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Can Computerized Hounsfield Unit Estimation Be Used as Predictor for Ureteric Stone Localization by Fluoroscopy during Extra Corporal Shock Wave Lithotripsy and Ureteroscopy?

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Abstract

Current minimally invasive interventions for ureteric stones involve either ESWL or Ureteroscopy and stone localization is mandatory for successful treatment in both. **Objectives:** To avoid doing KUB radiograph before ESWL routinely by correlating the stone attenuation value on CT KUB with stone visualization at fluoroscopy. **Methods:** This is a prospective cross sectional hospital based, Multicentric study carried out on 1010 patients with ureteric stones in Sudan from August 2014 to March 2016. **Results:** Mean stone density in HU was 704.45 ± 300 (SD) ranging (81 - 1873) HU. All of the stones were localized using fluoroscopy and only 26.5% of them were not seen under fluoroscopy. I.V contrast was used mostly, and also mainly in the upper ureter. More than 80% of the application of contrast through the ureteric catheter was in the lower ureteric stones. 91.2% of patients with stone density ≤ 400 HU failed to appear at fluoroscopy and therefore 400 HU attenuation value can be used as a cut-off level to request doing KUB before ESWL and Ureteroscopy. **Conclusion:** the ureteric stones with density ≤400 HU the likelihood of being non-visualized at fluoroscopy is 91.2% therefore if the stone has ≤400 HU at CT KUB it is mandatory to do KUB before treatment above that it is most likely to be seen at fluoroscopy and no need to request KUB for them before ESWL or URS. 1) **Inclusion Criteria:** All patients diagnosed by CT scan to have ureteric stones for ESWL or Ureteroscopy. 2) **Exclusion Criteria:** Patients for whom treatment of ureteric stone by ESWL or ureteroscopy is not indicated like severe infection or poor kidney function where nephrectomy is needed.

Keywords

Ureteric Stones, Hounsfield Unit, Attenuation, KUB, CT KUB, Cut off Level, Visualization of Ureteric Stones, ESWL, Ureteroscopy

1. Introduction

Urinary calculus is the third most common urological problem after urinary tract infection and prostate disease with a lifetime prevalence of urolithiasis at 10% - 15% [1]. Ureteral stones may cause ureterohydronephrosis and acute pyelonephritis with pain and patients may need immediate and rapid medical intervention, the size, localization, and composition of the stone, the severity of the obstruction, symptoms and the anatomy of the urinary system are all involved in determining the proper treatment approach [2]. NCCT and IVU both reliably determine stone position [3] [4] [5]. This is important for ureteric calculi where location, along with stone size and obstruction are the main factors in deciding treatment [6].

Computed tomography (CT) has long replaced the plain abdominal radiograph as the gold standard in the diagnosis of urolithiasis [7]. It is now firmly recognized as the best imaging method for establishing the diagnosis of acute ureteric colic and is replacing intra-venous urography (IVU) at an increasing number of centers [8]. In computerized tomography (CT), the Hounsfield unit (HU) is used to assess tissue and body fluid density. In urinary system calculus, HU is useful in assessing the compactness of individual stones [9]. Previous studies conducted on this subject have demonstrated a reverse correlation between the HU and extracorporeal shock wave lithotripsy (ESWL) for stone breakability [10] [11]. In addition, it has been shown that the Hounsfield density (HD) value, obtained by dividing the HU value of the stone by its dimensions can determine the composition of the stones [12]. Advances in ureteroscope design and ongoing development in ESWL have resulted in a change in the balance in the use of these treatment modalities in the management of ureteric stones, ESWL is now the most widely used method of managing proximal ureteral calculi [13] [14]. Fluoroscopy is the only possible method used for ureteric stone localization during ESWL and Ureteroscopy, there are ureteric stones which are not seen under fluoroscopy during ESWL and Ureteroscopy and this is suggesting that, there's some ureteral stone with a HU estimation that can be correlated with a radio-opaque stone and can be sent to the shockwave lithotripsy or ureteroscopy right away, whereas others ureteral stones with a HU estimation that can correlate with a radiolucent stone which needs the injection of contrast medium for localization by fluoroscopy during ESWL and Ureteroscopy.

In this study, we try to use the CT sonogram attenuation value of a stone to predict its appearance under fluoroscopy during ESWL and Ureteroscopy without the need for a preoperative KUB. And by that patient can avoid having to undergo a plain abdominal radiograph as routinely and can be well prepared for the possible use of contrast.

