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ORIGINAL PAPER

Can the CT planning image determine whether a kidney stone is radiopaque on a plain KUB?

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Abstract Almost all kidney stones are CT positive. Before a CT scan can be done a CT planning image (CTI) is generated in order to select the exact scanning area. The CTI looks approximately like a normal kidney–ureter–bladder abdominal radiography (KUB) but with reduced quality. It has been used as a guide, assuming that if the kidney stone could be seen on the CTI the kidney stone also would be visible on a conventional plain KUB (radiopaque). From the perspective of diagnosis and treatment as well as follow-up it is of importance to know whether a kidney stone is radiopaque or not. The aim of this study was to evaluate whether the CTI actually can predict radiopacity. CT scans and corresponding KUB's were analysed in 76 consecutive kidney stone patients. The CT scan and the KUB were performed on the same day. All patients were examined with the same CT scanner (64 slice GE light speed VCT). Three radiologists evaluated the images in plenum. The following was recorded regarding the kidney stones: X-ray positive (radiopaque on KUB), CTI positive (radiopaque on CTI), location (*a* kidney, *b* upper two-thirds of ureter and *c* lower one-thirds of ureter including the bladder), size and Hounsfield units (HU). We also measured the patient's 'anterior–posterior depth' (APD) at the kidney stone level in axial plane, and whether the stone was homogeneous/inhomogeneous. 54 of the 76 patients (71%) had radiopaque stones on KUB. 43 (57%) of these also could be seen on the CTI, resulting in a positive predicting value (PPV) of 100% and a negative predictive value (NPV) of 67%. In the 54 KUB positive kidney stones the mean kidney stone diameter was 7 mm (2–30 mm), mean HU's 1,007 (294–1,782 HU), location: *a*:32, *b*:9 and *c*:13 patients. APD was mean 23.6 cm (13–39 cm). In the KUB positive and CTI negative kidney stones (11 patients) mean kidney stone diameter was 4 mm (2–9 mm), mean HU's 742 (294–1,253 HU), location: *a*:32, *b*:9 and *c*:13 patients. APD in this group was mean 26.1 cm (13–37 cm). If the kidney stone can be seen on the CTI it is also visible on a plain KUB (PPV 100%). The CTI do, however, underestimate the radiopacity of a stone on a plain KUB (NPV 67%). Kidney stone HU > 742, stone location in the kidney and proximal ureter and APD < 26 cm independently predict agreement between CTI and KUB with regard to radiopacity.

Keywords Urolithiasis · X-ray · KUB · CT · HU

Abbreviations

NCHCT	Non-contrast helical CT
KUB	Kidney–ureter–bladder abdominal radiography
CTI	CT planning image
APD	Patient's anterior–posterior depth
HU	Hounsfield units
PACS	Picture archiving communication system
mSv	Milli sieverts
mA	Milli ampere

Introduction

Almost all kidney stones are CT positive [1]. The prevalence of kidney stones is approximately 10–15% [2, 3].

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Non-contrast low-dose CT scan (NCHCT) is golden standard when a patient presents with symptoms related to acute renal obstruction. Before a CT scan can be done a CT planning image (CTI) is generated in order to select the exact scanning area. The CTI looks approximately like a normal kidney–ureter–bladder abdominal radiography (KUB) but with reduced quality. It has been assumed that if the kidney stone could be seen on the CTI the kidney stone also would be visible on a conventional plain KUB (radiopaque). The data on this subject in the literature are, however, very sparse. From the perspective of diagnosis and treatment as well as follow-up it is of importance to know whether a kidney stone is radiopaque or not.

Aim

The aim of this study was to evaluate whether the CTI actually can predict radiopacity. We also wanted to evaluate factors that may influence the ability of CTI to visualise kidney stones in patients with kidney stones seen on NCHCT.

Materials and methods

CT scans and corresponding KUB's were analysed in 76 consecutive kidney stone patients in the period 2007–2009. The CT scan and the KUB were performed on the same day within 1 h. All patients were examined with the same CT scanner (64 slice GE light speed VCT) and with the same X-ray equipment (Arcoma Arco ceil with standard of 68 kV using AGFA CR85-X). CT images were acquired at 0.625 mm with 1 mm spacing between images. Scanning area was from diaphragm to the pubic symphysis including both kidneys proximally and the bladder distally. CTI was generated anterior–posterior (AP) with 10 mA and lateral with 20 mA. Reconstructions were made in 2.5 mm slice thickness transverse and coronal. The coronal reconstruction images were made both perpendicular and angled at the longitudinal axis of the kidney. The CTI had a resolution of 1.7×1.9 pixels/mm^2. All images were stored in a local picture archiving and communication system (PACS).

