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Attenuation Measurements of Kidneys on Unenhanced CT in Ureterolithiasis

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ABSTRACT

Introduction
Urolithiasis is a common disease worldwide that affects a wide range of patients. This study evaluated the diagnostic utility of attenuation values of bilateral kidneys on unenhanced helical Computed Tomography (CT) in ureterolithiasis patients.

Methods
This cross-sectional study was performed in patients with ureteric calculus referred for unenhanced helical CT of the kidney, ureter, and bladder (CT-KUB). The attenuation of the renal parenchyma in Hounsfield units (HU) was measured, and a mean attenuation value was determined for obstructed and contralateral kidneys of each patient and compared.

Results
Among the 95 patients, 40 had ureteric stones on the left kidney and 55 on the right kidney. Lower average attenuation value in obstructed kidneys (on the side of the ureteric stone) was seen in 75 (78.9%) patients. 79% (N=69) of patients and 3.15% (N=3) of patients showed zero average attenuation difference. Mean attenuation values in the upper pole, middle portion, and lower pole were 28.60 HU, 30.23 HU, and 30.59 HU for obstructed kidneys and 32.74 HU, 33.41 HU, and 31.93 HU for contralateral kidneys. Mean of mean attenuation values in the three regions were 29.81 HU for obstructed kidneys and 32.69 HU for contralateral kidneys. A significant difference of 2.88 HU was found in mean attenuation values between the obstructed kidneys and the contralateral kidneys.

Conclusion
Attenuation values between the kidneys can serve as a means of differentiating between obstructed and non-obstructed kidneys in unenhanced CT KUB.

Keywords
Attenuation; renal parenchyma; secondary signs; ureterolithiasis

INTRODUCTION

Urolithiasis affects approximately 4–20% of the population globally.[1,2] Clinical presentations and urine analysis can provide leads for the diagnosis of ureteric stone, but the radiological examinations are definitive for the diagnosis.[3] The exact sensitivity and specificity of radiological examinations may vary in different studies, but the sensitivity and specificity of unenhanced helical Computed tomography (CT) Kidney, ureter, and bladder (KUB) were shown to be highest consistently.[4] According to Moş et al., among the various radiological examinations for diagnosing the ureteric stone, such as plain radiograph, ultrasonography (USG), and CT KUB, the sensitivity of CT is highest, i.e., 91.11%, followed by USG, which is 73.27% sensitive.[5-7]

In cases of small stone size, low stone attenuation, recent passage of stone, effect of respiratory movements during the scan, decreased retroperitoneal fat, and phleboliths along the course of the ureter, the identification of ureteric stone may not be easy. In such cases, secondary signs can be paramount for detecting a ureteric stone.[4,8] The attenuation difference between the affected and contralateral kidney can predict the presence of a ureteric stone with 89 % sensitivity and 100% specificity.[4,9]

Particularly, an attenuation difference of more than or equal to 5 Hounsfield units (HU) is a useful secondary sign; however, an attenuation difference value less than 5 HU can also be useful for the diagnosis of ureteric stone when combined with the presence of other secondary signs. [4,10] The purpose of this study is to evaluate the diagnostic utility of kidney attenuation values on unenhanced CT in patients with ureteric stone.

METHODS

This cross-sectional study was performed in patients referred for CT KUB and plain abdomen CT examinations for various clinical indications from August to November 2019. Data were collected after approval from the Institutional Review Board of the Institute of Medicine (IOM) with reference number 60/ (60-11) E². A total of 95 patients with unilateral ureteric stones were included by convenient sampling. Patients with unilateral ureterolithiasis whose renal parenchyma was difficult to differentiate, or chronic renal parenchymal disease were excluded from the study.

All the cases that met the inclusion criteria (all ages and genders with unilateral ureteric stone) and consented were included. None of the patients were subjected to additional radiation dose for the sole purpose of this study. All CT examinations (non-contrast) were performed in a 128-slice MDCT Siemens Somatom Definition AS+ CT scanner using a helical technique (collimation, 1 mm; pitch, 1.0) from the level of the T12 vertebral body to the pubic symphysis in one breath-hold. Scans were acquired using 175–350 mAs at 120 kVp.

