Dual Energy Computed Tomography for Non-Invasive Differentiation of Renal Stones

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Purpose

In the United Arab Emirates (UAE), and likewise in the entire Middle East, renal stones are frequently diagnosed. The incidence of pure uric acid (UA) stones is far higher than in Western countries. UA calculi are reported in the West in ~ 10%, whereas they occur in the Middle East in ~ 30% (1).

Computed tomography (CT) has become the method of first choice for diagnosis, localization, and identification of associated complications of renal stones (2-7). Several articles have been published to date proposing dual-energy computed tomography (DECT) for determination of urinary tract stone composition (7-12).

Our study was conducted to non-invasively evaluate renal stone composition by DECT in the local UAE patient population. The main goal was to differentiate between pure UA stones, mixed stones, and stones with high calcium content. Therefore patients with suspected renal stones were examined with dual-energy computed tomography. If our hypothesis of non-invasive determination of stone composition by DECT can be confirmed, invasive procedures, i.e., surgical stone extraction or extra-corporal shockwave lithotripsy (ESWL), may be avoided. Furthermore ESWL is not recommended in stones with very high calcium content in order to prevent potential major post-ESWL complications. Consequently patients with UA stones may receive sole pharmacological therapy for stone dissolution.
Methods and Materials

The Institutional Review Board (IRB) approved the prospective clinical and in vivo trial (AAMDHREC # 10/26), a collaborative research project between the College of Medicine and Health Sciences (CMHS)/ UAEU and the Al Ain - VAMED Hospital (AAH), a CMHS teaching hospital. DECT in 31 in- and out-patients from the AAH Urology- and Emergency Departments with suspected renal stones were conducted at the Clinical Imaging Department of the AAH. After signed informed consent, those patients were prospectively examined with unenhanced DECT at 80 kV and 140 kV. Body weight was limited to 95 kg to prevent too noisy images and hardening artifacts with subsequent wrong data recording. The AAH Siemens DECT Somatom Definition Dual Source 64 Slices, with a Syngo MMWP, version VE 1A software (Siemens Comp. Erlangen/Germany) was utilized for all examinations. The applied DECT protocol for all patients used a slice thickness of 0.6 mm, 0.7 pitch, and reconstruction at 1.5 mm slice thickness. Regions of interest (ROI) were hand drawn and defined at unenhanced 80 kV and 140 kV DECT images, as described by Matlaga (7). Attenuation values were measured and compared with published data (7-12).

Additionally 10 excreted renal stones were in vitro examined in a water phantom at 80 kV and 140 kV using the identical DECT protocol. Subsequently these 10 calculi were analyzed by in vitro Fourier Transform Infra-Red Spectroscopy (IRS) at the Biomnis Laboratoires (Lyon/ France).

Dual-energy indices, DEI = [HU (80 kV) - HU (140 kV)] / [HU (80 kV) + HU (140 kV) + 2000] were calculated in agreement with published data by Graser (9) and Eibner (12).
Results

31 exclusively male patients were included in our study with an age distribution from 24 to 52 years; the mean age was 36 years.

In 29 of 31 patients renal stones were detected. In total 39 calculi were identified in 29 subjects; diameters of these stones ranged from 2 mm to 12 mm. Attenuation values were characteristic for uric acid stones in nine (9) patients: > 160.80 HU at 80 kV, and 107.90 HU - 651.20 HU at 140 kV (7-10) (fig. 1, 2). Calculated DEI, according to the above described formula, were 0.0071 - 0.0269 in those nine (9) patients.

Higher attenuation values, i.e. > 1300 HU at 80 kV, and > 1000 HU at 140 kV, suggestive of stones with calcium content were determined in 30 stones. Those included 17 mixed renal stones (fig. 3, 4) with DEI from 0.0413 to 0.0863, and 13 high-level calcium containing stones with DEI from 0.0862 to 0.1186 (fig. 5, 6).

In vitro (water bath) examinations of 10 excreted renal stones depicted density values, typical for a UA stone in one (1) case, for mixed stones in five (5) cases, and for high-level calcium-content calculi four (4) times. Results of DECT in vitro measurement in the water bath were eventually confirmed by Fourier Transform Infra-Red Spectroscopy (IRS) analysis for those 10 calculi at the Biomnis Laboratoires, Lyon/France.

Laboratory IRS results correspondingly showed in one (1) case a pure uric acid stone, in four (4) cases mixed calculi, and in five (5) cases high-level calcium-containing stones.
Fig. 1: DECT sagittal plane, in vitro water bath density measurement of an uric acid renal stone at 80 kV and at 140 kV

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Fig. 2: Excreted uric acid (UA) urinary tract stone

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Fig. 3: Axial DECT: Right distal ureteral calculus: mixed urinary tract stone
Fig. 4: DECT, coronal matched image at 80 kV and 140 kV for density measurement: mixed urinary tract stone (stone from Fig. 3)

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**Fig. 5:** DECT, coronal reformation, left supra-vesical and intra-renal calculi: high-level calcium containing stones

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Fig. 6: DECT, corresponding matched image at 80 kV and 140 kV for density measurement: high-level calcium containing stone (stone from Fig. 5)

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Conclusion

DECT at 80 kV and 140 kV, including DEI calculation (9, 12), proved to be a **reliable modality** for determination of renal stone composition, especially for differentiation between pure uric acid stones, mixed stones, and high-level calcium containing calculi. DECT is far superior to conventional radiographs or to single-energy CT for determination of renal tract stone composition.

DEI calculation is deemed reliable for differentiation between UA stones, mixed stones, and calculi with high calcium content. DEI calculation of UA stones in our UAE patient population was 0.0071 to 0.0269, DEI of mixed stones was 0.0413 to 0.0863, and DEI of high-level calcium stones was 0.0862 to 0.1186. Our results for these three (3) sub-groups are in accordance with recently published data (7-12).

Due to the small total number of patients in our clinical study, further differentiation between calcium oxalate calculi and calcium phosphate urinary tract stones was not carried out. Uric acid renal stones occurred in 23% in our UAE patient population which is in accordance with the current literature (1).

As a consequence of the in vivo results of our clinical trial, patients with **pure uric acid stones** may be **treated solely pharmacologically** after stone characterization by DECT.
References

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