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Detection of urolithiasis using low-dose CT—A noise simulation study

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ABSTRACT

How does an acquisition at reduced doses using automatic tube current modulation techniques compare to the normal standard dose CT? Does it affect the sensitivity for detection of calcifications?

CT raw data of 54 patients with suspected urolithiasis acquired with automatic tube current modulation techniques were used for image noise simulations with 100%, 50% and 25% dose simulated. Data were analyzed by independent readers with regard to the presence of urolithiasis, stone location, size, density and differential diagnoses. The mean effective dose per standard examination/50%/25% simulation was 7.3 mSv/3.8 mSv/1.9 mSv. Sensitivities/specificities for detection of urolithiasis were calculated for all dose simulations and resulted in 0.94/0.98 in the 50% dose level group and 0.82/0.97 in the 25% dose level group. Low-dose CT with tube current modulation can be used as a standard procedure for the evaluation of patients with suspected acute renal colic.

1. Introduction

Urolithiasis is a frequent clinical problem, which may lead to emergency situations. The incidence and prevalence rates of kidney stones may be affected by genetic, nutritional, and environmental factors. About 0.1–0.4% of the population is believed to have kidney stones every year in the USA and Europe [1]. The male to female ratio is 3:1 and the peak age at presentation is in the third to fifth life decade [2]. Renal stones tend to reoccur, and the recurrence rate is about 75% during 20 years. In 1995 Smith et al. first described unenhanced helical computed tomography (CT) as an initial imaging modality for the detection of urolithiasis in patients with acute flank pain and hematuria [3].

The clinical manifestation in terms of e.g. acute flank pain depends on location and size of the stones. In literature it still remains unclear whether non-obstructing nephrolithiasis can cause symptoms [4]. In addition to locating the stone, another important part of the diagnostics is to reveal why the patient formed the stone in order to prevent recurrence.

Before introduction of multislice computed tomography (MSCT) intravenous urography (IVU) was the declared golden standard for the evaluation of acute flank colic and diagnosis of ureteral concrements. But even in case of total ureteral obstruction the reason cannot be detected in all cases [5]. Moreover pain induced by the diuresis of the contrast medium is quite common in IVU. The detection rate for concrements in IVU is described as about 70–90% in literature [6]. For plain radiography a sensitivity of 57% and specificity of 71% as well as a poor detection rate of 50–70% is reported [6,7]. Ultrasound as imaging alternative is mainly used for the imaging of the kidneys and the proximal parts of the ureters. The quality of the ultrasound pictures is strongly dependent on many factors not influenceable by the radiologist (intestinal gas, obesity, ...) and it detects only 50–60% of ureteral calculi [8]. The sensitivity of CT especially in the distal parts of the ureters is higher than of ultrasound [9]. In normal dosed CT, sensitivity and specificity is among 94–100% and 97% respectively [10–13]. Therefore CT is now recommended by many authors as the initial diagnostic imaging technique in patients with suspected renal colic [14,15].

Recent radiological CT protocols for the detection of urolithiasis vary among the effective dose administered. Depending on the protocol used it ranges from 8 to 16 mSv [16,17]. The mean effective dose for an IVU examination is described as 2.6 mSv [18]. The higher dose of unenhanced helical CT compared to IVU is of particular concern because of repeated stone formation in young patients and therefore repeated CT examinations. The introduction of MSCT did not alter the radiation dose significantly [19]. A lot of studies try to reduce the exposure, i.e. the tube-current–time product or mAs value, in order to reduce the effective dose. Recent studies describe a successful reduction of the effective dose administered down to 0.7–2.3 mSv [13,20–22].

Image noise is inversely proportional to the square root of the dose or mAs value [23,24]. A main concern in the higher noise and

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therefore minor image quality of low-dose CT studies is a possible decreased accuracy in detecting both ureteral concrements and alternative diagnoses, which is one of the advantages of CT compared to other imaging modalities [25]. The most important alternative diagnoses are cholecystolithiasis, diverticulitis, appendicitis, tumors located in the pelvis and aortic aneurysms [9] that are all potentially visible even in dose reduced CT studies [26].

2. Research question

How does an acquisition at reduced doses using automatic tube current modulation techniques compared to the normal standard dose CT affect the diagnostic performance in suspected urolithiasis? Does it affect the sensitivity for the detection of calcifications?

3. Method

The CT raw data of 54 consecutive patients, being examined routinely in CT for suspected urolithiasis were stored digitally. All patients were scanned using a Sensation 64 Scanner (Siemens, Germany) with CareDose4d activated and the following scanning parameters: effective mAs 170, tube voltage 120 kV, pitch 1.4.

The scan range should evaluate the anatomic region from the upper pole of the kidneys to the lower part of the symphysis.

