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Visibility of Urinary Stones in Plain Kidney, Ureter and Bladder Radiographs and Computed Tomography Scout View with Correlation with CT Hounsfield Unit

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Abstract

Background: Urinary calculus remains to be a common presentation in the hospital. It is the third most common urological problem after urinary tract infection and prostate disease with life time prevalence of urolithiasis at 10-15%.The prevalence has risen over a 20-year period from the mid 1970's to the mid 1990's. The diagnosis of urolithiasis is largely dependent on analyzing the clinical presentation and physical examination. Suspicion is confirmed with radiologic tests, particularly the multidetector computed tomography scan. The advent of multidetector computed tomography has not only provided detection and confirmation of calculi, but also accurate detection of its size and location.

Aim of Study: In this study, we explore the diagnostic utility of KUP and CT scanogram attenuation value of a stone to predict its appearance in Plain KUP radiograph in the hope to decrease the need for an additional CT of patients.

Patients and Methods: This was a retrospective study was conducted at Radiodiagnosis Department in Ain Shams University. It included patients diagnosed to have urolithiasis after undergoing CT scanogram with a typical clinical picture of suspected urinary calculi such as flank pain and/or hematuria. Patients included in this study must have concurrent or follow-up plain kidneys; ureter and urinary bladder radiograph. The duration of the study ranged from 6-12 months.

Results: This study conducted on 60 cases with age ranged from 19 to 64 years and with mean±SD of 44.48±12.02; they were 24 females (40.0%) and 36 males (60.0%) with total 118 stones, the visible 65 (55.1%) and not visible 53 (44.9%) of scout-CT. The visible 66 (55.9%) and not visible 52 (44.1 %) of KUB X-ray, the ranged size 1-90 with median 7.55 (4-15) and the ranged density "hounsfield" 50-1700 with median 657 (400-1100).

Conclusion: The cut-off value at which urinary calculi not identified by CT Scout, but KUB radiographically opaque is set at >600, with sensitivity of 84.85% specificity of 82.69%, and Scout-CT which was >689, with sensitivity of 81.54% specificity of 92.45%, The CT-scout film with an optimal HU cut-off value, when utilized together, can further aid clinicians in deciding the plan of management for patients with urolithiasis.

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Key Words: *Hounsfield units – NCCT – Magnetic resonance imaging – MDCT.*

Introduction

URINARY calculus remains to be a common presentation in the hospital. It is the third most common urological problem after urinary tract infection and prostate disease with life time prevalence of urolithiasis at 10-15%. The prevalence has risen over a 20-year period from the mid 1970's to the mid 1990's **[1]**.

The diagnosis of urolithiasis is largely dependent on analyzing the clinical presentation and physical examination. Imaging has an important role in urolithiasis and aids not only in the initial diagnosis but also in planning treatment and follow-up of patients with renal and ureteric stones. Since the 1990s noncontrast computed tomography (NC-CT) has become the gold standard imaging modality **[2]**.

Various imaging modalities are available to evaluate hydronephrosis and renal calculi (conventional X-ray of the abdomen; specific X-ray examination of the kidney, ureter and bladder (KUB), ultrasound (US), MDCT; and magnetic resonance imaging (MRI), although most recent protocols limit the choices of initial imaging modalities in an acute setting to MDCT and ultrasound **[3]**.

Noncontrast CT of the abdomen and pelvis consistently provides the most accurate diagnosis but also exposes patients to ionizing radiation **[3]**.

Traditionally US has a lower sensitivity and specificity than CT, but does not require use of radiation. However, when these imaging modalities were compared in a randomized controlled trial they were found to have equivalent diagnostic accuracy within the emergency department. Both modalities have advantages and disadvantages **[3]**.

KUB plain film radiography is most helpful in evaluating for interval stone growth in patients with known stone disease, and is less useful in the setting of acute stones [3].

In recent years, the use of non-contrast MDCT in patients with urinary system stones has increased. Hounsfield units (HU), a parameter generated from standard CT, are related to the density of the stone [4].

