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ORIGINAL RESEARCH

Determining the Opacity of Urinary Stone Using only the Computed Tomography Imaging, Is KUB still Needed?

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Abstract: Introduction: Defining the opacity of urinary stones by Kidney -Ureter-Bladder (KUB) imaging in the selection of treatment modality is considered necessary by many urologists. This imposes more radiation to patients and additional health costs. The objective of this study is evaluation of the capability of Computed Tomography (CT) imaging in predicting the opacity of urinary calculi. Methods: In this prospective study, the appearance of stones and the body characteristics of all our patients were recorded and analyzed. The setup for reviewing the imaging was as follows: first: CT-scout, then KUB and finally CT scan. The sensitivity and specificity of the CT-scout and Hounsfield unit in detecting stone opacity was calculated. The effect of stone size and body parameters in CT on predicting non-opaque stones were then analyzed. CT scout-negative KUB-positive urolithiasis were analyzed separately. Results: Among 197 participants, all opaque calculi in CT scout were also visible on KUB. Among scout-negative urinary stones, twenty-eight (14.21%) were KUB opaque. For predicting the opacity by CT scan parameters, the most desirable HU cut-off was 504 HU and 510 HU in KUB and CT scout, with 80.8% and 86.5% sensitivity, respectively. The overall sensitivity of CT-scout was 86.27% and specificity was 64.29%. Stone diameter ≥5mm and subcutaneous fat width of ≤25.40 mm augmented the sensitivity in our study groups. Conclusion: All opaque calculi on scout imaging are also opaque on KUB and this could obviate the necessity of KUB imaging in this group of patients. HU above 504 in scout-negative stones has the best sensitivity and specificity in foretelling the opacity of stones and size ≥5mm and subcutaneous fat width of ≤25.40 mm augment their predictability potential.

Keywords: Urolithiasis; Tomography; Spiral Computed; Radiography

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1. Introduction

In recent years, the Helical CT has gained its acceptance as the method of choice for assessment of urinary stones, owing to its safety, accuracy, speed and not operator dependency and has dominated other modalities of assessing urinary calculi, e.g.; sonography, standard x-ray and excretory urography (1). Additionally, it provides an opportunity for alternative diagnosis in case of abdominal pain without urinary stones (2). Furthermore, it gives information about the patients' body characteristics which are important in predicting the opacity of stones.

Notwithstanding the fact that nearly all urinary stones are CT positive, we still need conventional x-ray (Kidney-Ureter-Bladder; KUB) imaging in treatment planning (3-7). In addition to stone size, composition and location (1), opacity of urinary calculi is also an important factor in determining the treatment approaches; Medical (chemical dissolution) or surgical (extracorporeal or endoscopic) and also in follow up

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planning (3-7).
CT scout or the mapping image of CT, a coronal digital image routinely taken beforehand to assist in patient positioning, from xiphoid process to pubic symphysis, has also been cited in several studies and proposed that if interpreted carefully, can replace baseline KUB (8-11). In this study, we determine the reliability of CT parameters and CT scout in predicting the opacity of calculi in KUB The definition of stone opacity has not yet been defined in CT imaging (3-7). Hence, formulating a model for predicting the opacity based on the data obtained from CT would be cost effective and beneficial. Regarding previous studies, we conducted this study to incorporate all the variables used in different models in a single study to achieve a comprehensive deduction.

