Original Article

# Use of computed tomography scout film and Hounsfield unit of computed tomography scan in predicting the radio-opacity of urinary calculi in plain kidney, ureter and bladder radiographs

Michael E. Chua[1], Odina R. Gomez[2], Lorelei D. Sapno[1], Steve L. Lim[1], Marcelino L. Morales Jr.[1,3]

[1]St. Luke's Medical Center, Institute of Urology, [2]St. Luke's Medical Center, Institute of Radiology, [3]National Kidney and Transplant Institute, Department of Urology, Philippines

## Abstract

**Objective:** The objective of this study is to determine the diagnostic utility of computed tomography (CT)-scout film with an optimal non-contrast helical CT scan Hounsfield unit (HU) in predicting the appearance of urinary calculus in the plain kidneys, ureter, urinary bladder (KUB)-radiograph.

**Methods:** A prospective cross-sectional study was executed and data were collected from June 2007 to June 2012 at a tertiary hospital. The included subjects were diagnosed to have <10mm urolithiasis with non-contrast helical CT scan and KUB X-ray, which were carried out on the same day. Both KUB radiographs and CT-scout film were read by two qualified radiologists with inter-observer standardization prior to the study. Urolithiasis characteristics such as stone location, CT attenuation value, CT-scout film and KUB radiograph appearance were recorded independently by two observers. Univariate logistic analysis with receiver operating characteristic curve was generated to determine the best cut-off HU value of urolithiases not identified in CT-scout film, but determined radio-opaque in KUB X-ray. Subsequently, its sensitivity, specificity, predictive values and likelihood ratios were calculated. Statistical significance was set at *P* value of 0.05 or less.

**Results:** Two hundred and three valid cases were included. 73 out of 75 CT-scout film detected urolithiasis were identified on plain radiograph and determined as radio-opaque. The determined best cut off value of HU utilized for prediction of radiographic characteristics was 630HU at which urinary calculi were not seen at CT-scout film and were KUB X-ray radio-opaque. The set HU cut-off was established of ideal accuracy with an overall sensitivity of 82.2%, specificity of 96.9% and a positive predictive value of 96.5% and negative predictive value of 83.5%.

**Conclusion:** Urolithiases identified on the CT-scout film were also seen as radiopaque on the KUB radiograph while those stones not visible on the CT-scout film, but above the optimal HU cut-off value of 630 are also likely to be radiopaque.

**Key Words:** Computed tomography scout film, Hounsfield units, kidneys, ureter, urinary bladder radiograph, non-contrast helical computed tomography scan, urolithiasis

**Address for correspondence:**
Dr. Michael Chua, 2246 Simeon de Jesus St., Tondo Manila, Philippines. E-mail: auhc_ekim@yahoo.com
**Received:** 06.03.2013, **Accepted:** 29.05.2013

| Access this article online | |
|---|---|
| Quick Response Code: | Website: www.urologyannals.com |
| | DOI: 10.4103/0974-7796.134270 |

## INTRODUCTION

Urinary calculus remains to be a common presentation in the hospital.[1] It is the third most common urological problem after urinary tract infection and prostate disease with life time prevalence of urolithiasis at 10-15%.[2] The

prevalence has risen over a 20-year period from the mid 1970's to the mid 1990's.[2] The diagnosis of urolithiasis is largely dependent on analyzing the clinical presentation and physical examination. Suspicion is confirmed with radiologic tests, particularly the non-contrast enhanced computed tomography (CT) scan. The advent of non-enhanced CT has not only provided detection and confirmation of calculi, but also accurate detection of its size and location.[1] Non-contrast helical 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.[3] Non-contrast helical CT scan has long replaced the plain abdominal radiograph as the gold standard in the diagnosis of urolithiasis.[4] 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.[5] Due to the higher radiation dose with CT, conventional or digital radiography is being used to monitor the passage of stones if radiographic follow-up is believed to be indicated.