2. Objectives

To avoid doing KUB radiograph routinely by correlating the stone attenuation value on CT KUB with stone visualization at fluoroscopy.

3. Methodology

A prospective descriptive cross-sectional, hospital-based multicenter study of all patients with ureteric stones who undergoing ESWL or ureteroscopy from august 2014 to march 2016.

Patients' selection:

Inclusion criteria: All patients diagnosed by CT scan to have ureteric stones for ESWL or Ureteroscopy. Exclusion criteria: Patients with severe infection or poor kidney function when URS or ESWL are not indicated.

Sampling: statistician consultation for the quantity needed for proper representation of Sudanese patients with ureteric stones.

Methods of data collection: Standard structured forms were filled in an interview with the patients by the researcher.

Data management and analysis plan: The data has been fed to Statistical Package for Social Sciences (SPSS) version 17, Illinois-Chicago©.

Ethical consideration: Ethical approval was obtained from the council of Urology, the ethical committee of SMSB, and the Hospital directorate. Verbal consent was obtained from the patients.

4. Results

1010 patients were included in our study; the mean age was 37.6 years ranging from 1 - 90. Two third of the patients were males, and more than half of them came from the countryside. More than half of the stones were in the upper ureter, 26.1% were in the lower ureter, and only 20.7% were in the mid ureter. Pie chart in Figure 1 shows the distribution of the stone site. Mean stone density in HU was 704.45 ± 300 (SD) with a minimum density of 81 HU and a maximum of 1873 HU.

93.3% of the patients had an X-ray-KUB film, of which most of the stones were visible 75%. All of the stones were localized using fluoroscopy and only 26.5% of them were not seen under fluoroscopy. Most of the stones (84.1%) were treated by ESWL. In correlation of the operator and the treatment plan using the Pearson Chi-square test, it was found that the bulk of cases was done by the registrars, 50.9% ESWL and 63.8% URS, and the rest were done by (residents) medical officers (MO) and consultants.

In correlation with the fate of the stone and the operator using the Pearson

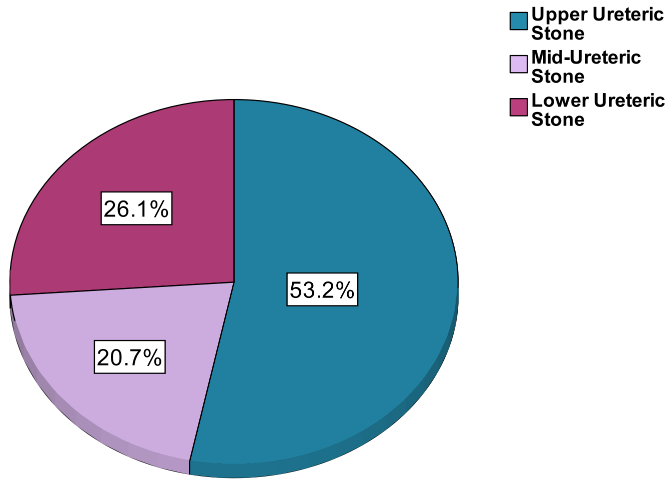

Figure 1. Pie chart shows the distribution of the stone site in percentages.

Chi-square test, it was found that the majority of nonvisible stones were operated by the registrars and most IV contrasts were used by them in 65.9% of cases. Failure of localization was in 20 cases 70% of them were among the registrar as an operator. *P* value was 0.001. The majority (65.7%) of nonvisible stones were localized using IV contrast injection. 13.8% localized by contrast injection through a ureteric catheter and 13.1% only by passages of a ureteric catheter. Failure of localization was in 7.5% of the cases and their procedure was postponed. See **Table 1**.

In correlation with the fate of the stone and the treatment plan (ESWL vs. URS), it was found that 12 (1%) of the patients had both of the procedures. On the other hand, (95%) of the failure rate was ESWL (19 patients). See **Table 2**.

Correlation using the Pearson Chi-square test between the site of the stone and the appearance under fluoroscopy signified that the majority of nonvisible stones were in the lower ureter 116 (43.3%), 32.1% were in the upper ureter, and 24.6% in the mid ureter. See **Table 3**. *P* value was 0.001.