2. Methods

After obtaining our research center review board approval, the study was performed in a prospective cross-sectional design and the patients with the diagnosis of urinary stone by non-contrast spiral CT scan were included. CT scan and KUB were taken from all these patients on the same day and images were reviewed by an experienced urologist and our associate radiologist, independently. Any KUB with poor quality or bowel gas superimposition and any patient with CT evidence of nephrocalcinosis or missed KUB/CT were excluded. Discrepancies in image interpretation was discussed in a joined session and in case of disagreement, the patient's data was excluded from the study.
Study period was from September 2015 to December 2018. Stone parameters on CT were location, side, size, Hounsfield units (HU) and opacity in scout imaging. For quantifying the body characteristics of the patients, anterior-posterior (AP) diameter of patient at the level of stone and subcutaneous fat thickness at umbilicus level were recorded. For comparing the variables, the median value of AP diameter and subcutaneous fat thickness was calculated and used.
There was no limit for stone size. It was measured in the axial plane and the maximum diameter was recorded. The sizes were divided into diameters of ≥5 mm and <5 mm because that is the threshold size for therapeutic interventions. The HU was measured by placing the cursor on the brightest pixel of the stone. The location of stones described in the imaging was Upper (kidney and upper third of the ureter), Mid (mid-ureter) and Lower (bony pelvis). In patients with multiple stones, the characteristics of each stone were recorded separately. The setup for reviewing the imaging was as follows: first: CT-scout, then KUB and finally CT scan. This was to prevent any bias in image interpretation. It causes blindness for the reviewer. Patients were divided into two groups according to KUB, opaque and non-opaque, and the results of CT-scout were compared with the KUB.

The images were taken by Philips 64 CT scanner and the imaging protocol included a slice thickness of 3 mm with collimation of 32×1.25 and slice increment of 1.5 mm. The pitch was 0.97. The device setting for scout images was 120KVp and 50 mAs.
SPSS (V.23) (SPSS Inc, Chicago), and MedCalc (V.17.2) (MedCalc, Ostend, Belgium) was used for statistical analysis. The normality of the variables was checked by Kolmogorov-Smirnov (K-S) test. Mann-Whitney U was used to compare quantitative variables between 2 groups (opaque and non-opaque). To determine the best HU cut-off value for identifying calculi likely to be radio-opaque on CT scout and KUB, Receiver Operating Characteristics (ROC) curve and the area under curve (AUC) were used in SPSS program. Using the calculated cut-off values, Hounsfield units were changed into dichotomous variables and sensitivity, specificity, predictive values and likelihood ratio of each variable were measured. We also did a separate analysis for scout-negative, KUB-positive stones to determine the best cut-off value for these calculi located in the so-called Gray Zone of diagnosis, to increase the chance of predicting the opacity. P value < 0.05 was considered statistically significant. To reach the area under ROC (AUROC) curve equal to 85%, according to the calculation, 156 samples were needed. McNemar test was used for dependent qualitative variables.

3. Results

Of total number of 220 cases, 197 stone patients (129 (65%) males and 68 (35%) females) were eligible for this study (16 cases didn't have KUB, 6 cases had very poor quality KUBs and one case was excluded due to nephrocalcinosis). The mean age of our participants was 49.7 years (median: 51 years (range:17-84)) (table 1). The mean± SD stone diameter was 12.37±9.78 mm. In case of laterality, 95 (48.2%) stones were on the right and 99 (50.3 %) stones were on the left side. Three patients (1.5%) had midline (bladder) stones. Regarding location, 150 (76.1%), 14 (7.1%) and 33 (16.8%) stones were noted in the upper, mid and lower segments, respectively.
Of total stone number of 197, 183 (93%) were opaque on KUB films and 155 (79%) on CT scout films. All 155 CT scout positive stones were also KUB positive. Forty-two stones (21%) were non-opaque on scout imaging, out of which, 28 (14% overall and 67% of CT scout negative stones) were KUB opaque.
Using Kolmogorov-Smirnov test, it was found that Hounsfield numbers did not have a normal distribution, so Mann-Whitney U test was used. The median HU of opaque stones on KUB film was 822 (range: 13- 1545) which was higher than non-opaque stones 410 (range: 89-773) and the difference was significant ($p<0.001$). This difference in

