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Diagnostic Value of Attenuation Measurement of the Kidney on Unenhanced Helical CT in Obstructive Urolithiasis

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ABSTRACT

Purpose: The aim of this study was to evaluate the diagnostic value of attenuation measurements of kidney on unenhanced helical CT in comparison with other secondary signs of obstructive urolithiasis.

Material and methods: One hundred and fifty patients with acute unilateral flank pain, in whom a ureteral stone was clinically suspected based on the symptoms, of either sex and above the age of 18 years were evaluated using unenhanced helical computed tomography, and 50 control subjects who had been admitted for other acute abdominal emergencies but without urinary complains were included in this retrospective review.

Attenuation values were measured with region of interest (ROI) (≈ 40 mm^2) in upper, middle, lower portion of renal parenchyma (cortex) (soft tissue window, center: 20H, width: 300H). A mean attenuation value (in Hounsfield units) was calculated for each kidney from the three measurements.A difference in the mean attenuation values was calculated or higher attenuation kidney minus lower attenuation kidney (when no ureteral stone was detected in controls). Presence or absence of hydroureter , perinephric fat stranding , soft tissue rim surrounding the identified ureteral stone was noted.

Results: In 129 patients with urolithiasis (86%), the difference between the parenchymal densities of the obstructed and non-obstructed kidneys was 5.4 Hounsfield units (HU) or greater and was always lower on the obstructed side. In the remaining 21 patients (14%), the density difference was less than 5.4 HU but was still lower on the obstructed side. All subjects in the control group had a density difference of less than 5.4 HU.

A renal parenchymal density difference of 5.4 HU or greater had 86.26% sensitivity, 98.26% specificity, 99.17% positive predictive value, 69.36% negative predictive value, and 86% accuracy in predicting the presence of an acute obstructing ureteral stone. Measuring the attenuation difference was more sensitive, specific and accurate in predicting acute obstruction compared to other secondary signs such as hydroureter , perinephric stranding and soft tissue rim sign.

Conclusions: These data suggest that the renal parenchymal density difference of greater than or equal to 5.4HU may be a valuable secondary sign of acute obstructing ureteral stone disease. In addition, it showed better diagnostic accuracy than other secondary signs and has advantage of being a numerical parameter.

Keywords: obstructive urolithiasis, attenuation, renal parenchymal density

INTRODUCTION

Urolithiasis is a universal problem that has become increasingly preva¬lent and is more common in Asians3, and tends to present between 30 to 60 yrs of age with a predilection for males.Between 5 - 12% of the world population have urinary stone during their lifetime with recurrence rate as high as 50%5. In the Indian scenario, the prevalence rate of the kidney stone is 12-15% and recurrence rate is 50%6.

As per ACR appropriateness criteria for suspicion of stone disease, Non contrast Computed tomography (NCCT) is the most accurate imaging technique for the evaluation of urinary stones 85. Unenhanced CT scan of abdomen has a sensitivity of 96–100%, a specificity of 95.5–100%, and an accuracy of 96–98% in the diagnosis of obstructive urolithiasis7, 8, hence obviating the use of contrast. Unenhanced CT performed in the emergency department setting for the evaluation of urolithiasis makes up just over 22% of all CT examinations conducted for the evaluation of acute abdominal pain9.

Direct identification of the stone is diagnostic of urolithiais. Nonetheless, a stone may not be identified due to low attenuation, respiratory movement, confusion with phleboliths, too small size or recent passage. Therefore,to arrive at a diagnosis , several auxiliary signs of obstructive urolithiasis are described, such as soft tissue rim sign ,perinephric/periureteric fat stranding and hydroureter. Hydroureter, which is the most common secondary sign of ureteral stones, is detected on CT in 64-90% of patients.10

Following ureteral obstruction , renal parenchyma becomes edematous and may appear bulky due to upstream changes , this is referred to as “PALE KIDNEY SIGN”, attributed to the hypodense appearance of obstructed kidney, which is a subjective secondary sign on non-contrast CT scan11,12. However in the present study,we would like to determine its diagnostic value as objective criterion by measuring the difference between attenuation values (HU) of cortex of the affected and the normal kidney.Attenuation difference has the advantage of being the only measurable indicator in comparison to other secondary signs.

