commercially available application of the dual energy vendor’s post-processing software package ("Kidney Stone", Syngovia, Siemens Medical Solutions) was used. This software automatically identifies a kidney stone and assigns a red or blue color to the stone when the low-energy to high energy densities ratio is below or over 1.21 cut-off ratio. When the user points the stone, the software reveals its size, densities and the ratio. Immediately after, in a clinical standard workstation (Alma workstation, Alma IT Systems, Barcelona, Spain), the radiologist drew a region of interest (ROI) in the stone in 80kV images and an identical ROI in the corresponding Sn140kV image to obtain the density values. Values were collected in a database and low to high-energy ratios were automatically calculated (UH at 80kV/ UH at Sn140kV).

Stones were obtained after spontaneous passage or after an endoscopic procedure.

Urinary stones were studied ex vivo with infrared spectrometry with a quantitative composition analysis. Stones with a predominant uric acid component, superior to 60%, were classified as uric acid stones.

ROC curves were performed for both automatic and manually obtained ratios.
Fig. 1: Figure 1. Uric acid stone. A) and B) are images of the "Kidney Stone" app. The red-colored right ureteral stone is identified by the software with a highest diameter of 7.8 mm and a low to high energy densities ratio of 1.08 (i.e. 552/510) as seen in A). In its corresponding graph depicted in B), although with higher densities, the stone is below the given cut-point ratio of 1.21. C) and D) are the same axial image with the 80kV tube acquisition (C) and Sn140kV (D) with identical manually-drawn ROI with mean densities of 564 UH and 558 UH that result in a 1.01 ratio.

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**Fig. 2**: Figure 2. Non-uric acid stone. A) and B) are images of the "Kidney Stone" app. The blue-colored left renal pelvis stone is identified by the software with a highest diameter of 4.3 mm and a low to high energy densities ratio of 1.56 (i.e. 1330/861) as seen in A). In its corresponding graph depicted in B), the stone is way over the given cut-point ratio of 1.21. C) and D) are the same axial image with the 80kV tube acquisition (C) and Sn140kV (D) with identical manually-drawn ROI with mean densities of 984 UH and 676 UH that result in a 1.46 densities ratio.

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Results

6 stones in 6 different patients were uric acid stones in the ex vivo analysis. Uric acid stones had a mean ratio and standard deviation (SD, expressed in brackets) for software and manual analysis of 1.01 (0.11) and 0.91 (0.1). The mean ratio and SD of the 59 non-acid uric stones was 1.62(0.1) with the software analysis and 1.61 (0.11) with manually drawn ROIs (Table 1).

Table 1.

<table>
<thead>
<tr>
<th>Stone Composition</th>
<th>N</th>
<th>Size in mm Mean (SD)</th>
<th>Localization</th>
<th>Software Ratio Mean (SD)</th>
<th>Manual Ratio Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uric Acid</td>
<td>6</td>
<td>13 (16)</td>
<td>Renal 4, Ureteral 2</td>
<td>1.01 (0.11)</td>
<td>0.91 (0.1)</td>
</tr>
<tr>
<td>Non Uric Acid</td>
<td>59</td>
<td>8 (5)</td>
<td>Renal 29, Ureteral 30</td>
<td>1.62 (0.1)</td>
<td>1.61 (0.11)</td>
</tr>
</tbody>
</table>

The manual densities ratio was performed in all the 65 stones but the software automatic post-process failed to obtain density measures in 14 stones (22% of the stones, 3 uric acid and 11 non-uric acid stones). These stones were all correctly classified as uric or non-uric acid stones by means of the color assigned by the software but as no values of size and density were obtained they were not included in the statistical analysis.

The paired T-test revealed statistical differences (p=0.041) between manual and software obtained ratios, with slightly lower ratios for manual ratios (mean difference of 0.015 and 0.051 standard deviation).

All stones were correctly identified both with automatically or manually obtained ratios using the cut-off value of 1.21 for the low to high-energy density ratio (Fig 3.). Area under the ROC curve for both methods of radiological assessment was 1 (Fig 4.).
Fig. 3: Figure 3. Box-plot for low to high energy densities ratio. The graph shows box-plot of the densities ratio of uric acid stones on the left and non uric acid stones on the right. Blue and green box-plots are to differentiate software and manually obtained ratios. Very clear differentiation of the ratios can be observed with no superimposition of the box plots between uric acid and non uric acid stones. Note that for both type of stones, the mean ratios are higher in the software obtained groups.

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Fig. 4: Figure 4. ROC Curves. Both ROC curves are "ideal" curves with 1 as the area under the curve. Just one is seen as both are identical and are therefore superimposed in the graph.

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Conclusion

DECT correctly identified all uric acid stones with 100% accuracy, with neither false positive or false negative cases. The prevalence of uric acid stones in our series was 9.2% (6 out of 65 stones) and is concordant to previously published data (1). All of our uric acid stones had a minimum percentage of uric acid of 95% and should therefore be considered pure uric acid stones.

We used a so-called "second generation" DECT (SOMATON Definition Flash, Siemens Healthcare) that has an added tin filter to the high-energy tube. The use of a tin filter in the high-energy x-ray beam radiation reduces the overlap of the radiation spectrum of both x-ray beams as it filters the lower energy photons of the high-energy spectra. This reduction of the overlap translates into a theoretically improved differentiation of materials, specifically that of uric acid from non-uric acid stones as previously reported (7,8). Our scanner is a dual-source DECT but similar results can be obtained with single-source DECT (9).

The specific software was not able to give density and size values in up to 22% of the stones. These values were necessary for our study and can be relevant when planning treatment, specially the size. Most of these stones were either in contact with urinary catheters, other stones or were extremely small, probably affecting automatic segmentation of the stones. In any case, the stones were correctly colored and classified as uric or non-uric acid stones.

The results obtained for manual and specific software measurements, although statistically different, are similar with no clinical differences as all stones were correctly classified. This comparison suggests that is not essential to purchase a specific application. On the other hand, we did not measure the time spent with one and another post processing method but our impression is that the automatic software post process is significantly quicker than the manual post process, a fact to bear in mind when assessing the need for the specific software.

Dual-energy CT allows for accurate identification of uric acid calculi in a routine clinical setting.
Personal information

Genitourinary Section, Radiology, Hospital Clínic de Barcelona, Barcelona, Spain.

M.P. Luque and R. Castañeda
Urology, Hospital Clínic de Barcelona, Barcelona, Spain.

A. Ciudin
Urology, Hospital Clínic de Barcelona and Hospital de Mollet, Barcelona, Spain.

Contact authors at rsalvado@clinic.ub.es
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