Dual Energy Computerized Tomography with a Split Bolus—A 1-Stop Shop for Patients with Suspected Urinary Stones?

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Abbreviations and Acronyms

3D = 3-dimensional

CT = computerized tomography

DECT = dual energy computerized tomography

PNL = percutaneous nephrolitholapaxy

SWL = shock wave lithotripsy

TNC = true noncontrast phase

VNC = virtual noncontrast phase

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Study received institutional review board approval.

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Purpose: We evaluated a dual energy, split bolus computerized tomography protocol that provides virtual noncontrast, parenchymal and urographic phases in a single scan. We assessed the sensitivity of the virtual noncontrast phase using this protocol to detect urinary stones compared to the gold standard of the true noncontrast phase.

Materials and Methods: We prospectively enrolled in the study 81 patients who underwent unenhanced single energy computerized tomography at 120 kV/200 mA as well as contrast enhanced dual energy computerized tomography on a Somatom® Definition Flash-CT (tube A 80 kV/233 mA and tube B SN 140 kV/180 mA with 1/0.8 mm slice thickness). For the split bolus protocol 400 mg/ml Iomeron® were injected at 2 time points, that is 15 ml 10 minutes before the scan and 80 ml 65 seconds before the scan. In a consensus reading 2 readers evaluated the presence and diameter of stones on the true and virtual noncontrast phases.

Results: Of the 350 stones noted on the true noncontrast phase we found 289 on the virtual noncontrast phase as well as 13 false-positive and 66 false-negative stones. Sensitivity was 98.4%, 89.8% and 82.6% per patient, segment and stone, respectively. The diameter measured on the virtual noncontrast phase corresponded to a mean ± SD 92.5% ± 31.6% of the diameter on the true noncontrast phase. The mean effective dose was 4.8 ± 1.8 and 10.5 ± 3.7 mSv for the true and virtual noncontrast phases, respectively.

Conclusions: The proposed protocol allows for combining 3 phases in a single scan while still enabling the detection of urinary stones at high sensitivity. This technique halves the radiation dose and provides the surgeon with better anatomical information on the calyceal system. Therefore, it is a valuable diagnostic tool for kidney stone treatment planning and followup.

Key Words: kidney; urolithiasis; tomography, x-ray computed; radiation dosage, contrast media

Unenhanced CT of the kidneys and urinary tract has become the diagnostic standard of care for patients with suspected urolithiasis.[1] However, in those who require treatment planning for stone disease 1 or 2 additional scans might be needed for a complete examination, which multiplies the radiation dose. In these patients a small amount of intravenous contrast material can be initially injected 10 minutes before the main contrast bolus, allowing the acquisition of a combined venous and urographic phase in a

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single scan. This is termed the split bolus technique[2] for single energy CT. However, this technique is limited because urinary stones are sometimes masked by accumulation of the surrounding contrast agent in the urinary tract and an additional unenhanced scan is often needed to accurately evaluate urolithiasis.[3]

DECT was proposed to overcome this limitation. It can virtually remove the contrast agent from contrast enhanced scans,[4,5] resulting in a so-called VNC image. When combined with split bolus application, the unenhanced, parenchymal and urographic phases can be acquired in a single scan. Previous groups investigated the dual energy split bolus protocol and found only moderate sensitivity for stone detection.[6–8] The reasons for this are different scan and reconstruction protocols.

In this study we propose a new split bolus protocol for DECT in patients with suspected urolithiasis that decreases the amount of iodine in the urinary system at the time of the scan, thus, allowing for better post-processing of the dual energy data sets. We assessed the sensitivity of VNC reconstructions using this protocol for detecting urinary stones compared to the gold standard of TNC.

MATERIALS AND METHODS

Study Design

The research protocol for this prospective study was approved by the institutional review board (Medical University of Vienna, Protocol #529/2011). Between January 2011 and March 2012 we prospectively included 82 patients with suspicion of urolithiasis on ultrasound who were referred from the urological department for multiphasic multidetector CT. One patient was excluded due to heavy breathing artifact, leaving the remaining 81 available for analysis.