MATERIALS AND METHODS

During the period January 2017 to January 2018, a total of 150 patients who had presented to emergency department and referred for CT scan based on clinical symptoms of urinary colic were evaluated with unenhanced helical CT retrospectively. Patients of either sex or those above age of 18 years were included. Pregnant patients, chronic kidney disease, nephrocalcinosis and patients with a condition that might asymmetrically affect one kidney, such as renal carcinoma, radiotherapy and those with history of nephrectomy were excluded.Controls included patients who had been admitted to the emergency department and eventually diagnosed with other acute abdominal emergency such as acute appendicitis, acute cholecystitis .None of the subjects in the control group had any urinary complaints. This study was approved by institutional ethics committee.

Proper informed consent was taken from patient after explaining about the risks and benefits of examination. Essential clinical history was obtained mainly regarding previous surgery or interventional procedure.

All studies were performed on Philips 64 slice Brilliance Computed tomography scanner using pitch of 1, 130 kVp, and 80-100 mAs . Neither oral nor intravenous contrast material was administered. Scan included diaphragm domes to upper border of pubic symphysis in one breath hold. All the image data were sent electronically to a workstation [Philips Tera-recon] for analysis. Scans were reviewed by radiologist at a single workstation, they were evaluated at a soft tissue setting with window width of 300 Hounsfield units(HU) and window level of 40 HU for presence of urolithiasis/ureterolithiasis and its secondary signs : hydroureter, perinephric fat stranding and soft tissue rim sign. Other non-urinary abnormalities were also evaluated simultaneously.

Attenuation values were measured with elliptic region of interest (ROI) in upper, middle, lower parts of renal parenchyma (cortex) (soft tissue window, center: 20H, width: 300H), excluding the renal sinus complex. At the upper pole, measurement was made at the level of uppermost calyx .In the middle portion, the measurement was made at the level of the hilum and in the lower pole the ROI was placed in the last section in which the collecting system could be identified.All measurements were made with a similar-sized ROI (≈ 40 mm2) in the posterior part of the kidney parenchyma. A mean attenuation value (in Hounsfield units) was calculated for each kidney from the three measurements.A difference in the mean attenuation values of both kidneys was

Volume 3, Issue 4; July-August 2020; Page No.587-595

calculated or higher attenuation kidney minus lower attenuation kidney (when no ureteral stone was detected in controls). Presence or absence of hydroureter , perinephric fat stranding , soft tissue rim surrounding the identified ureteral stone was noted.

Statistical Analysis was performed with help of Epi Info (TM) 7.2.2.2 EPI INFO is a trademark of the Centres for Disease Control and Prevention (CDC).

Descriptive statistical analysis was performed to calculate the means with corresponding standard deviations (s.d.). Test of proportion was used to find the Standard Normal Deviate (Z) to compare the difference proportions and Chi-square ( ) test was performed to find the associations. Odds ratio (OR) with 96% confidence intervals was calculated to find the risk factors. Area under curve (AUC) was calculated by plotting Receiver Operating Curve to find the cut off value of a parameter for cases. Diagnostic accuracy, sensitivity, specificity, positive predictive value and negative predictive value were calculated to compare the findings of different diagnostic tools. p value< 0.05 was considered to be statistically significant.

Ethical statement

This study was approved by our Institute's Research Ethics Committee (EC no: 69/2017), and informed consents were obtained from all patients prior to enrolment. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

RESULTS

DESCRIPTIVE STATISTICS OF RENAL PARENCHYMAL DENSITIES

	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
CONTROLS	36.40	2.93	33.47	39.33
OBSTRUCTED	28.81	2.18	26.63	30.99
UNOBSTRUCTED	35.64	1.22	34.42	36.86

Of the 150 patients with, urinary stone,ureteral stones were identified on CT in 136 patients and the rest 14 of them had obstructive calculus at vesico-ureteric junction. Majority had one or more of the secondary signs of ureteral obstruction.