The fate of the nonvisible stone has been further correlated with the site of the stone using the Pearson Chi-square test as clear in **Table 4**. I.V contrast was used mostly, and also mainly in the upper ureter. More than 80% of the application of contrast through the ureteric catheter was in the lower ureteric stones, and also the ureteric catheter. *P* value 0.001. 45% of failure of localization occurred in the lower ureter (9 cases). Density has been grouped in 400 HU apart, except the last group ranged from 800 to 1837. In correlation of the grouped densities with appearance under fluoroscopy using Pearson Chi-square test, densities up to 400 HU total numbers of patients were 181; stones that were not seen under fluoroscopy were 165 (91.2%).

On the other hand, the number of patients with a stone density of more than ranging from 400 - 800 HU was 448, and 99 (22.1%) were not seen and those with a stone density of more than 800 HU were 381, and only 1% of them not

Table 1. Shows the correlation fate of non-visible stones.

	IV contrast injection	Contrast injection through the ureteric catheter	Passage of Ureteric Catheter only	Postponed	Total
Non-Visible stones under Fluoroscopy	176	37	35	20	268
Percentage	65.7%	13.8%	13.1%	7.5%	100.0%

Table 2. Shows the correlation between the treatment plan and the fate of the nonvisible stone.

Non-Visible Stone	ESWL	URS	Total
IV contrast injection	176 100.0%	0 0.0%	176 100.0%
Contrast injection through the ureteric catheter	1 2.7%	36 97.3%	37 100.0%
Passage of Ureteric Catheter only	11 31.4%	24 68.6%	35 100.0%
Failure of localization	19 95.0%	1 5.0%	20 100.0%
Total	849 84.1%	160 15.8%	1010 100.0%

Table 3. Shows the appearance of the stone under fluoroscopy in correlation to the site of the stone.

Visibility Under Fluoroscopy	Upper Ureteric Stone	Mid-Ureteric Stone	Lower Ureteric Stone	Total
Visible	451 60.8%	143 19.3%	148 19.9%	742 100.0%
Non-Visible	86 32.1%	66 24.6%	116 43.3%	268 100.0%
Total	537 53.2%	209 20.7%	264 26.1%	1010 100.0%

seen under fluoroscopy. *P* value was 0.001

Correlation between the grouped densities and the treatment plan was done to assess the integrity of the decision made. >80% of the patients with densities less than 400 HU underwent ESWL when only 8.8% of them were seen under fluo

Table 4. Shows the fate of the nonvisible stone in correlation with the site of the stone.

Nonvisible stones	Upper Ureteric Stone	Mid-Ureteric Stone	Lower Ureteric Stone	
IV contrast injection	67 (38.1%)	52 (29.5%)	57 (32.4%)	176 (100%)
Contrast injection through the ureteric catheter	5 (13.5%)	2 (5.4%)	30 (81.1%)	37 (100%)
Passage of Ureteric Catheter only	8 (22.9%)	7 (20%)	20 (57.1%)	35 (100%)
Failed	6 (30%)	5 (25%)	9 (45%)	20 (100%)
Total	86 (53.2%)	66 (20.7%)	116 (26.1%)	268 (100%)

Table 5. Shows the relation between grouped densities and the fate of the stone.

		Categorized densities (HU)			
		<400	401 - 800	>800	Total
Visible Stone		16	349	377	742
		8.8%	77.9%	99.0%	73.5%
Fate of Non-Visible Stone	IV contrast injection	110	64	2	176
		60.8%	14.3%	0.5%	17.4%
	Contrast injection through the ureteric catheter	19	17	1	37
		10.5%	3.8%	0.3%	3.7%
	Passage of Ureteric Catheter only	20	14	1	35
		11.0%	3.1%	0.3%	3.5%
	Postponed	16	4	0	20
		8.8%	0.9%	0.0%	2.0%
Total		181	448	381	1010
		100.0%	100.0%	100.0%	100.0%

roscopy.

Using contrast increased the visibility up to 71%, and 8.8% of the patients with stone density up to 400 HU localization failed and the procedure was postponed, see Table 5. Pearson Chi-square test was used for both correlations and the P value was 0.001.

5. Discussion

More than 90% of urolithiasis cases are treated with SWL which is known to be the primary treatment modality for stones in the kidney and ureter [15].