Most studies investigating the utility of Hounsfield units (HU) in predicting the chemical composition of urinary stones are *in vitro* studies involving analysis and imaging of actual stones in phantom. *In vivo* studies correlating attenuation values with chemical composition of retrieved stones, uric acid stones and calcium oxalate stones were statistically differentiated using HU.[6] A significant difference was found between the Hounsfield measurement of uric acid calculi (mean344 ± 152HU) and that of calcium oxalate calculi (mean652 ± 490HU) whose stones were chemically analyzed.[6] HU density in another study was also significantly different between stones with the mean HU densities of the stones composed of calcium oxalate, struvite and uric acid were 812 ± 135, 614 ± 121 and 413 ± 143, respectively.[7] In a study investigating the correlation between stone composition and stone appearance on plain abdominal film showed grossly specific radiographic appearances, but clinical test revealed poor correct rate in prediction of stone composition from plain abdominal film. This suggest that prediction of stone component based on stone density and appearance on plain abdominal film may not be accurate enough.[8] A kidney stone with a HU associated with radiolucency can undergo medical dissolution first. The presence of asymptomatic ureteral stone with a HU that is correlated with a radiopaque stone can be sent to the shockwave lithotripsy right away. On the other hand, the presence of a ureteral stone with a HU that is correlated with a radiolucent stone can undergo retrograde pyelography instead. A patient can then avoid undergoing a plain abdominal radiograph.

This offers the advantage of avoiding additional radiation exposure as well as time and cost and minimizes the anxiety and discomfort of the symptomatic patient regarding an additional diagnostic test. Prior to a formal non-contrast helical CT scanning, a CT-scout film is routinely generated for technicians to select and set the scanning area. The CT-scout film is similar to a plain KUB X-ray, but with reduced quality and less radiation exposure to the patient. Our study would like to use the CT scout as a presumptive imaging with the support of Hounsfield unit of urolithiasis detected from non-contrast helical CT scan to predict opacity characteristic of an urolithiasis in plain radiograph. In current perspectives, there are still inconsistencies regarding HU range's predictability of radiographic characteristic of a stone in radiograph. Hence, with the similarity of CT scout and plain KUB X-ray, we would like to utilize the CT-scout as an adjunctive measure to increase the accuracy of predictive value of HU.

## MATERIALS AND METHODS

This is a cross-sectional study of radiographic data from June 2007 to June 2012 at a tertiary hospital, of patients who were diagnosed to have urolithiasis, by undergoing non-contrast helical CT scan and subsequently a KUB X-ray on the same day. This study included patients with stone size of 10 mm or less, whose age ranges from 18 years to 79 years, diagnosed with urolithiasis identified through non-contrast helical CT scan and kidneys, ureter, urinary bladder (KUB) radiograph taken on the same day. Excluded cases were those with suboptimal KUB radiograph classified as having intervening bowel gas or very dense fat. Furthermore excluded are those with other urinary tract diseases, such as chronic renal failure, associated renal parenchymal pathology and nephrocalcinosis that may interfere with CT scout film review. At 95% confidence level, sample size was estimated using the sensitivity of plain abdominal radiograph at 48% in detecting urolithiasis and 7% difference from the true sensitivity was applied. In order to have statistically sound findings from this study, the estimated sample size was calculated at 195 patients.

All non-contrast helical CT scans were performed using Philips 64 CT scanner. The imaging protocol included a section thickness of 1 mm for a detector configuration of 2 mm × 1 mm, rotation time 0.75s, pitch 1.172 table feed 1mm per rotation, tube voltage 120 kv and effective tube current time product 0.45 mA. The mean ± SD CT dose index was ± 15.1 mGy. Axial and coronal reconstructions were created in multiplane reconstruction application both KUB radiographs and non-contrast helical CT scan images were reviewed by a 3rd-year radiology resident as well as aboard certified experienced radiologist. Re-evaluation was carried out if there was disparity between the evaluation of the two readers

of either KUB radiograph or the non-contrast helical CT scan until they reach a consensus decision.

All CT-scout film was evaluated first, followed by the KUBX-ray. The reader was informed of the side of the body where the patient perceived the pain. However, the name, age and sex of patient on the radiograph were concealed. They were also blinded as to the result of the non-contrast helical CT scan. A radiopaque lesion found along the course of the urinary tract was identified as an opaque urolithiasis after differentiation from other calcific densities such as phleboliths.