In patients with a ureteral stone, the mean parenchymal density of the obstructed kidneys was 28.81 +/- 2.18 HU (range 24.4 to 32.2) and that of the nonobstructed kidneys was 35.64 +/- 1.22 HU (range 29.4 to 38.6). The

mean renal parenchymal density difference between the obstructed and nonobstructed kidney was 6.3 HU (range 2.1 to 9.8 HU). This difference was statistically significant (P < 0.0001). The parenchymal density of the obstructed kidney was always lower than that of the nonobstructed kidney.In 129 (86.26%) of 150 patients with ureteral stone disease, the difference between the parenchymal densities was 5.4HU or more, although the difference was less than 5.4 HU in 21 patients. The overall statistical analysis showed that if cut off value was considered to be 6 HU, it had sensitivity of 74%, specificity of 98%, PPV of 99.11% and NPV of 55.68%. Similarly at 4 HU the diagnostic capabilities were 84% sensitivity , 98% specificity, PPV of 99.2% and NPV of 70.2%.The mean parenchymal density of the Right and Left kidneys of the control group was 36.24±2.9 (range 28.6 - 40.5) and 36.58±3.11 (range 28 - 41.5), respectively, with the average 36.4 +/- 2.93 HU.

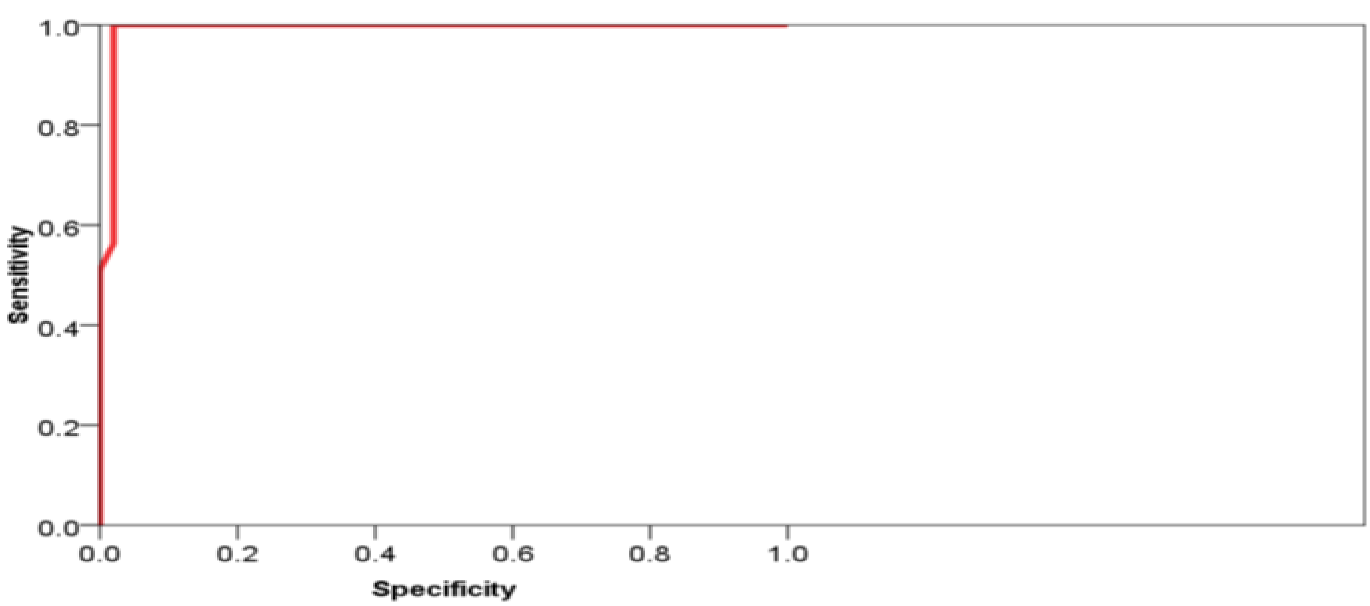
The renal parenchymal density difference was 0.846 (range 0.2 to 6.4) which was not statistically significant (P =0.511). The parenchymal density difference was always greater for the cases than the controls. The CT scans of 50 controls were reported to be negative for ureteral stone disease .Of these, alternative diagnoses unrelated to ureterolitiasis were found on CT in 48 patients: 2 patients had normal CT abdomen. Alternative diagnosis like- appendicitis in 24 patients, had acute interstitial pancreatitis in 9 patients, chronic cholecystitis and common bile duct stones in 8 patients, proved surgically and by Endoscopic retrograde pancreato-cholangiography in all patients, Ruptured hemorragic cyst in 5 patients, pelvic inflammatory disease and pelvic abscesses in 2 patients.