NCCT scan provides several advantages over the KUB radiograph such as detection of radiolucent calculi, sensitivity for small stones, identification of other causes of flank pain as well as avoidance of any preparation prior to the procedure [5].

Multidetector CT scan has long replaced the plain abdominal radiograph as the gold standard in the diagnosis of urolithiasis [6]. However, a KUB radiograph has remained part of the protocol for most clinicians even after a non-contrast helical CT scan is carried out because of its impact in clinical decision making prior to treatment [7].

KUB X-ray has been the preferred mode of follow up imaging provided the stone is visible on plain X-ray or radio-opaque. It has a much lower dose of radiation and is considerably cheaper, quicker and exposes patients to less radiation, CT scout film should be reported before proceeding to KUB. If the stone is visible on CT scout film, then the decision to use KUB for follow-up can be made. This minimizes radiation exposure and other costs [8].

Aim of the work:

In this study, we explore the diagnostic utility of KUP and CT scanogram attenuation value of a stone to predict its appearance in Plain KUP radiograph in the hope to decrease the need for an additional CT of patients.

Patients and Methods

Type of the study: Retrospective study.

Study period: Six months Twelve months (from August 2019 till August 2020).

Study setting: The study will be conducted in Radiodiagnosis Department in Ain Shams University.

Study population: A list of inclusion and exclusion criteria will ensure the consistency of the study population.

Inclusion criteria:

- Patients aged 18 years old and above.
- Diagnosed to have urolithiasis after undergoing CT stonogram with a typical clinical picture of suspected urinary calculi such as flank pain and/or hematuria. Patients included in this study must have concurrent or follow-up plain kidneys; ureter and urinary bladder (KUB) radiograph.

Exclusion criteria:

- If the KUB X-ray film will be evaluated as suboptimal to clearly delineate abdominal structures and difficult to identify urinary stones due to intervening bowel gas or poor image contrast as an effect of decreased radio-exposure caused by a morbidly obese patient.
- Patients with computed tomographic evidence of other urinary tract diseases, such as chronic renal failure and nephrocalcinosis, will also not be included.

Sample size: A sixty (60) cases.

Study tools:

1- History and clinical data of urolithiasis patients.

2- All CT-scout films evaluated first, followed by KUB X-ray.

3- In the evaluation of the NCCT scan Detect stones which appear as focal hyperdensities located within the urinary system. Then documentation of the location (pelvocalyceal system, proximal, middle, or distal ureter, or ureterovesical junction [UVJ] or ureinary bladder), In case of multiple lithiases, stones from different locations will document separately.

4- The stones will be identified and differentiated from phleboliths when at least one of the following two criteria was noted: The presence of a soft-tissue rim surrounding the calcification, Location of the calcification within the course of the ureter.

5- Stone size (diameter in millimeter) was measured using standard metric software devices provided with the workstation.

6- Attenuation values in HU will be systematically measured with an elliptic region of interest (ROI) in the 90% area of the stone at antero-posterior view in coronal cut of the CT scanogram.

Devices: CT stone protocol imaging performed by using a 64-multidetector computed tomography scanner (GE-64 slice optima) without intervenous or contrast material. All patients scanning in the supine position from the superior aspect of the kidney to the inferior aspect of the symphysis pubis.

Ethical considerations: The study will be presented for the approval from the ethical committee of the Department of Radiology, Faculty of Medicine, Ain Shams University. Written consent will be taken from all participates before recruitment in the study after explanation of the purpose and procedure of the study.

Data management and analysis: The collected data will be coded, tabulated, and statistically analyzed using SPSS program (Statistical Package for Social Sciences).

Statistical analysis:

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when parametric and presented as median with inter-quartile range (IQR) when non parametric. Also qualitative variables were presented as number and percentages.

Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group.

Receiver operating characteristic curve (ROC) was used in the quantitative and qualitative form to assess the best cut off point with its sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and area under curve (AUC).

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following: *p*-value >0.05: Non significant (NS), *p*-value <0.05: Significant (S) and *p*-value <0.01: Highly significant (HS).

Results

This study conducted on 60 cases with age ranged from 19 to 64 years and with mean ± SD of 44.48±12.02; they were 24 females (40.0%) and 36 males (60.0%) with total 118 stones. They were admitted from Ain Shams University Hospital.