Three radiologists evaluated the images in plenum. The following was recorded regarding the kidney stones: X-ray positive (radiopaque on KUB), CTI positive (radiopaque on CTI), location (*a* kidney, *b* upper two-thirds of ureter and *c* lower one-thirds of ureter including the bladder), size, side (right/left) and Hounsfield units (HU). We also measured the patient's 'anterior–posterior depth' (APD) at the skin to stone distance in axial plane, and whether the stone was homogeneous/inhomogeneous.

Data were recorded as binary outcomes: radiopaque kidney stones on KUB and CTI yes/no. Data were analysed by logistic regression.

Results

54 of the 76 patients (71%) had radiopaque stones on KUB. 43 (57%) of these cases also could be seen on the CTI, resulting in a positive predicting value (PPV) of 100% (95% CI: 91.8–100%) and a negative predictive value (NPV) of 67% (95% CI: 48.2–82%). This difference was highly significant ($P \leq 0.0001$).

The kidney stones identified on KUB were mean 7.02 mm (2–30 mm) in length compared to mean 4.05 mm (2–10 mm) in those that were missed. Mean kidney stone size seen on CTI was 7.77 mm (2–30 mm) and those missed was 4.10 mm (2–10 mm). These differences were not statistically significant.

Mean HU of the kidney stones seen on the KUB was 1,007 HU (294–1,782 HU) compared to 656 HU (150–1,271 HU) in those not seen on CTI ($P = 0.001$). Mean kidney stone HU seen on the CTI was 1,075 HU (368–1,782 HU) versus those not seen with 685 HU (150–1,271 HU) ($P \leq 0.0001$) (Fig. 1).

Mean APD in patients with radiopaque kidney stones on KUB was 23.6 cm (16–37 cm) and those missed was 24.0 cm (16–36 cm). Mean APD in patients with radiopaque kidney stones on CTI was 23 cm (16–33 cm) and those missed was 24.79 cm (16–37 cm) ($P = 0.009$) (Table 1).

There was a higher agreement between KUB and CTI with regard to detecting the stones as radiopaque if the stones were located in the kidney and the upper ureter compared to stones located in the distal part of the ureter ($P < 0.008$) (Table 2; Fig. 2).

In the 54 KUB positive kidney stones the mean kidney stone diameter was 7 mm (2–30 mm), mean HU's 1,007 (294–1,782 HU) and APD was mean 23.6 cm (13–39 cm). In this group 32 stones were located in the kidney, 9 stones in the proximal two-thirds of ureter and 3 stones in the lower one-thirds of ureter including the bladder.

In the KUB positive and CTI negative kidney stones (11 patients) mean kidney stone diameter was 4 mm (2–9 mm), mean HU's 742 (294–1,253 HU) and APD in this group was mean 26.1 cm (13–37 cm). In this group 6 stones were located in the kidney, 2 stones in the proximal two-thirds of ureter and three stones in the lower one-thirds of ureter including the bladder.

Discussion

It is important to determine whether a kidney stone is radiopaque or not, since this information can be used for