Measuring the difference in the average parenchymal attenuation between the obstructed and non obstructed kidney was the most sensitive sign (86.26 %) and with highest specificity , which was statistically significant at a cut off value of 5.4 HU . However, this sign was absent in 21 patients with ureterolithiasis . Unilateral hydroureter had low sensitivity (79.33%) compared to other secondary signs but a high specificity (90 %) . Unilateral hydroureter also had high PPV , & accuracy (95.97 % & 82 % respectively) .

Similarly, perinephric fat stranding had a high specificity (86%), but comparitively lower sensitivity (82%) .Perinephric stranding was absent in 26 patients with ureterolithiasis . On the other hand, perinephric stranding was unilateral or bilaterally asymmetrical in 7 of the 50 controls. Five of these 7 patients had acute pancreatitis with ill defined fat stranding extending into perinephric space and thickening of Gerota's fascia.

Of 150 patients with ureteral stones visible on CT , 40 were in the proximal ureter , 37 within the mid-ureter , 47 within the distal ureter & 26 within the pelviureteric junction . Of the 124 stones within the proximal, mid, & distal ureter, 112 were surrounded by a circumferential rim of soft tissue attenuation (tissue rim sign) . The presence or absence of this sign around the 25 stones at the ureterovesical junction couldn't be estimated . On the other hand, of the 200 patients included in this study, 153 extraurinary calcifications were present in 102 patients. None of these 153 extraurinary calcifications was surrounded by a rim of soft tissue attenuation.

Table-13: Area under curve (AUC) for difference in HU of higher kidney attenuation value from the lower kidney attenuation to find the cutoff for the attenuation difference in urolithiaisis.



From ROC the area under curve (AUC) showed that the cut-off value of difference in HU of left kidney and right kidney for urolithiaisis was 5.4HU with sensitivity 86.26% and specificity 98.26%.

SECONDARY SIGN	SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
Parenchymal attenuation difference(at 5.4HU from ROC curve)	86.26%	98.26%	99.17%	69.36%	86%
Hydroureter	79.33%	90%	95.97%	59.21%	82%
Perinephric fat stranding	82.67%	86%	94.66%	62.32%	83.50%
Soft tissue rim sign	73.33%	80%	91.60%	50%	75%

DISCUSSION

Secondary CT signs of ureteral obstruction are often present and useful in cases in which a stone is not readily identified .Undoubtedly, the most direct CT finding characteristic of ureteral lithiasis is stone identification in the lumen of the ureter. NCCT has high accuracy in this regard and adopted as a gold standard .For those who seek further stone confirmation must often rely on further workup such as stone recovery due to passage during micturition, follow-up CT, lithotripsy, and ureteroscopic stone removal.

In our study, cases were sorted on the basis of unequivocal identification of ureteral stone, for interpretation of attenuation measurement results. Of the 150 scans suitable for this investigation, most of them showed varied combination of unilateral secondary signs -pelvicalyceal system dilatation, perinephric stranding, soft tissue rim around the stone, and renal parenchymal attenuation difference in the presence of visible calculus.

Several secondary signs of obstructive urolithiasis have been proposed to resolve the issue of lack of visualization of a stone due to small size,radiolucent calculi, respiratory movement, and partial volume averaging. The role of these signs is to help diagnose patients with acute flank pain with inconclusive evidence of ureteral stone. These signs, however, are not universally present and may vary in degree of severity from patient to patient depending on duration and completeness of obstruction.

Georgiades et al. was the first study that emphasized the subjective evaluation of the attenuation difference, which is the visual identification of a low-attenuating kidney parenchyma (Pale kidney sign). Renal attenuation measurements (attenuation difference between the kidneys) as an adjunct sign of obstructive urolithiasis can provide additional diagnostic benefit compared to other secondary signs. The attenuation differences between kidneys are objective, numerical parameters, eliminating the subjectivity associated with other signs. The choice of attenuation difference values rather than absolute attenuation values is made to allow better reproducibility with different CT scanners and calibration settings of display.