Table (1): Demographic data of the studied patients.

	Total No. = 60
Age (years):	
Mean ± SD	44.48±12.02
Range	19-64
Sex:	
Females	24 (40.0%)
Males	36 (60.0%)

Table (2): Results of scout and KUB among all 118 stones of the studied patients.

	Total No. of stones = 118 No. (%)
Scout:	
Not visible	53 (44.9%)
Visible	65 (55.1%)
KUB:	
Not visible	52 (44.1 %)
Visible	66 (55.9%)

Table (3): Size and density of stones among the studied patients.

	Total No. of stones = 118
Size (mm):	
Median (IQR)	7.55 (4-15)
Range	1-90
Density (Hu):	
Median (IQR)	657 (400-1100)
Range	50-1700

Table (4): Relation of Scout results with side and site of stones among the studied patients.

	Scout		Test value	*p*-value	Sig.
	Not visible No. = 53	Visible No. = 65			
Side:					
Right kidney	18 (34.0%)	35 (54.3%)	5.647*	0.227	NS
Left kidney	35 (66.0%)	30 (45.7%)			
Site:					
Kidney	40 (75.5%)	48 (73.9%)	0.079*	0.961	NS
Ureter	12 (22.6%)	16 (24.6%)			
Urinary bladder	1 (1.9%)	1 (1.5%)			

p-value >0.05: Non significant. *p*-value <0.01: Highly significant.
p-value <0.05: Significant. *: Chi-square test.

The previous table shows that there was no statistically significant relation found between visibility by Scout method and side or site of the studied stones with p-value=0.227 and 0.961 respectively.

Table (5): Relation of density with the other studied parameters among the studied patients.

	Density (Hu)		Test value	p-value	Sig.
	Median (IQR)	Range			
Side:					
Right kidney	835 (530-1219)	150-1700	10.251	0.036	S
Left kidney	600 (365-945)	50-1449			
Site:					
Calceal	804 (224-1384)	224-1384	1.207	0.751	NS
Kidney	644.5 (365-1103)	50-1700			
Ureter	719.5 (510-995.5)	90-1527			
Urinary bladder	1060 (600-1520)	600-1520			

p-value >0.05: Non significant. p-value <0.01: Highly significant.
p-value <0.05: Significant. #: Kruskal-Wallis test.

The previous table shows that there was no statistically significant relation found between density and side of stone (p=0.071) and also site of stone (p=0.015) while there was statistically significant increase in the density with the increase of number of stones with p-value=0.015.

Case 1:

A 46 year-old male patient present with a 4-week history of right-sided loin pain.