Examination was evaluated for the side and location of ureterolithiasis and its secondary signs, along with bilateral parenchymal attenuation. Attenuation values were systematically measured with a circular region of interest (ROI) in the upper, middle, and lower pole of renal parenchyma with a soft-tissue window: center, 40 HU; width, 300 HU. In the upper pole, the ROI was placed in the first section that depicted the collecting system. 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 (≈ 50-pixel size) in the posterior region of the kidney parenchyma. To prevent measurement bias, the ROI was shifted whenever a rib was near the designated location. From the three measurements, a mean attenuation value (in Hounsfield units) was determined for each kidney. Attenuation values in the upper pole, middle, and lower pole were coded as O1, O2, and O3 for the obstructed kidney and C1, C2, and C3 for a contralateral kidney. The mean attenuation was calculated as the sum of attenuation values in three regions divided by three for each kidney and represented by X1 for obstructed kidneys and X2 for the contralateral kidney. The differences in attenuation values were calculated as C1-O1, C2-O2, C3-O3, and X2-X1.

The pertinent exam data was gathered using a pre-made proforma and input into a Microsoft Excel spreadsheet. To analyze the data, SPSS 26 was used. Frequencies of categorical data and mean with standard deviation of continuous data were calculated. A paired t-test was performed to test the significance of the observed difference in attenuation between obstructed and contralateral kidneys. The attenuation difference values were also compared for the location of the stone in ureter, for which an independent sample t-test was used as the test of significance. All the tests of significance were performed with a 95% confidence interval.

RESULTS

Out of the total 95 patients, 34 (35.8%) were females and 61 (64.2%) were males. The mean age was 34.63±13.36 years (range: 17 to 87 years). Forty patients had documented ureteral stones on the left side and 55 had them on the right side. Thirty-three patients had a stone in the distal ureter, and 62 had a stone in the proximal ureter.

The means of O1, O2, O3, X1, C1, C2, C3, and X2 are shown in Table 1. Largest difference in attenuation

Table 1. Means of attenuation in different parts of the kidney with ureteric stone and the contralateral kidney

Attenuation	Kidney							
	Obstructed kidney				Contralateral kidney			
	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
Attenuation in upper pole of Kidney (HU*)	28.60	6.85	13.00	48.00	32.74	5.38	23.00	49.00
Attenuation in middle portion of kidney (HU)	30.23	5.64	18.00	49.00	33.41	5.29	24.00	57.00
Attenuation in lower pole of kidney (HU)	30.59	5.96	17.00	47.00	31.93	5.84	15.00	52.00
Average attenuation# (HU)	29.81	4.33	22.33	47.00	32.69	3.98	25.33	51.33

is observed for the upper pole, with a mean C1-O1 equal to 4.137 HU. The smallest difference in attenuation was observed for the lower pole, with a mean C3-O3 equal to 1.337 HU. X2-X1 is 2.884 HU. The attenuation differences observed in the upper pole (C1-O1), middle portion (C2-O2), and average attenuation (X2-X1) were highly significant ($p<0.0001$) (Table 2).

The minimum and maximum renal parenchymal differences in different regions of renal parenchyma and the average renal parenchymal attenuation difference is shown in Table 3. No significant difference in the attenuation was seen concerning the location of the stone in the ureter (Table 4).