median HU was also seen in CT scout opaque (854, range: 13-1545) and non-opaque stones (455, range: 89-1227) (p<0.001).
ROC determined the best CT HU attenuation level cut-off with both highest sensitivity and specificity at which urinary calculi are to be observed opaque on CT scout film at 510 HU (AUC=0.808, standard error=0.0365, p value<0.001, 95%CI: 0.746-0.861) (figure 1). The overall sensitivity was 86.45% and specificity was 64.29% (table 2).
For KUB, this value was set at 504 HU (AUC=0.836, Standard error= 0.0443, p<0.001, 95% CI: 0.777-0.885) (see figure 1). The overall sensitivity was 80.87% and specificity was 78.57% (table 3).
For each of the cut-off values, sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR) and negative likelihood ratio (NLR) was calculated according to our study variables. Results are displayed in tables 2 to 3.
In CT scout unidentified but KUB positive urolithiasis, ROC determined the best CT HU attenuation level cut-off at 504 HU (AUC=0.628, standard error= 0.0889, p=0.15, 95% CI: 0.465-0.772). The overall sensitivity was 46.4% and specificity was 78.6%. The calculated cut-off was not statistically significant. Considering KUB as the standard for opacity detection, CT scout was significantly inferior to the KUB (P <0.0001).

4. Discussion

Replacing KUB with CT requires using all the information which can be extracted from CT; including visibility of stone in CT scout view, HU, stone location and its size, subcutaneous fat thickness and anterio-posterior diameter of body at stone level.
Several previous studies have cited the ability of CT in predicting the opacity of urinary calculi in KUB imaging and the ability of scout imaging to replace KUB. The first study by Chu et al in 1999 (8) revealed that the size of the stone and the kilo voltage setting of the device are key components in prediction of stone opacity. Stones less than 3 mm are best visualized at kilo voltage setting of 80-100 KVp whereas stones larger than or equal to 3 mm will be visible at all kilo voltage settings. In their conclusion the Achilles heel of scout film is in the diagnosis of mid-sized stones, and hence KUB should be required in these cases.
This comparison was pursued by Johnston (11) and YAP (12). Johnston (11) reported a 47% sensitivity for stones larger than 5.22 mm and YAP (12) remarked a 52% sensitivity for upper tract stones larger than 4 mm. The sensitivity of scout imaging in detecting urinary calculi in our study is much higher Than previous studies (79% versus 42-69%) (3, 11-13). Also, despite previous reports of lower sensitivity of scout imaging, in comparison to KUB, in detecting upper and lower calculi (12), the sensitivity of scout for upper and lower located stones were 84% and 88%, respectively. We believe that this notable difference is due to bias in patient selection, because our hospital is a tertiary center for stone surgery and majority of our patients do have large stone burden (mean stone diameter 12.37±9.78 mm) mostly in need of intervention. However, our results are similar with previous studies and show acceptable sensitivity of scout images in opaque stones.
With the area under curve (AUC) of 0.808, cut-off level of 510 HU in scout positive stones has good predictability potential of the opacity of urinary stone with sensitivity of 86.27%. Contributing this cut-off to the study variables reveals that the sensitivity increases in upper location (87 %), ≥5mm size (88.8 %), right sided stones (90.1 %), lipid thickness of ≤25.40 mm (88.37%) and AP diameter of ≤230.00 mm (87.5%) (see table 2). Sensitivity for mid-ureteral stones is 100% but because of very small number of cases, it's not reliable. Only size ≥5mm (p< 0.001) and subcutaneous fat thickness ≤25.40 mm (p<0.006) Were reliable factors to predict opacity in KUB.
In KUB positive stones, HU cut-off level of 504 HU (AUC: 0.836) showed the better sensitivity in the same parameters as in scout view (see table 3). Likewise, size ≥5mm (p< 0.001) and subcutaneous fat thickness ≤25.40 mm (p: 0.018) were the significant contributors to visibility in KUB at this cut-off. Justifying the contribution of larger size, location, reduced fat thickness and AP diameter in increasing the visibility of urinary stones is quite rational and were previously well explained (1, 3, 12-17). However, we couldn't explain the role of laterality (right side location) in increasing the sensitivity of visibility in both KUB and scout imaging and the chance of random finding could not be ruled out.
Regarding the best HU cut-off for predicting opacity in KUB, different numbers have been reported; 498.5 HU in Chua (184 cases) (18), 610 HU in Chua (203 cases) (10) or 772 HU in Sfoungaristos (375 patients) (13). In all these studies, the average stone size was less than 10 mm. Cut-off level of 504 in KUB positive and 510 in scout positive stones in our patient with average calculi size of >12 mm may indicate that the value reported in Sfoungaristos's report is much more realistic since in smaller stones, the density (i.e., the HU) should be larger in order to become opaque (13).
Nevertheless, the controversy in anticipating opacity in scout negative stones still exist. In other words, the problem with scout is not in its positive predictive value but in its negative predictive value. The incorporation of HU for predicting opacity was mostly pioneered by studies done by Huang and Chua (9, 10). Chua (10) found that in scout negative stones, HU>630 will predict the opacity by 82% sensitivity and 96.9% specificity. As a result, they concluded that KUB should be part of diagnostic imaging in scout negative stones