CT Protocol

The supplementary material (http://jurology.com/) shows a detailed scan protocol and image reconstruction description. All scans were performed with a second-generation, dual energy multidetector Somatom Definition Flash CT scanner using a single energy, low dose TNC scan as the reference for stone imaging and a contrast enhanced DECT scan. For this purpose a split bolus protocol was used, consisting of manual injection of 15 ml Iomeron contrast agent (400 mg/ml) 10 minutes before examination, followed by the main bolus of 80 ml contrast agent via the cubital vein. The contrast enhanced dual energy scan was performed at a 65-second delay after the second injection. The dual energy data sets were post-processed to reconstruct transverse and coronal virtual noncontrast images (fig. 1).

Image Interpretation

Two consultant radiologists (MT and DK) blinded to results independently evaluated VNC and TNC images on our PACS system (Impax 5.5 picture archiving and communication system, Agfa HealthCare, Elmwood Park, New Jersey). Each reader initially evaluated VNC images. To avoid memorizing the data the TNC images were read after a delay of 30 days. Each reader reevaluated the images side by side in a consensus reading. To allow for corresponding assignment of urinary stones the urinary tract was divided into 11 segments (fig. 2). The longest anteroposterior and transverse diameters were measured for each urinary stone and are shown in mm.

In addition, all 195 stones with a diameter of greater than 3 mm on TNC scans were subjected to volume measurement. The 69 stones that were grouped together and the 5 false-negative stones on VNC were excluded from this analysis. One reader (MT) measured the volume

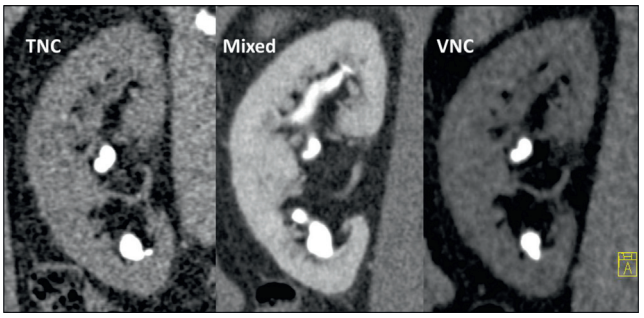

Figure 1. Coronal reconstruction of TNC CT and dual energy, split bolus CT in patient with urinary stone disease. Mixed image shows iodine contrast medium in parenchyma and urinary system. VNC reconstruction shows stones remaining after subtracting iodine contrast.

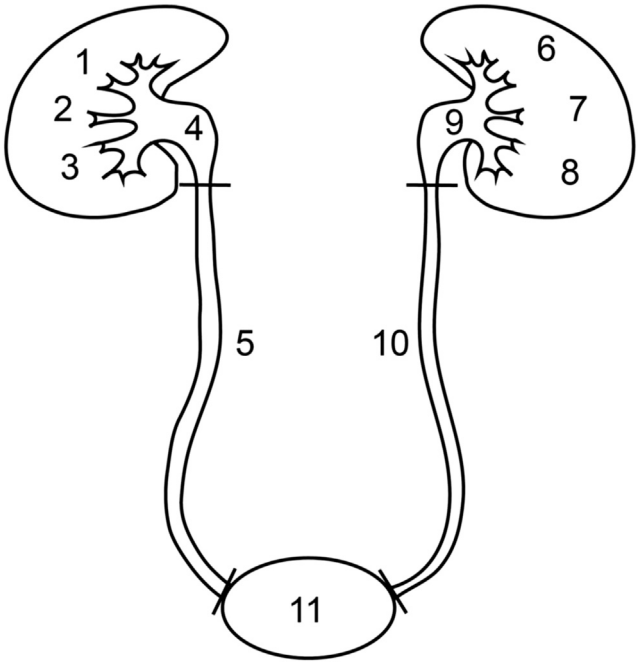

Figure 2. Urinary tract segments used for study documentation. Four segments per kidney were defined. Each ureter was counted as 1 segment per side and bladder was counted as single segment, resulting in 11 segments per patient.