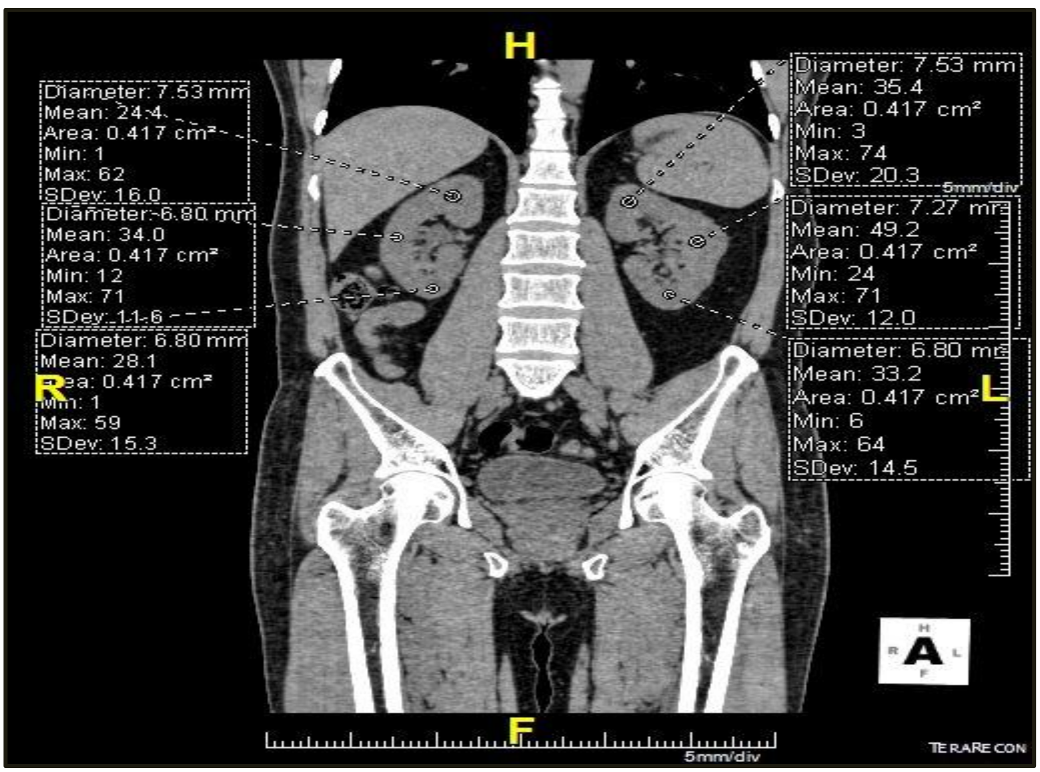
Regarding the attenuation measurements, of 26 patients with ureterolithiasis, only one did not show lower attenuation values in the obstructed kidney (5%). Using our data, we found it to be evident that attenuation difference values between kidneys are much more variable than originally suggested. Also, attenuation difference values between kidneys high enough to be useful for diagnostic classification (≥ 5.4 H) are highly prevalent. This finding may be a result of the fact that most of the ureteral stones in the current study produced significant ureteral obstruction at the time of presentation. Absence of this signs more than cut off point in 21 patients under this study is explained by the fact that there is no significant difference in attenuation value if there is partial and short term ureteral obstruction.

A common pathophysiological pathway, represented by edema, congestion and hyperemia, and increased lymphatic flow, may explain both low parenchymal attenuation and other signs such as perinephric stranding. This hypothesis has been confirmed by the increased association of difference values greater than or equal to 5.4 HU with other secondary signs, when compared to values less than 5.0 H, in patients with lithiasis.