with HU<630. The most comprehensive study in this regard was done by Sfoungaristos (13). In their evaluation of 375 patients, they found that 54.4% of scout negative stones are radiopaque on KUB and in scout-negative films, stone diameter >9.7mm, stone location (other than mid-ureter), fat width of anterior abdominal wall ≤ 23.9 mm and HU >772 could independently predict stone opacity and if all of them were present, the probability of scout-negative stone to be radio-opaque would be 87.5%.
Our result in this group of patients (Scout negative but KUB positive) did not show statistical significance (504 HU, AUC=0.628, p=0.15) and cannot be referred. Designing a specific study in this group of stone/patients with adequate numbers to completely define the characteristics of stones and the contributory variables seems necessary.
The other drawback in our research is that we couldn't match the HU and visibility potential with stone composition due to our study design and lack of precise stone analysis system in our center. Matching the composition to opacity, especially in small sized stones, could help delineate the differences between opaque and non-opaque urolithiasis.

5. Conclusion

Radio opaque stones in scout CT imaging are almost always radio opaque in KUB imaging too. But radio lucent stones in scout imaging might be radio opaque in KUB imaging specially when HU is more than 504, stone size is more than 5mm and subcutaneous fat is more than 25.4 mm.

6. Appendix

6.1. Acknowledgment

None.

6.2. Conflict of interest

No conflict of interest.

6.3. Funding support

None.

6.4. Author's contributions

Research conception & design: Majid Ali Asgari. Performing the experiments: Navid Masoumi, Taraneh Faghihi Langroudi, Amirhesam Alirezaei. Data acquisition: Navid Masoumi, Mehdi Dehghani. Data analysis and interpretation: Navid Masoumi, Fahimeh Bagheri, Mehdi Dehghani. Statistical analysis: Fahimeh Bagheri. Drafting of the manuscript: Navid Masoumi, Mehdi Dehghani. Critical revision of the manuscript: Navid Masoumi, Majid Ali Asgari, Mehdi Dehghani. Approval of final manuscript: all authors.

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A. CT scout positive: AUC=0.808, P<0.0001. **B.** KUB positive: AUC=0.836, P<0.0001.

Figure 1: Receiver Operating Characteristics curve for determination of best Hounsfield unit cut-off value for defining urinary stones' opacity in CT scout films and Kidney-Ureter-Bladder.

Table 1: Demographic characteristics.

