Dual Source CT: Detecting Urinary Stones by Spiral Dual Energy Computed Tomography With Virtual Non-Enhanced Images

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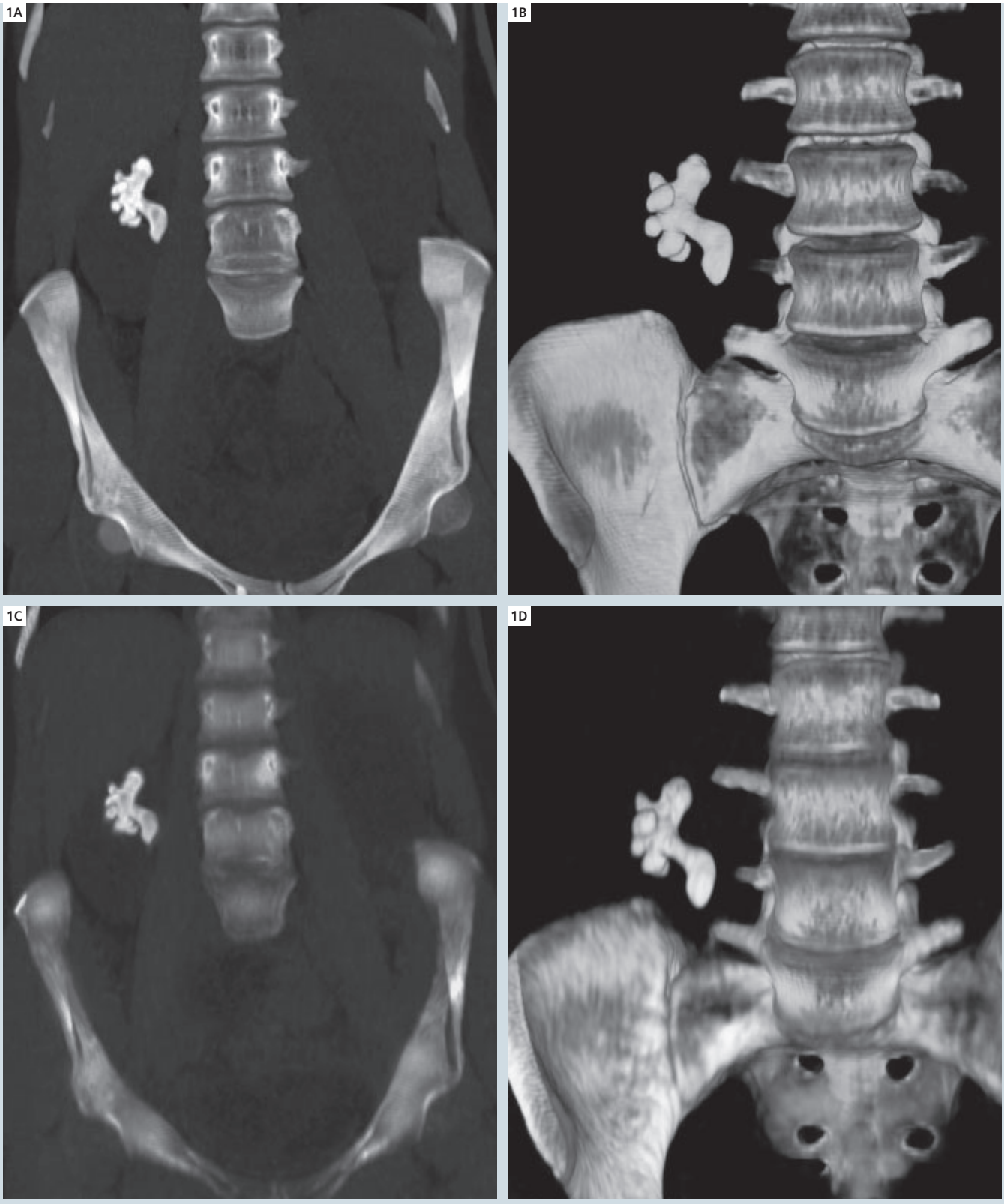
The Dual Source CT scanner is composed of two x-ray tubes and two detector units arranged on the rotating gantry with an angular offset of 90°[1]. When running both tubes at the same voltage, a high temporal resolution is achieved that is used primarily for the evaluation of coronary arteries[1]. When operating the x-ray tubes at different tube voltages, two different x-ray spectra are simultaneously obtained that improve the characterization and differentiation of various tissues[2].