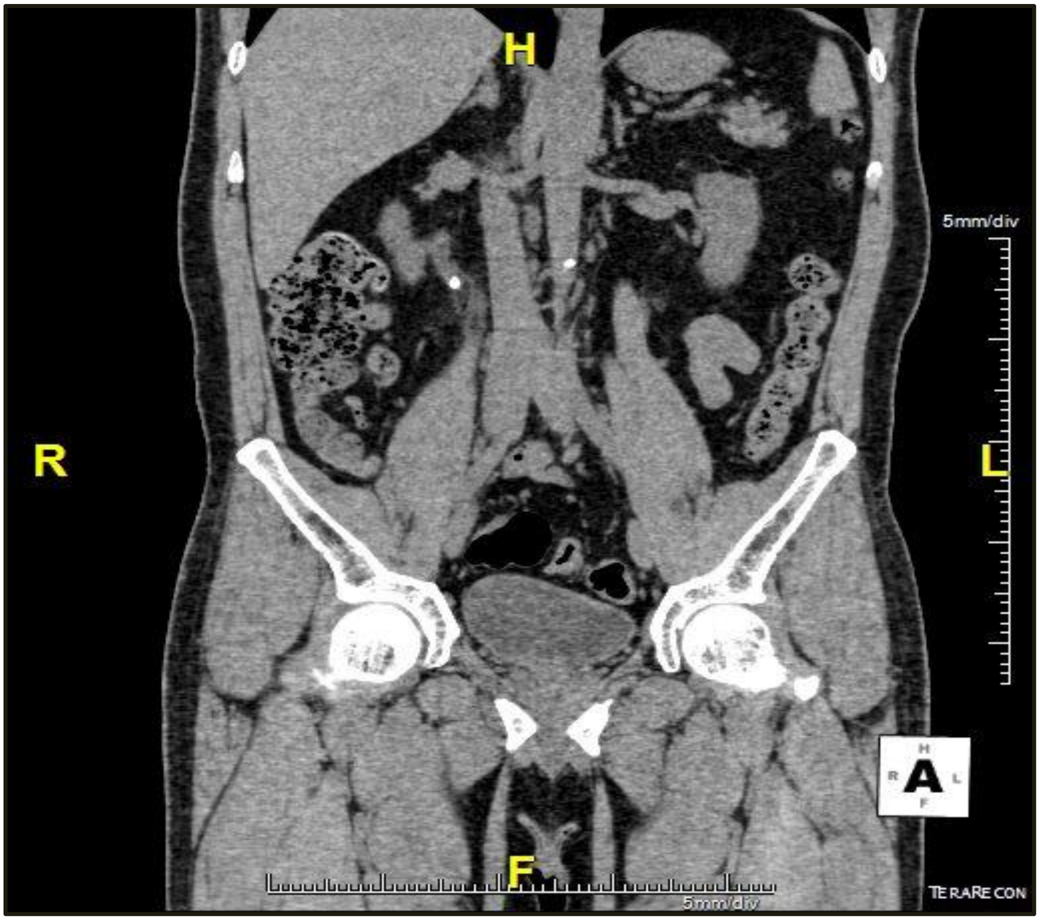
Patients with no CT evidence of ureteral lithiasis were considered the control group of this study. This choice is justified by the main purpose of the proposed sign, which is to exclude ureterolithiasis. To rule out hypothesis that an attenuation difference between kidneys above the arrived cut off could also be found in patients with other abdominal diseases. To address this question, the inclusion of patients with nonspecific symptoms or nonurinary abdominal diseases as an additional control group was considered. At the end the study , it is seen that there was no statistically significant difference in renal parenchymal densities in control group ,although few of them had other secondary signs due to other abdominal pathology, hence decreasing their specificity .