In the evaluation of the non-contrast helical CT scan, each stone was viewed during rotation of all three coordinate axes to establish its identity as a single stone. Urolithiases were defined as focal hyperdensities located within the upper urinary system. The reader was asked to document the location, whether it was identified in the upper collecting system (renal parenchyma, pelvocalyceal system, proximal ureter) or lower collecting system (middle, distal ureter, or ureterovesical junction[UVJ]). In cases of multiple urolithiases, representative stones from different locations were evaluated separately. Ureteral calcifications were identified and differentiated from phleboliths when at least one of the following two criteria was noted:

a. Presence of a soft-tissue rim surrounding the calcification or
b. location of the calcification within the course of the ureter.

Attenuation values in HU were systematically measured with an elliptic region of interest (ROI) in the area of the stone. Stone size (diameter in millimeter) is measured using the standard metric software devices provided in the workstation.

Each stone identified on the non-contrast helical CT scan was classified according to its appearance in the CT scout and KUB radiograph as either radiolucent, less than or equal to the radiodensity of the 12$^{th}$ rib or greater than the radiodensity of the 12$^{th}$ rib. Each stone identified was measured with its HU attenuation value in non-contrast helical CT scan evaluation. The pixel specs determination of HU attenuation value on ROI is carried out by measuring the urolithiasis at coronal plane at 300% magnification to assure the whole area of urolithiasis was analyzed. Finally, for the purpose of validation that the stones being identified on the same case are the same, the radiologists were requested to indicate and classify each stone according to its location as either being in the renal parenchyma, pelvicalyceal system, proximal, middle or distal ureter or UVJ.

### Statistical analysis

All data were subsequently encoded in the Microsoft excel spread sheet and statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS for Windows, version 14.0, SPSS, Chicago, Ill). Demographic data of the cases included in the study were collated and summarized. Univariate logistic analysis with receiver operating characteristic (ROC) curve was constructed to determine the best cut-off value for determining what Hounsfield value at which a calculus can be seen by CT Scout or KUB alone and the cut-off value at which none can be seen by CT Scout, but KUB X-ray identified radio-opaque. Finally, the sensitivity, specificity, positive predictive value, negative predictive value, negative and positive likelihood ratios (LR) of the CT scan attenuation and KUB cut-off levels were calculated and determined. All data analyses were conducted at 0.05 level of significance or at 95% confidence interval.

## RESULTS

A total of 203 valid cases of radiographic studies were included and analyzed in this study to determine the utility of CT-scout film and determination of best optimal HU for the prediction of urinary calculi appearance on the KUB radiograph. In all cases, the mean stone size is 6.8 ± 1.2mm (mean ± SD); with 62.1% (126/203) from the male population and37.9% (77/203) from females.

In the cases reviewed, comparable laterality of urolithiases were noted with 51.2% (104/203) of stones on the left side and 48.8% (99/203) located on the right. Signs of obstruction were also noted in the radiographic records to support the presence of urolithiasis and subsequent structural changes, of which, 40.9% (83/203) had asymmetrical renal enlargement, 16.7% (34/203) had perirenal stranding, peripelvic stranding and ureteral dilatation and 8.9% (18/203) presented with renal pelvic dilatation.

Stones were also described based on their location. Upper collecting system [Figure 1] includes the renal parenchyma, pelvocalyceal system and proximal ureter, whereas the lower collecting system [Figure 2] includes the mid and distal ureter, and UVJ.

In the CT-scout film, 58.06% (54/93) of stones were seen in the upper collecting system compared to only 20% (22/110) seen in the lower collecting system. In the KUB radiograph, 77.42% (72/93) opaque stones were noted in the upper collecting system compared to lower collecting system, which showed only 30% (33/110).

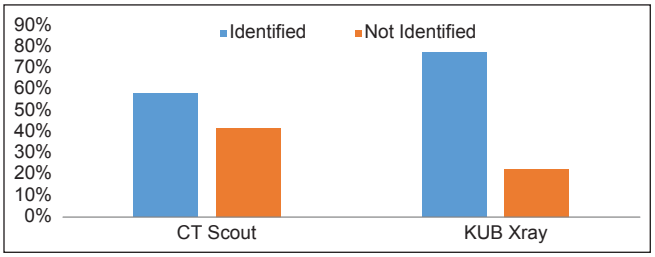


**Figure 1:** Appearance of stone by location: Upper collecting system

With the data at hand, analysis of variance was done. The mean HU for stones to be identified by CT scout film is 651HU ( ± 316 SD). 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%. The positive LR was 21 while the negative LR 0.013 [Table 1].