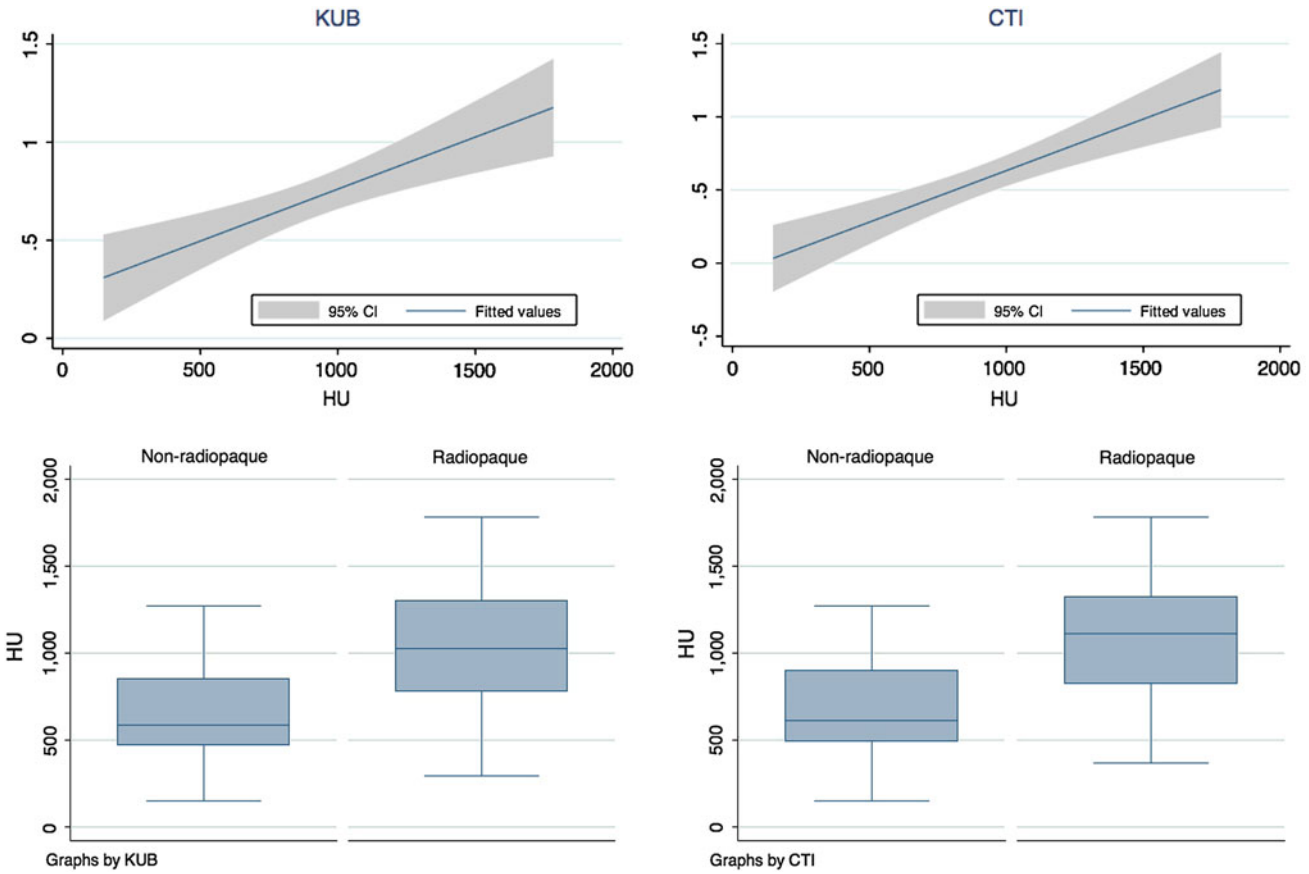

Fig. 1 Two-way graph and box and whiskers plot for the KUB versus CTI showing kidney stone radiopacity regarding HU

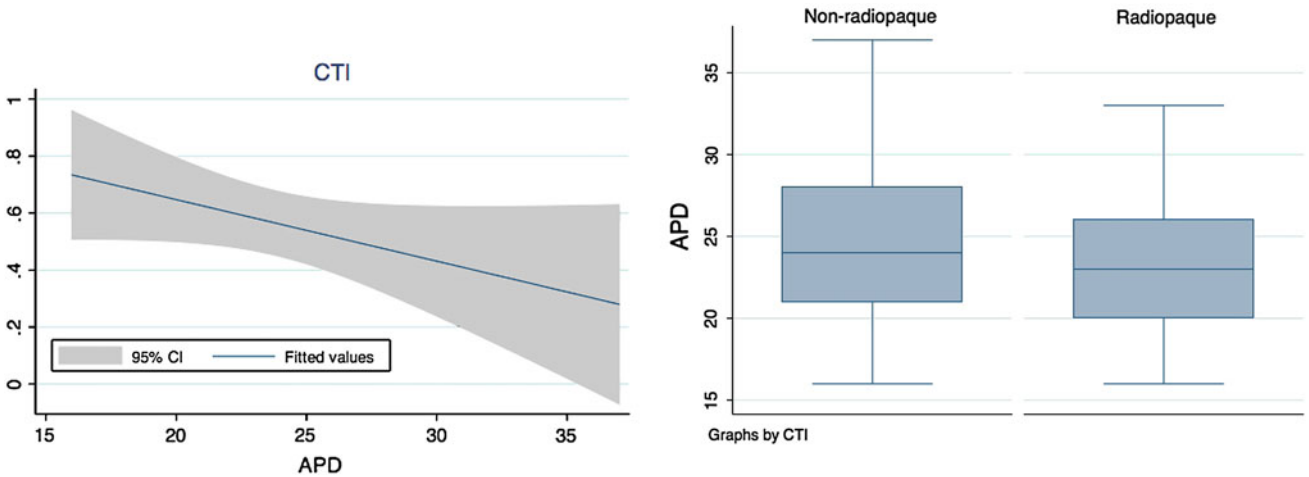

Fig. 2 Two-way graph and box and whiskers plot for the CTI showing kidney stone radiopacity regarding the patient's 'anterior–posterior depth' (APD) at the skin to stone distance in axial plane