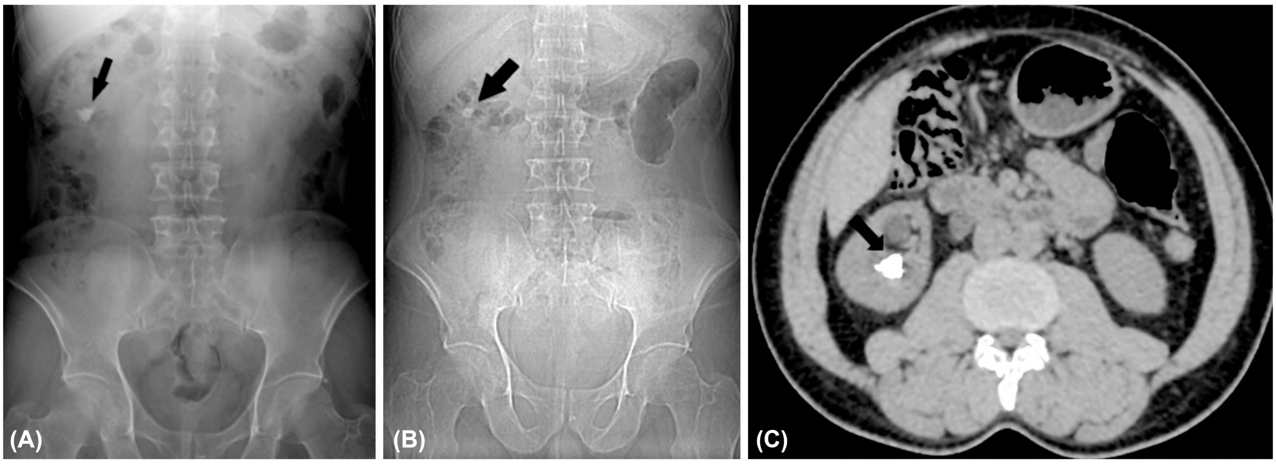

Fig. (1): Left kidney stone visible on all three images-KUB, CT scou and CTUT 17x13mm size, 1700 HU.

Discussion

Urinary calculus remains to be a common presentation in the hospital. It is the third most common urological problem after urinary tract infection and prostate disease with life time prevalence of urolithiasis at 10-15% [3].

Multidetector CT scan provides several advantages over the KUB radiograph such as detection of radiolucent calculi, sensitivity for small stones, identification of other causes of flank pain as well as avoidance of any preparation prior to the procedure. Non-contrast helical CT scan has long replaced the plain abdominal radiograph as the gold standard in the diagnosis of urolithiasis [9].

In the present study, males represented about 60% and females represented about 40%. Boyceet al., [10] studied 395 patients, 81% of them were males and 19% were females. The same statements were mentioned by Soomro et al., [11] who studied 60 patients. 68% of them were males and 32% were females.

The mean age of the studied 60 patients was 44.48 years. This is approximately the same as mentioned by Abbad et al., [12] who studied 124 patients and the mean age of them were 45 years. Also, the mean age of the study population by Yap et al., [13] was 44.7 years.

There were 53 stones (44.7%) identified on the right side and 65 stones (55.3%) on the left side. Chua et al., [14], studied 203 stones and found that 104 stones (51.2%) are on the right side and 99 stones (48.8%) are on the left side. Also, Abou El-Ghar et al., [15], studied 50 patients and found that stones are located on right and left sides in 27 and 23 patients respectively.

The median stone CT density in the present study was 657HU. This is approximately the same as mentioned by Ibrahim et al., [16] whostudied 51 patients and found that the median stone CT density is 871 HU.

In this study, there was statistically significant increase in the size and density in visible stones by scout than non visible stones with *p*-value <0.001 and <0.001 and that was the same mentioned by Yap et al., [13] as the *p*-value for both variables for both observers was 0.0001, which is statistically significant.

There was no statistically significant relation found between visibility by Scout method or KUB radiograph and side or site of the studied stones with *p*-value=0.227 and 0.961 respectively which agrees with Johnston et al., [17] who stated that there was no significant difference between stone location and visibility on either imaging method.

But that disagrees with Johnston et al., [17] who stated that the stones seen on CT scout were on average 5.23mm whilst those missed were 4.66mm, which was not significant (*p*=0.214).

A possible explanation for the discrepancy could be that the interpretation of digital CT scout radiographs requires training and optimal settings to be used depending on the patient's size, location of the stones and overlying structures.

In the KUB radiograph, 77.3% stones were noted in the kidney compared to the urinary bladder and ureter, which showed only 1.5%, 21.2% respectively. Chua et al., [14] found that in the KUB radiograph, 77.42% opaque stones were noted in the kidney compared to ureter and urinary bladder, which showed only 30%.

In the current study, there was non-significant difference as regard to side and site in the KUB radiograph which disagree with Huang et al., [18], who stated that non-middle ureteral location and higher calculi densities on non-contrast helical CT scan are significant predictors of visibility on KUB radiography.

In this study, there was statistically significant increase in the size in visible stones by KUB than non visible stones with *p*-value <0.001. This finding is similar to the study by Yap et al., [13], which also illustrated that calculi in the upper ureter that are larger than 4mm are more likely to be seen on the KUB radiograph.

But in the study done by Johnston et al., [17] there was nonstatistically significant difference in between size and visibility by KUB as those seen on KUB were 4.93mm and those missed were 4.90mm, with (*p*=0.767).