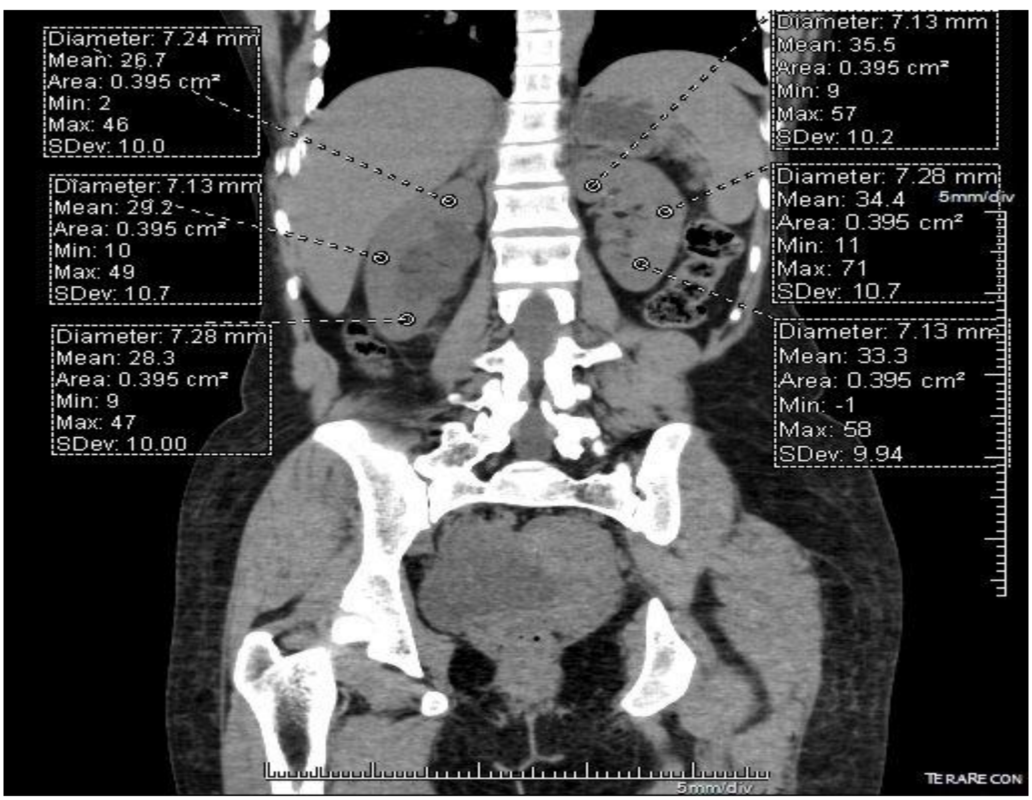
In conclusion, attenuation difference between kidneys 5.4 HU or greater had highest sensitivity (86.26%), specificity (98.26%), positive predictive value (99.17%), and accuracy (86%) in the diagnosis of ureterolithiasis. Its diagnostic performance was similar to that of other secondary signs of obstructive ureterolithiasis in identifying those without the stone. Measuring the attenuation difference had the additional advantage of being the only quantifiable indicator.