selection of treatment modality and follow-up imaging modality. CTI is given different names depending on the company that produces the CT scanner (Scout, Topogram etc.). Today most centres have the possibility to save the CTI in PACS. Only very sparse data exist in the literature on the clinical use of the CTI [4–9]. One recent study [9] reported radiopacity on KUB (63%) and CTI (47%). This corresponds quite well to our data, in which kidney stones were seen on the KUB (71%) versus 57% on CTI. A very important finding was that all kidney stones visible on the CTI also were visible on the KUB (PPV 100%). This finding corresponds well with previous studies [7–9]. In

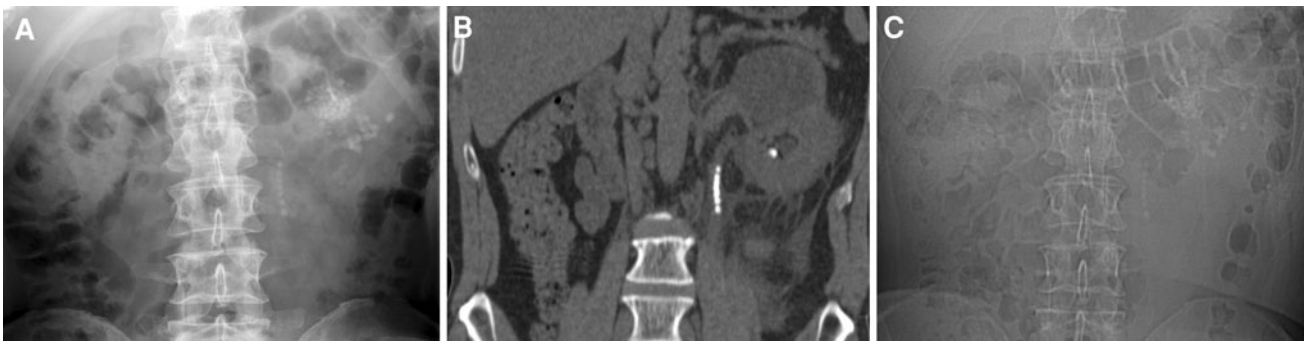

Fig. 3 Multiple kidney stones seen in left kidney and proximal ureter. **a** KUB **b** CT coronal reconstruction and **c** CTI

Table 1 Mean kidney stone size, HU and APD

	Size (mm)	HU	ADP (cm)
All 76 patients	6.16 (2–30)	906 (150–1,782)	23.78 (16–37)
KUB positive (54 patients)	7.02 (2–30)	1007 (294–1,782)	23.64 (13–39)
KUB negative (22 patients)	4.05 (2–10)	656 (150–1,271)	24.09 (12–37)
CTI positive (43 patients)	7.77 (2–30)	1075 (368–1,782)	23 (13–20)
CTI negative (33 patients)	4.06 (2–10)	685 (150–1,271)	24.79 (16–37)
KUB positive CTI negative (11 patients)	4.09 (2–9)	742 (294–1,253)	26.1 (15–37)

Table 2 Kidney stone location

Kidney stone location	All patients kidney stone location (%)	KUB positive kidney stone radiopaque (%)	CTI positive, kidney stone radiopaque (%)	*P* value
1	51.3 (39/76)	82 (32/39)	67 (26/39)	<0.214
2	17.1 (13/76)	69 (9/13)	54 (7/13)	<0.200
3	31.6 (24/76)	54 (13/24)	42 (10/24)	<0.008

case of CTI negative kidney stones in our data a subsequent KUB would have found it radiopaque in 25% of cases (11/43). One other study showed a similar result (33%) [9] (Fig. 3).

Only HU and location of the kidney stone seem to influence the radiopacity of the kidney stones on KUB and CTI. APD only seems to influence the radiopacity of the kidney stones on CTI.

Several studies have shown that HU of kidney stones can predict the composition of the stone and recent studies also highlight the opportunities with dual source energy CT scanner [10, 11]. HU in the range 400–700 are often uric acid, ammonium urate or struvite stones. HU above 700 are often calcium oxalate monohydrate, brushite and poly-crystalline stones. Our study indicates that stones with HU above 742 are more likely to be radiopaque on both CTI and KUB (Fig. 1).