While the ROC determined the best HU cut-off value, in which urinary calculi are seen opaque in KUB X-ray was set at 610 HU with sensitivity of 82.9% and specificity of 93.9%. The negative predictive value was 83.5% while positive predictive value was 96.5%. The positive LR was 26.5, where as negative LR was 0.18. The cut-off value at which urinary calculi are not seen by CT Scout film, but were identified at KUB X-ray was at 630 HU [Table 1]. The overall sensitivity was 82.2% and specificity was 96.9%. Positive predictive value was 96.5% and negative predictive value was 83.5%. The positive LR was 26.51 while the negative LR was 0.18 [Table 1].

The area under the curve was 0.962 [Table 2, Figure 3]. This proves that those stones not identified in the CT Scout image, but with attenuation value above the set cut-off of 630 HU is accurate in determining patients with the stone in question and have optimal accuracy.

## DISCUSSION

Few studies have cited the ability of CT-scout film to replace plain KUB X-ray in evaluating urinary calculi. In a study by Assi (2000), 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.[9] This is similar to the one conducted by Ege (2004) 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(5 mm or larger).[10]

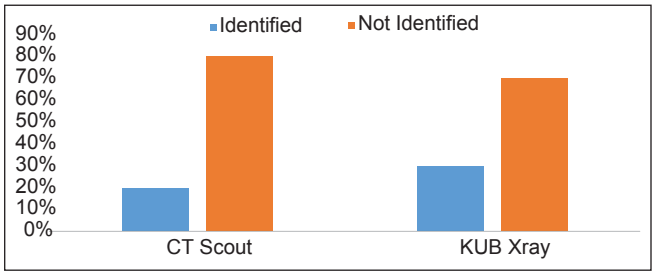


**Figure 2:** Appearance of stone by location: Lower collecting system

A routine KUB X-ray taken shortly after the initial non-contrast helical CT scan is usually carried to determine the radiopacity of stone has become the standard management protocol for most institutions. With the studies presented in the previous years, we conducted our own, reviewing 203 radiographic records taken from June 2007 to June 2012, which used CT-scout film and KUB X-ray carried out simultaneously in diagnosing the presence of urinary calculi. In our study, worth noting is the finding that most of the lithiases seen on CT scout (73/75) were also seen as opaque on KUBX-ray. The set cut-off at HU of 710 with ROC determination with the sensitivity of 98.7% and specificity of 95.3% was determined from the urolithiasis identified in the CT scout film. Similar to our findings were those of Johnston (2005), where in stones were seen on 47% (51/108) of the CT scout films and 63% (68/108) of the KUB X-rays; this difference was determined to be significant ($P = 0.02$); a key finding of this study was that all stones seen on CT scout were also seen on KUB.[11]

The cut-off value at which none can be seen on CT Scout, but can be identified on KUB X-ray was set at 630 HU, in the stones with attenuation value equal or higher than the set cut-off point is considered radiopaque and those with HU below the set cut-off point maybe considered radiolucent. Predictive value revealed in the present study is considerably better than the one cited in an earlier study by Chua (2012) without utilizing the CT-scout film and relied solely on CT attenuation value.[12] The set cut-off of 498.5 HU in the earlier study was only able to provide 87.3% of specificity in contrast to present study of 96.9%. Although a lower sensitivity was noted in the present study, a sensitivity of 82.2% is still considered acceptable. For clinical applicability in particular, the derived predictive values are better in this study (positive