Lower average attenuation value in obstructed kidneys was seen in 75.79% (N=69) of patients, and 3.15% (N=3) of patients showed zero average attenuation difference (X2-X1). The value of X2-X1 was greater than or equal to 5 HU in 32.68 % (N=32) of patients. Attenuation value in the upper

Table 2. Significance of observed difference in attenuation between obstructed and contralateral kidneys

Attenuation		Paired Differences					t	p (2-tailed)
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	Attenuation in upper pole of contralateral Kidney - Attenuation in upper pole of obstructed Kidney (C1-O1) (HU)	4.13	9.04	0.92	5.97	2.29	4.46	<0.0001
Pair 2	Attenuation in middle of contralateral kidney - Attenuation in middle of obstructed kidney (C2-O2) (HU)	3.17	6.46	0.66	4.49	1.86	4.79	<0.0001
Pair 3	Attenuation in lower pole of contralateral kidney - Attenuation in lower pole of obstructed kidney (C3-O3) (HU)	1.33	6.39	0.65	2.63	0.03	2.03	0.04
Pair 4	Average attenuation in contralateral kidney - Average attenuation in obstructed kidney (X2-X1) (HU)	2.88	4.62	0.47	3.82	1.94	6.07	<0.0001

***Table 3**. Variation in renal parenchymal attenuation in terms of minimum and maximum*

Attenuation difference	Minimum (HU)	Maximum (HU)
Attenuation difference in upper pole (C1-O1)	-25.00	33.00
Attenuation difference in middle (C2-O2)	-13.00	19.00
Attenuation difference in lower pole (C3-O3)	-18.00	17.00
Average attenuation difference (X2-X1)	-9.00	12.33

pole of the obstructed kidney was lower in 69.47% (N=66), and 7.37% had zero C1-O1 value.

DISCUSSION

Changes in intraurethral pressure, renal blood flow, renal edema, and renal lymphatic drainage during a specified period represent the pathophysiological mechanism underlying the emergence of secondary signals, such as renal parenchymal attenuation difference, caused by ureteric stones in unenhanced CT.[11] Initially, the renal parenchymal difference weren't well established as secondary sign in predicting the presence of ureteric stone compared to stranding, hydronephrosis and renal enlargement.[8] The renal parenchymal difference was assigned as the objective parameter for the determination of renal edema, such that an attenuation difference greater than 5 HU ascertained the presence of renal edema.[10] Our study focused on the cases with ureteric stone; however, any form of obstruction, either due to ureteric masses or stricture, can result in such a decrease in attenuation values. Therefore, decreased attenuation of the renal parenchyma can be a secondary sign in equivocal cases of obstruction in which the cause and site of the obstruction cannot be ascertained.

Before Goldman et al. demonstrated a sensitivity of 69% and specificity of 79% with a cutoff of 5 HU, the diagnostic use of renal parenchymal attenuation difference for ureteric stones was not well established.[12] Recent evidence shows that among the various secondary signs, renal parenchymal density difference has the highest sensitivity (89%) and specificity (100%) for predicting the presence of ureteric stone.[4] Also, this is an objective measurement-based parameter, which eliminates the subjectivity associated with other signs.[12] The best sensitivity and specificity of renal parenchymal attenuation difference is obtained for a cutoff of 5 HU, which is in contrast to the finding of our study, as only 33.68% of patients in our study have X2-X1 value greater than or equal to 5 HU.[4,12] This difference may be justifiable in terms of the degree of ureteral obstruction, patient cohort characteristics, and duration of ureteric obstruction.

In the study of Goldman et al., only patients with acute unilateral renal colic were included.[12] But our study included all patients having unilateral ureteral stones irrespective of the duration of symptoms. Thus, we consider the inclusion of patients with chronic ureteric stone as the cause of a lower true positive rate for 5 HU as cutoff X2-X1. The acutely obstructed side's average parenchymal attenuation value (24.21 ± 3.68) was lower than that of the chronically obstructed side (30.85 ± 4.53) and the normal kidneys (29.62 ± 3.03 on the equivalent site), according to Erbaș et al. The finding of Erbas et al., i.e., lesser parenchymal attenuation difference in the case of a chronically obstructed kidney compared to an acutely obstructed kidney, is in favor of this study.[13]

A prospective study by Özer et al. suggested that taking a low cutoff value (e.g., 3 HU) would mitigate the false-negative results due to a cutoff of 5 H

***Table 4**. Significance of observed difference in the attenuation difference with respect to location of stone in ureter*