In our study over 50% of the kidney stones were located in the kidney. The radiopacity of kidney stones decreased for both KUB and CTI, when kidney stones were located in the ureter and the bladder (Table 2; Fig. 4).

The APD measure tells us how much soft tissue the X-ray has to penetrate to generate an X-ray image. All modern CT scanners have built-in "noise" detectors. If APD are more than expected the modality generates a higher radiation dose to optimise image quality. The CTI mSv are fixed and will not increase if the patient has a large APD, consequently the image quality is reduced compared to KUB.

Compared to NCHCT the KUB gives 1/6–1/8 of the radiation dose, it is quicker and much less expensive [12]. It is estimated that the chance of getting a fatal cancer from the radiation dose from a CT scan is 1/2,000 for every 10 mSv. Dependending on the patient's size and body

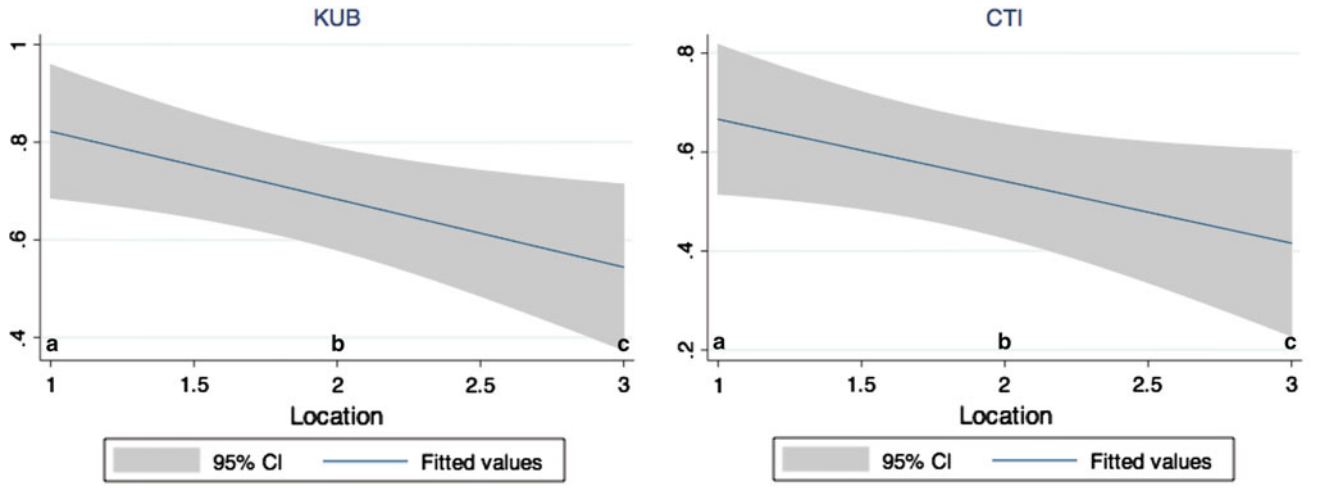

Fig. 4 Two-way graph for the KUB versus CTI showing kidney stone radiopacity regarding location. **a** Kidney, **b** upper two-thirds of ureter and **c** lower one-thirds of ureter including the bladder

habitus, NCHCT is approximately 6.5 mSv [12]. In our study the mean mSv was 8.08 (3–22.8). It is very important to perform radiological imaging according to the ALARA principal. This means that patients regardless of age and disease should be examined with X-ray radiation doses 'as low as reasonably achievably'. A recent study estimates that 2% of all future cancers will be due to radiation exposure from CT examinations [13].

Some centres still preform KUB after NCHCT as routine to predict radiopacity. Our study suggests that in order to avail unnecessary radiation exposure to patients, KUB should be spared for patients with CTI negative kidney stones.

In one study CTI was performed with a total of 50 mA [9]. In our NCHCT protocol the CTI AP image is generated at 10 mA. By increasing the mA product of the CTI the sensitivity for detecting kidney stones on CTI might be increased but such data are still missing.

Conclusion

If the kidney stone can be seen on the CTI it is also visible on a plain KUB (PPV 100%). The CTI do, however, underestimate the radiopacity of a stone on a plain KUB (NPV 67%). Kidney stone HU > 742, stone location in the kidney and proximal ureter and APD < 26 cm independently predict agreement between CTI and KUB with regard to radiopacity.

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