In the current study, the best cut off point for density to differentiate between visible and non-visible stones by Scout method was found >689 with sensitivity of 81.54%, specificity of 92.45% and area under curve (AUC) of 0.934%.Chua et al., [14] found that by using ROC determination of best CT HU attenuation level cut-off at which urinary calculi are likely to be seen opaque on CT scout was determined at the value of 710 HU. The sensitivity was 98.7% and specificity was 95.3%, positive predictive value was 95.7% and negative predictive value was 98.5%.

In another study by Bellin et al., [19] studied 100 patients and reported that sensitivity, specificity and accuracy of non-enhanced multi-slice CT for determining stone composition to differentiate between visible and non-visible stones are 91%, 92% and 81% respectively. Chua et al., [14] also examined 184 cases and reported 89.3% sensitivity, 87.3% specificity and 77.5% accuracy of non-enhanced multi-slice CT for determining stone composition to differentiate between visible and non-visible stones.

In this study, the best cut off point for density to differentiate between visible and non visible stones by KUB method was found >600 with sensitivity of 84.85%, specificity of 82.69% and area under curve (AUC) of 87.6%. In the study done by Chua et al. (14)by using ROC determination for density by KUB method the best cut-off level at which urinary calculi are likely to be seen was determined at the value of 610 HU. The sensitivity was 82.9% and specificity was 93.9%, positive predictive value was 96.5% and negative predictive value was 83.5%.

Jackman et al., [20] reported sensitivities of 17% and 48% for CT scout film and KUB, respectively.

One further study by Ege et al., [21] reported sensitivities of 40% and 52% for CT scout and KUB, respectively.

There was a high statistical significance in the correlation between the size and the mean CT density of the stones with p-value 0.000. Ibrahim et al., [16] studied 51 patients by un-enhanced 16-detector computerized tomography and found the same statements with p-value 0.019. Also, Nakadaa et al., [22] agreed with this statement in their study carried on 129 patients with p-value 0.002.

Also, Memarsadeghi et al., [23] and Saw et al., [7] who postulated that overlapping 3-mm sections of unenhanced CT scan are sufficient for the detection of urinary stone disease and reflect a better attenuation measurement; hence, the degree of attenuation was affected by stone size.

In the present study, there was no statistically significant difference found between the results of Scout and KUB with p-value=0.896 but Chua et al., [14] commented that there was a high statistically significant difference found between the results of Scout CT and KUB with p-value <0.0001.

In a study by Assi et al., [24], it has been shown that abdominal radiography is more sensitive than CT-scout film in revealing ureteral calculi; however, there were still some calculi revealed on unenhanced helical CT, which cannot be seen on either abdominal radiography or CT scout radiography.

This is similar to the one conducted by Ege et al., [21] that demonstrated plain KUB X-ray is more sensitive than CT-scout film; however, this study also illustrated that CT-scout film can be used as a baseline study in most patients with larger ureteral stones (5mm or larger).

In the current study, there was 55.1% of the stones visible by scout film while 55.9% seen by KUB with no significant difference in between. Disagrees to our findings were those of Johnston et al., [17], where in stones were seen on 47% of the CT scout films and 63% of the KUB X-rays; this difference was determined to be significant (p=0.02).

In another small study with 60 patients, Assi et al., [24] reported that 47% (28) of ureteric calculi were seen on CT scout film compared with 60% (36) seen on KUB X-rays.

Also Foell et al., [25] stated that Stone visibility was 60.4% on KUB while it was 43.5% on scout film with a high significant difference in between (p<0.001).

One of the other important findings in our study is that all the patients whose calculi were visible on CT scout radiographs were detected on plain KUB. The KUB method can predict the results of Scout method by sensitivity of 83.1%, specificity of 77.4% and accuracy of 80.5%, which is much higher than that reported previously of 59% by Levine et al., [26]. This is because of our small sample size and our interpretation of the plain radiographs with access to and knowledge of CT KUB findings, although without knowledge of the scout radiograph findings, unlike the previously published group.

Also, in the study done by Chua et al., [14] the sensitivity was 82.2% and specificity was 96.9%. Positive predictive value was 96.5% and negative predictive value was 83.5%.