The anonymized data of all patients were processed with a dedicated noise simulation software (DoseTutor, VAMP GmbH, Erlangen, Germany) to obtain different noise simulations by modifying image noise, taking into account tube current modulation and automatic exposure control techniques [27–30]. The software was evaluated and used in the EU project “Safety and Efficacy of Computed Tomography” [31].

Three different noise levels with corresponding variations of mAs were simulated, including 100% mAs (accordingly noise level 1), 50% mAs (accordingly noise level 1.41) and 25% mAs (accordingly noise level 2). The study group consisted of 16 female and 38 male patients. The mean age of the male patients was 45.9 years (SD 16.9 years), of the female patients 40.6 years (SD 18.6 years).

Two different readers blinded for the corresponding results of each patient evaluated the images based on the scoring as described below. Both readers had at least four years of experience in genitourinary radiology. The images were analyzed in the following order, interrupted by an interval of at least two weeks between each reading session: 25%, 50% simulations, 100% (normal dose) images. See Fig. 1 for example images.

Window width and window level settings were presented by default as W:340/L:30, but could be manually adjusted as necessary by the readers on a patient-by-patient basis. The readers were free to vary their viewing distance on the basis of individual preferences.

3.1. Scoring

The scoring was based on criteria defined in literature.

The presence of ureterolithiasis was defined by the presence of a high-density structure within the ureter lumen [3].

We decided to differentiate between nephroliths and pelvicaliceal calcifications, since nephroliths are not associated with flank pain [32].

The size of stone was measured in maximum dimension on a standardized window and level setting on the images in the axial plane. Additionally the density in Hounsfield Units (HU) was measured of the biggest calculus [33].

Secondary signs for ureteral obstruction were evaluated:

- The presence or absence of hydroureter or obstruction was considered when unilateral ureteral dilatation (>2 mm diameter [34]) was present at a certain level below which the caliber was normal [3,35].
- The presence or absence of hydronephrosis was defined as dilatation of the collecting system compared with the contralateral side [35].
- Perinephric fat stranding was defined as increased density or stranding of the perinephric fat compared with the contralateral side [35].

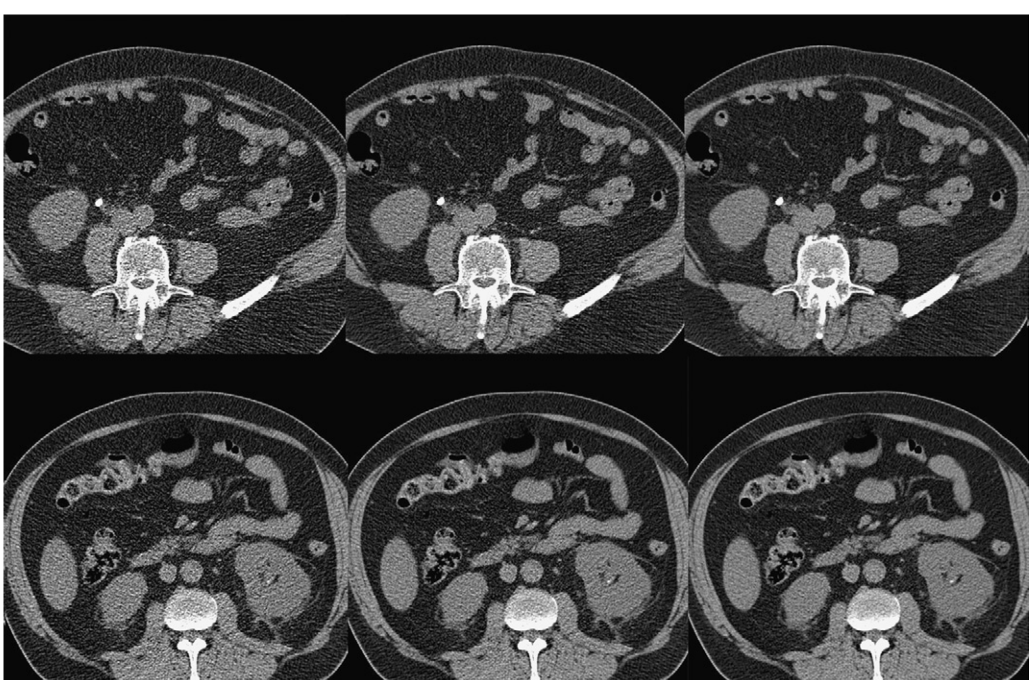

Fig. 1. From left to right: 25%, 50% dose simulations and the original scan at 100% dose of two patients with a right ureteral concrements (upper part) and a punctual calcification in the left upper renal pelvis (lower part) demonstrating reduction of image noise with increasing dose and therefore increasing diagnostic accuracy.