PICTORIAL ESSAY



Volume 3, Issue 4; July-August 2020; Page No.587-595





Volume 3, Issue 4; July-August 2020; Page No.587-595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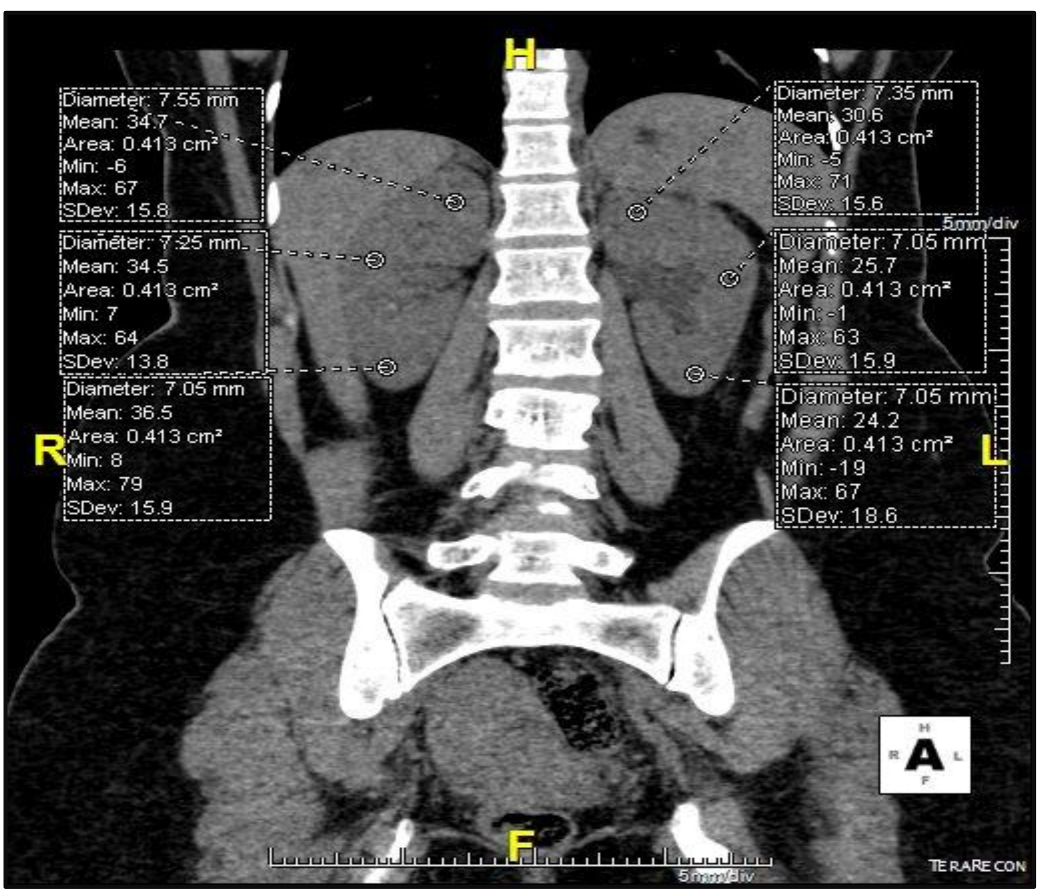
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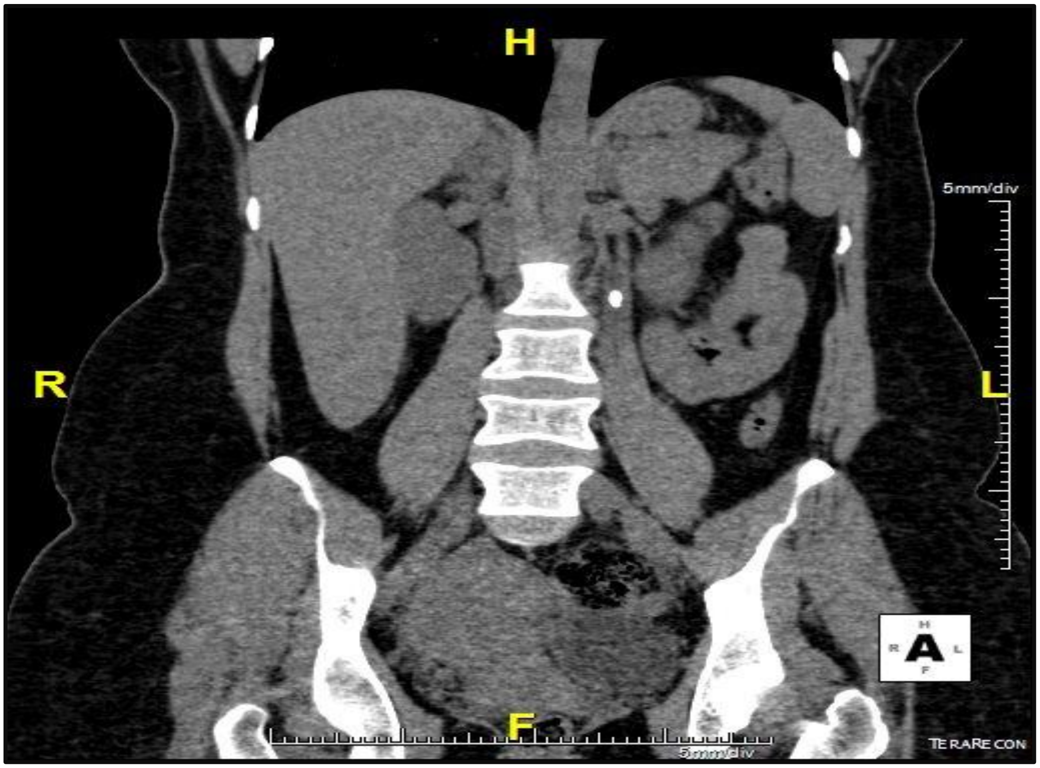

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