CT for the Detection of Urinary Stones

Non-enhanced CT of the urinary tract is recognized as the most accurate technique for the detection of urinary stones[3]. Advantages of CT are the high sensitivity and specificity of the diagnosis and the simultaneous recognition of other associated pathologies. Most often, non-enhanced CT scans are performed for the purpose of stone detection when a contrast-enhanced scan is subsequently planned. But, performing several phases may not be routinely justified especially for younger patients. Thus, techniques should be developed that enable the detection of urinary stones using only one contrast-enhanced scan that would reduce the total radiation exposure to the patient. For this purpose virtual non-enhanced images may be generated by the use of spiral Dual Energy CT. This technique could prove useful when only contrast-enhanced imaging has been performed and further information of non-enhanced images would be necessary for the validation of the diagnosis in retrospect. Dual energy allows for the decomposition of voxel data through attenuation values at different kV levels. A material decomposition algorithm divides each voxel into soft tissue and iodine. Separate image series are gained that bear either the iodine content or the residual image, giving rise to virtual non-enhanced images. In this study, we have assessed the potential of virtual non-enhanced images using dual source, dual energy data for the detection of urinary stones.

Dual Energy Scanning and Set-Up

A three-phase CT scan protocol consisting of a standard non-enhanced scan, a nephrographic and an excretory phase of contrast enhancement were performed with 40 patients with suspected urinary stone disease. Automated real-time, anatomy-based dose modulation (CARE Dose4D) was used with all patients. The nephrographic phase was acquired in the dual source, spiral dual energy mode with tube voltages set at 80 kV and 140 kV and quality reference-tube current time products set at 400 effective mAs and 95 effective mAs, respectively. Virtual non-enhanced CT images were reconstructed using a software analysis tool recommended by Siemens. Thereby, as mentioned above, voxel data is decomposed by a three-material decomposition algorithm that divides each voxel into soft tissue, fat (together representing one of the two main components), and iodine (second main component). Information about these two main components of the voxel was then transcribed into separate stacks



1 Comparison of standard non-enhanced CT and dual energy virtual non-enhanced CT reconstruction. A 43-year-old female patient with a history of chronic urinary stone disease. Fig. 1A + B: Standard non-enhanced CT reconstructions at the level of the kidneys show a staghorn calculus in the right renal pelvis (Fig. 1A: transverse image; Fig. 1B: volume rendered image). Fig. 1C + D: Virtual non-enhanced CT reconstructions from contrast-enhanced. Dual Energy CT similarly demonstrate the right pelvic urinary stone (Fig. 1C: transverse image; Fig. 1D: volume rendered image).

of DICOM image files and a series of virtual non-enhanced images were displayed for read-out. Agreement between non-enhanced CT and virtual non-enhanced CT images regarding the diagnosis of urinary stone disease was observed (Figs. 1 and 2). Three false-negative and no false-positive ratings occurred using virtual non-enhanced CT images, and false-negative ratings occurred in obese patients only. Sensitivity and specificity for virtual non-enhanced CT for the diagnosis of urinary stone disease were 83 percent and 100 percent. Positive predictive and negative predictive values were 100 percent and 88 percent, respectively. Importantly, sensitivity decreased in abdominally obese patients. Nevertheless, the SOMATOM® Definition delivered highly reproducible results.