Also in the study done by Yap et al., [13] the sensitivity of the abdominal radiograph in detecting calculi is 73% group.

Conclusion:

Suffice to say that CT-scout film should be viewed before a decision to perform a subsequent KUB X-ray. For stones visible on the CT-scout film, requesting for a subsequent KUB X-ray can be omitted or used only for follow-up. With that, unnecessary radiation exposure can be avoided wherein the diagnosis of urolithiasis has already been established; hence, nearly half of the KUB X-rays usually done in an institution could be avoided in the acute setting. In stones not visible on the CT-scout film, CT attenuation value must be determined prior to deciding further management.

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رؤية حصوات المسالك البولية فى الصور الشعاعية للكلى والحالب والمثانة والتصوير الكشفى بالتصوير المقطعى المحوسب مع الارتباط بوحدة هونزفيلد المقطعية

الخلفية: تبقى الحصوات البولية عرضاً شائعاً فى المستشفى. إنها ثالث أكثر مشاكل المسالك البولية شيوعاً بعد عدوى المسالك البولية وأمراض البروستاتا مع انتشار تحص بولى مدى الحياة بنسبة ١٠–١٥٪، وقد ارتفع معدل الانتشار على مدى ٢٠ عاماً من منتصف السبعينيات إلى منتصف التسعينيات. يعتمد تشخيص تحص بولى إلى حد كبير على تحليل العرض السريرى والفحص البدنى. تم تأكيد الشك من خلال الاختبارات الإشعاعية، ولا سيما الفحص المقطعى المحسن غير المتباين. إن ظهور التصوير المقطعى غير المحسن لم يوفر فقط الكشف عن الحصوات وتأكيدها، ولكن أيضاً الكشف الدقيق عن حجمها وموقعها.

الهدف: هو تحديد أفضل مستوى قطع لوحدات هاونس فيلد فى مخطط التصوير المقطعى المحوسب الذى من شأنه أن يتنبأ بظهور الحصيات البولية فى الكشف المقطعى المحوسب والأشعة السينية العادية على الكليتين والحالب والمثانة.

الحالات والطرق: كانت هذه الدراسة بأثر رجعى أجريت فى قسم التشخيص الإشعاعى بجامعة عين شمس. وشملت المرضى الذين تم تشخيص إصابتهم بتحصى البول بعد الخضوع للتصوير الحجرى المقطعى المحوسب مع صورة سريرية نموذجية لحسابات المسالك البولية المشتبه بها مثل ألم الخاصرة و/أو بيلة دموية. يجب أن يكون لدى المرضى المشمو لين فى هذه الدراسة كلى عادية متزامنة أو متابعة، تصوير الحالب والمثانة البولية. تراوحت مدة الدراسة من ٦ إلى ١٢ شهراً.

النتائج: أظهرت النتائج الرئيسية للدراسة ما يلى: تراوحت أعمارهم بين ١٩ و ٦٤ بمتوسط ٤٤.٤٨±١٢.٠٢، بينما الإناث (٤٠.٠٪) والذكور (٦٠٪) من الجنس. أظهرت (٥٥.١٪) ولم تظهر (٤٤.٩٪) بالتصوير الكشفى بالتصوير المقطعى المحوسب. تظهر (٥٥.٩٪) ولا تظهر (٤٤.١٪) بالأشعة السينية العادية على الكلى والمثانة. يتراوح حجم الحصوات من ١–٩٠ بمتوسط (٤–١٥) ٧.٥٥. تراوحت الكثافة (ميدان الصيد) بمتوسط (٤٠٠–١١٠٠) ٦٥٧. يوجد فرق ذو دلالة إحصائية بين الكشفية المقطعية (يظهر وغير ظاهر) حسب الكثافة. توجد فروق ذات دلالة إحصائية بين بالأشعة السينية العادية على الكلى والمثانة (تظهر وغير ظاهرة) حسب الكثافة.

الاستنتاج: نوصى بإجراء مزيد من الدراسات المستقبلية على نطاق جغرافى كبير وعلى حجم عينة أكبر للتأكيد على استنتاجنا.