Variables	Value	P value
Age, y, mean (SD, range)	49.7 (16.19, 17-84)	
Gender, n (%)		
Male	129 (65)	
Female	68 (35)	
Laterality, n (%)		
Right	95 (48.2)	
Left	99 (50.3)	
Midline	3 (1.5)	
Location, n (%)		
Upper	150 (76.1)	
Mid	14 (7.1)	
Lower	33 (16.8)	
Stone size, mm, mean (SD, range)	12.37 (9.78, 1.8-81.40)	
Stone opacity, HU, mean (SD, range)	786.5 (330.3, 12.8-1545.5)	
AP diameter, mm, mean (SD, range)	225.9 (35.5, 115-306.7)	
Lipid Thickness, mm, mean (SD, range)	26.8 (11.25, 4.30-73.50)	
KUB opacity		<0.001
Opaque		
n (%)	183 (92.9)	
HU, median (range)	822.30 (12.8-1545.5)	
Non-opaque		
n (%)	14 (7.1)	
HU, median (range)	410.70 (89-773.30)	
CT-scout opacity		<0.001
Opaque		
n (%)	155 (78.7)	
HU, median (range)	854.00 (12.8-1545.5)	
Non- opaque		
n (%)	42 (21.3)	
HU, median (range)	455.75 (89-1227)	

AP: anterior-posterior of patient's body, HU: Hounsfield unit, n: number, SD: standard deviation.

Table 2: Se, Sp, PPV, NPV, PLR and NLR of 510 HU cut-off value in CT scout opaque stones according to our study variables.

	Se	Sp	PPV	NPV	PLR	NLR
Total	86.27	64.29	89.80	56.25	2.42	0.21
Location						
Upper	87.07	64.71	89.38	59.46	2.41	0.20
Mid	100.00	66.67	91.67	100.00	3.00	0.00
Lower	78.57	60.00	91.67	33.33	1.96	0.36
Size (axial diameter)						
<5mm	62.50	92.31	90.91	66.67	8.13	0.41
≥5mm	88.89	51.72	50.00	89.55	1.84	0.21
Side of Stone						
Right	90.14	62.50	87.67	68.18	2.40	0.16
Left	82.72	66.67	91.78	46.15	2.48	0.26
Lipid Thickness (mm) median value						
≤25.40	88.37	53.85	92.68	41.18	1.91	0.22
>25.40	84.06	68.97	86.57	64.52	2.71	0.23
AP diameter (mm) median value						
≤230.00	87.50	55.56	89.74	50.00	1.97	0.22
>230.00	85.53	70.83	90.14	60.71	2.93	0.21

AP: anterior-posterior of patient's body, Se: Sensitivity, Sp: Specificity, PPV: Positive Predictive Value, NPV: Negative Predictive Value, PLR: Positive Likelihood Ratio, NLR: Negative Likelihood Ratio.

Table 3: Se, Sp, PPV, NPV, PLR and NLR of 504 HU cut-off value in KUB opaque stones according to our study variables.

	Se	Sp	PPV	NPV	PLR	NLR
Total	80.87	78.75	98.01	23.91	3.77	0.24
Location						
Upper	81.29	81.82	98.26	25.71	4.47	0.23
Mid	91.67	50.00	91.67	50.00	1.83	0.17
Lower	75.00	100.00	100.00	11.11	-	0.25
Size (axial diameter)						
<5mm	57.14	100.00	100.00	47.06	-	0.43
≥5mm	83.54	50.00	97.78	10.34	1.67	0.33
Side of Stone						
Right	83.91	75.00	97.33	30.00	3.36	0.21
Left	77.42	83.33	98.63	19.23	4.65	0.27
Lipid Thickness (mm) median value						
≤25.40	85.57	50.00	98.81	6.67	1.71	0.29
>25.40	75.58	83.33	97.01	32.26	4.53	0.29
AP diameter (mm) median value						
≤230.00	87.78	100.00	100.00	42.11	-	0.12
>230.00	74.19	50.00	95.83	11.11	1.48	0.52

AP: anterior-posterior of patient's body, Se: Sensitivity, Sp: Specificity, PPV: Positive Predictive Value, NPV: Negative Predictive Value, PLR: Positive Likelihood Ratio, NLR: Negative Likelihood Ratio.