Dual Energy Imaging Enables new CT Applications

The Spiral Dual Energy analysis technique is related to the varying response of tissues to x-rays of different energies. The potential of dual energy imaging was actually investigated 20 years ago. However, at that time, the introduction into daily clinical routine was precluded by severe technical limitations[4]. With single-source CT scanners, dual energy data had to be separately acquired in two subsequent helical scans. If minimal changes in patient position occur, voxel decomposition will be valueless because both datasets no longer represent the same voxel. This is no longer true with the recently introduced SOMATOM Definition CT scanner utilizing two x-ray tubes for the acquisition of dual energy data simultaneously[2]. The other major problem of initial Dual Energy CT was the weak power reserve of the x-ray tube when it was operated with low voltage: images did not reach an adequate noise level when compared to images that were acquired with high tube voltages[4]. Both recent developments in tube and detector technology and the above mentioned advantage of dual energy data acquisition is the key to the clinical application of Dual Source, Dual Energy CT, i.e. virtual non-enhanced images can be reconstructed from the nephrographic phase CT data set when scanned in the dual energy mode. This technique allows for the diagnosis of urinary stone disease with good sensitivity and an excellent specificity. Iodine subtraction to generate a virtual non-enhanced CT image is one possible application of Dual Energy CT using the above described software algorithm from contrast-enhanced CT data. Three false-negative ratings occurred only in obese patients. It is most likely that this finding represents the general problem of CT imaging in obese patients that goes along with a higher image noise, and thereby is responsible for a deterioration of diagnostic accuracy. It appears that standard non-enhanced CT should be considered in abdominally obese patients rather than virtual non-enhanced CT through dual energy acquisition. Taken together, virtual non-enhanced CT images reconstructed from contrast-enhanced Dual Energy CT allows for the accurate detection of urinary stones with a good sensitivity and excellent specificity, keeping in mind that sensitivity is reduced in obese patients.

Future of Dual Energy in Imaging of the Urinary Tract

Body dual energy application not only preserves the possibility of calculating non-enhanced images from contrast-enhanced phases as shown in our study: ex-vivo studies have demonstrated that the decomposition of urinary stones was possible with the use of two different tube voltages[5,6]. Thus, Dual Source, Dual Energy CT has the potential to differentiate urinary stone compositions. This could be of high clinical relevance for proper medical management, keeping in mind that urinary alkalinisation is the therapy of choice in patients with uric acid stones, and shock waves can be avoided that potentially may harm the renal parenchyma.

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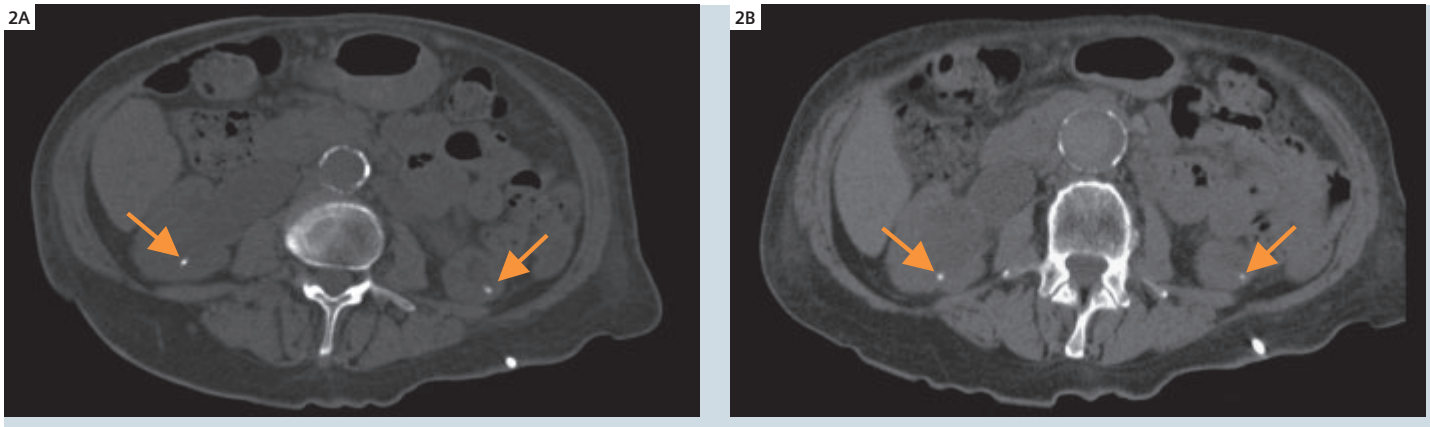

2 A 70-year-old female patient presenting with acute pyelonephritis and left sided ureteral obstruction. CT was performed after nephrostomy and pigtail insertion on the left side. Fig. 2A: Standard non-enhanced CT image at the level of the kidneys shows bilateral urinary stones (arrows). Fig. 2B: Virtual non-enhanced CT image similarly demonstrates the urinary stones on both sides.

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