Attenuation difference	Location of stone in ureter	Mean	Std. Deviation	Std. Error Mean	t	p
Average attenuation difference (X2-X1) (HU)	Distal	2.71	5.26	0.91	0.60	0.32
	Proximal	2.97	4.29	0.54		
Attenuation difference in upper pole (C1-O1) (HU)	Distal	4.90	7.40	1.28	0.72	0.93
	Proximal	3.72	9.83	1.24		
Attenuation difference in middle (C2-O2) (HU)	Distal	2.51	6.32	1.10	0.67	0.99
	Proximal	3.53	6.56	0.83		
Attenuation difference in lower pole (C3-O3) (HU)	Distal	0.72	6.02	1.04	0.25	0.03
	Proximal	1.66	6.60	0.83		

or greater, thereby increasing the sensitivity and negative predictive values.[9] In this study, taking 3 HU as a cutoff, X2-X1 increases the true positive rate to 48.42% (N=46), and taking 2 HU as a cutoff, the true positive rate further increases to 66.31% (N=63). Based on this fact, the cut-off for mean renal parenchymal attenuation difference must be reconsidered, particularly for chronic ureteric stone and the stone of unknown duration, to increase the true positive rate. The attenuation values were more affected in the upper poles, probably because of the angle between the long axis of the ureter and the upper pole, which is more vertical than the interpolar and lower pole regions.

Nevertheless, a lesser renal parenchymal attenuation difference than 5 HU has also been shown to be useful in predicting the presence of stone when combined with other secondary signs.[4] Also, the mean difference of X2 and X1 being highly significant in this study adds importance to the lesser value of renal parenchymal attenuation difference in diagnosing the ureteric stone.

The mean of C1-O1 being maximum compared C2-O2 and C3-O3 (table 2) and the mean renal parenchymal difference being in the decreasing order while moving from upper pole to lower pole leads to derivation of a new hypothesis that the renal parenchymal difference in upper pole is more compared to middle portion and lower pole and it can be more important for diagnosing ureteric stone than mean renal parenchymal attenuation difference (X2-X1). The attenuation values were more affected in the upper poles, probably because of the angle between the long axis of the ureter and the upper pole, which is more vertical than the interpolar and lower pole regions.

There are a few drawbacks in our study. Our study lacks a control group, which may include people who are asymptomatic, have nonspecific symptoms, or have other abdominal diseases. Another limitation is that the relationship between the magnitude of attenuation difference and clinical outcomes would have been established if the study were prospective. Having a limited sample size, only general conclusions have been drawn in our article without establishing a decisive cutoff value and without assigning sensitivity and specificity values for decreased attenuation. Differentiating patients as acute and chronic cases would have brought us to even more significant conclusions. As suggested by Erbas et al., the hydration status of patients may also affect these values, with renal medullary high attenuation values being marked in dehydrated patients.[13]

CONCLUSION

The attenuation values of the renal parenchyma can be a secondary sign in cases of unequivocal cases of ureteric obstruction, and it can also be a valuable tool for radiolucent stones or isodense ureteric masses, or incomplete ureteric obstruction. We suggest a lower cut-off of 3 or 2 for this purpose. However, it can depend on the site of obstruction, duration, and severity of the obstruction.

However, further case-control studies are required to establish a true cut-off for the renal parenchymal attenuation difference to diagnose ureteric stone. Also, renal parenchymal attenuation difference in the upper pole kidney can be more important than the difference in mean attenuation of the three renal regions.

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CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

AUTHOR CONTRIBUTIONS

- Avinash Gupta: Conceptualization, Data curation, Methodology, Writing- original draft, Writing- review and editing.
- Pradeep Raj Regmi: Conceptualization, Data curation, Methodology, Supervision, Validation, Writing- review and editing.
- Aayush Adhikari: Data curation, Methodology, Writing- original draft, Writing- review and editing.
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- Suraj Shrestha: Data curation, Methodology, Writing- original draft, Writing- review and editing.
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- Ramesh Khadayat: Supervision, Validation, Writing- review and editing.

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