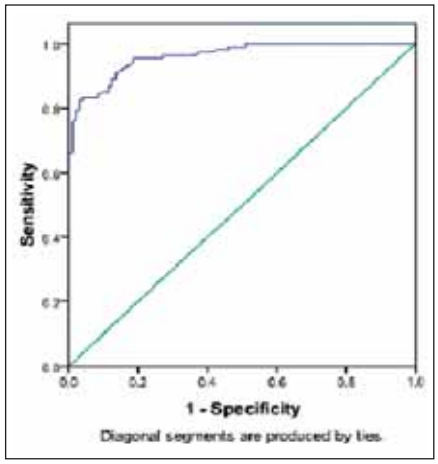


**Figure 3:** Receiver operating characteristic curve for determination of Hounsfield unit (HU) 630 set as the best HU cut-off value for determination of urolithiasis appearance unidentified in computed tomography scout and kidneys, ureter, urinary bladder X-ray determined radio-opaque

**Table 1: Setcut-off attenuation value of HU for each radiologic modality and combined in determination of urolithiasis' radiographic appearance**

| Radiologic modality | Set cut-off | Accuracy measures | Statistical significance |
|---|---|---|---|
| CT scout identified urolithiasis | 710 HU | Sensitivity=98.7%<br>Specificity=95.3%<br>Positive predictive value=0.957<br>Negative predictive value=0.985<br>Positive LR=21<br>Negative LR=0.136 | <0.001 |
| X-ray determined radio-opaque | 610 HU | Sensitivity=82.9%<br>Specificity=93.9%<br>Positive predictive value=0.965<br>Negative predictive value=0.835<br>Positive LR=26.5<br>Negative LR=0.183 | <0.001 |
| CT scout unidentified but X-ray determined radio-opaque | 630 HU | Sensitivity=82.2%<br>Specificity=96.9%<br>Positive predictive value=0.965<br>Negative predictive value=0.835<br>Positive LR=26.5<br>Negative LR=0.183 | <0.001 |

CT: Computed tomography, HU: Hounsfield unit, LR: Likelihood ratio

**Table 2: Area under the curve**

| Test result variable(s): Hounsfield | | | | |
|---|---|---|---|---|
| Area | Std. Error | *P*-value | 95% confidence interval (CI) | |
| | | | Lower CI | Upper CI |
| 0.962 | 0.011 | <0.0001 | 0.940 | 0.984 |

predictive value 93% vs. 96.5%, Negative predictive value 80.9% vs. 83.5%, respectively).

The location of the stone also has an influence on its appearance on CT-scout film, but not on the KUB radiograph. In this study, the number of calculi identified was greater in the upper collecting system compared with those in the lower collecting system as seen in both CT-scout film and KUB radiograph. In both imaging modalities, urolithiasis in the upper collecting system were better delineated as compared to the lower collecting system (CT scout 58% for upper collecting vs. 20% lower collecting system, while KUB radiography 77% for upper collecting vs. 30% for lower collecting system). This finding is better explained by structural hindrance, particularly in that there are more osseous structures and other overlying soft-tissue densities that obscure the lower collecting system. This finding is similar to the study by Yap (2012), which also illustrated that calculi in the upper ureter that are larger than 4 mm are more likely to be seen on the KUB radiograph.[13]

The radiographic records reviewed in this study involved only patients with stones measuring 10mm or less because these are the cases, which can be managed medically depending on the degree of radio-opacity. According to Chu (1999), the two important factors in patient management are stone size and location. Most stones measuring 4 mm or smaller in size will pass spontaneously, as will most stones located in the distal ureter at the time of diagnosis; however, the definitive diagnosis of stone passage is difficult.[14] Hence, the final decision whether to do medical dissolution or operative intervention depends on the stone's appearance by radiograph. In the study by Huang (2009), multivariate analyses of the 84 CT-scout film undetectable calculi revealed that non-middle ureteral location and higher calculi densities on non-contrast helical CT scan are significant predictors of visibility on KUB radiography.[15] All non-middle ureteral calculi with density >800 HU were visible on KUB radiography. Of the 23 calculi in the middle ureter or with density <200 HU, 17 (74%) were undetected on KUB radiograph.

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. Urolithiasis in which the attenuation value is >630 HU, patient may proceed with shockwave lithotripsy or intracorporeal lithotripsy while those with less than the cut-off value of HU, if with no indication for stone removal, medical dissolution can be offered without a need for additional KUB radiography or if with indication for active stone removal, retrograde pyelography must immediately be taken into consideration as the subsequent procedure.

## CONCLUSION

By definition, any stone visible on CT-scout film is likely to be radiopaque regard less of its location. The cut-off value at which urinary calculi not identified by CT Scout, but KUB radiographically

opaque is set at 630 HU with the overall sensitivity of 82.2% and specificityof 96.9%. 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.

## REFERENCES


1. Mahmood A, Silbergleit A, Olson R, Cotant M. Urolithiasis: The influence of stone size on management.Nat Clin Pract Urol 2007;4:570-3.
2. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC. Time trends in reported prevalence of kidney stones in the United States:1976-1994. Kidney Int 2003;63:1817-23.
3. Jellison FC, Smith JC, Heldt JP, Spengler NM, Nicolay LI, Ruckle HC, *et al*. Effect of low dose radiation computerized tomography protocols on distal ureteral calculus detection. J Urol 2009;182:2762-7.
4. Krishnamurthy MS,Ferucci PG, Sankey N, Chandhoke PS. Is stone radiodensity a useful parameter for predicting outcome of extra corporeal shock wavelitho tripsy fors tones <or=2cm? Int Braz J Urol 2005;31:3-8.
5. Saw KC, McAteer JA, Monga AG, Chua GT, Lingeman JE, Williams JCJr. HelicalC Tofurinary calculi: Effect of stone composition, stonesize, and scan collimation. AJRAm J Roentgenol 2000;175:329-32.
6. Nakada SY, Hoff DG, Attai S, Heisey D, Blankenbaker D, Pozniak M. Determination of stone composition by noncontrast spiral computed tomography in the clinical setting.Urology 2000;55:816-9.
7. Demire IA, Suma S. The efficacy of non-contras the licalcomputed tomography in the prediction of urinary stone composition *in vivo*. J Int Med Res 2003;31:1-5.
8. Wang SC, Hsu YS, Chen KK, Chang LS. Correlation between urinary tractpure stone composition and stone morphology on plain abdominal film. J Chin Med Assoc 2004;67:235-8.
9. Assi Z, Platt JF, Francis IR, Cohan RH, Korobkin M. Sensitivity of CT scoutra diography and abdominalra diography for revealing ureteral calculi on helical CT: Implications for radiologic follow-up. AJRAm J Roentgenol 2000;175:333-7.
10. Ege G, Akman H, Kuzucu K, Yildiz S. Can computed tomography scoutra diography replace plain film in the evaluation of patients with acuteurinary tractcolic? Acta Radiol 2004;45:469-73.
11. Johnston R, Lin A, Du J, Mark S. Comparison of kidney-ureter-bladderabdominalra diography and computed tomography scout films for identifying renal calculi. BJUInt 2009;104:670-3.
12. Chua ME, Gatchalian GT, Corsino MV, Reyes BB. Diagnostic utility of attenuation measurement (Hounsfield units) incomputed tomography stonogram in predicting the radio-opacity of urinary calculiin plain abdominal radiographs. Int Urol Nephrol 2012;44:1349-55.
13. Yap WW, Belfield JC, Bhatnagar P, Kennish S, Wah TM.Evaluation of the sensitivity of scout radiographs on unenhanced helical CT in identifying ureteric calculi: A large UK tertiary referral centre experience. Br J Radiol 2012;85:800-6.
14. Chu G, Rosenfield AT, Anderson K, Scout L, Smith RC. Sensitivity and value of digital CT scoutra diography for detecting ureteral stones in patients with ureterolithiasis diagnosed on unenhanced CT. AJRAm J Roentgenol 1999;173:417-23.
15. Huang CC, Chuang CK, Wong YC, Wang LJ, Wu CH. Useful prediction of ureteral calculi visibility on abdominal radiographs based on calculi characteristics on unenhanced helical CT and CT scout radiographs. Int J Clin Pract. 2009;63:292-8.


**How to cite this article:** Chua ME, Gomez OR, Sapno LD, Lim SL, Morales ML. Use of computed tomography scout film and Hounsfield unit of computed tomography scan in predicting the radio-opacity of urinary calculi in plain kidney, ureter and bladder radiographs. Urol Ann 2014;6:218-23.

**Source of Support:** Nil, **Conflict of Interest:** None declared.