The success of SWL depends on accurate stone localization proper fragmentation and complete clearance of fragments. Fluoroscopy is the only possible method used for ureteric stone localization during ESWL and Ureteroscopy, there are ureteric stones that are not seen under fluoroscopy during ESWL and Ureteroscopy although seen on CT KUB and we might need to postpone the procedure because of failure of localization. and this is suggesting that there is some ureteral stone with a HU estimation that can be correlated with a radio-opaque stone and can be sent for shockwave lithotripsy or ureteroscopy right away, whereas other ureteral stones with a HU estimation can be correlated with a radiolucent stone which needs the injection of contrast medium for localization by fluoroscopy during ESWL and Ureteroscopy or other methods of localization such as the passage of ureteric catheter up the ureter.

The demographic data from our study were comparable to the global picture of ureteric stone disease prevalence and incidence, with the peak incidence at the age range of 40 - 49 [16]. The 2:1 male-to-female ratio described in our study was similar to the previous study. The difference may be attributed to the protective effect of estrogen on stone formation in premenopausal women mainly before 45 years of age, due to enhanced renal calcium absorption and reduced bone resorption as the metabolic advantage [17]. Most of our patients came from the countryside.

The majority of nonvisible stones were in the lower ureter this is to illustrate that position of the stone had a great impact on the appearance of the stones under fluoroscopy which mimics other studies due to more osseous structures and other overlying soft-tissue densities that obscure the lower ureteric stones [17].

In this study all the stones were diagnosed by CT which is the best modality for diagnosing ureteric calculi would provide accurate information regarding stone presence and size, location, and adjacent anatomy so Patients suspected of having acute ureteral colic are best managed with a non-contrast helical CT scan [18]. Mean stone density in HU was 704.45 ± 300 (STD) with a minimum density of 81 HU and a maximum of 1873 HU. In computerized tomography (CT), the Hounsfield unit (HU) is used to assess tissue of body fluid density. According to these density measurements, the density of water is 0, the density of air is (−) 1000, the density of compact bone is (+) 1000, and the density of solid organs and soft tissues varies between 10 and 90 [9].

A set HU cut-off value with optimal sensitivity and specificity in predicting calculus' radiolucency or radio-opacity can change the clinical management of the urologists, and by that patients can avoid having to undergo a plain abdominal radiograph and can be well prepared for the possible use of contrast. This offers the advantage of avoiding additional radiation exposure, as well as time and cost, and minimizes the anxiety and discomfort of the patient regarding an additional diagnostic test. In our study the stone density has been grouped in 400 HU apart, except the last ranged from 800 to 1837. Roughly densities < 400 HU were 181; stones not seen under fluoroscopy were 165 (91.2%). On the other hand, the number of patients with stone density > 400 HU was 829 and those who were not seen under fluoroscopy were only 103 (12.4%). Stones with HU > 800 were visible in 99%. These findings were quite similar to the study done by

Huang et al. who described the CT attenuation-level HU and its predictive value on whether calculus is radio-opaque or radiolucent. In their study, multivariate analyses of the 84 CT scans that detected ureteral stones revealed that the significant predictor of visibility on KUB was the stone HU, All ureteric calculi with a density of > 800 HU were visible on KUB, while 17 (74%) of 23 calculi with the density < 200 HU were not visible on KUB so Ureteral calculi characteristics on UHCT are useful for predicting their visibility on KUB [19]. We found in our study that HU of < 400 is a cut level for doing preoperative KUB.

An earlier study found a threshold value of 498.5 HU in a CT sonogram was established as the optimal cut-off in determining whether calculus is radio-opaque or radiolucent and a HU below 498.5 identified the likeliness of the calculi to be radiolucent, and a HU above 498.5 [20]. Also, Michael et al. used the CT scout film and concluded that 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 an attenuation value equal to or higher than the set cut-off point is considered radiopaque and those with HU below the set cut-off point maybe considered radiolucent [17].

In this study, we have 17% of patients with stone density up to 400 HU. 8.8% appeared in x-ray KUB and under fluoroscopy; Correlation of the CT stonogram attenuation level with the stone composition has been studied extensively in recent literature. Patel *et al.* described that CT stonogram HU range of 879 ± 230 was mainly composed of calcium oxalate monohydrate, while HU range of 338 ± 145 was usually composed of uric acid stones [21]. Demirel et al. described a similar range of Hounsfield units for calcium oxalate stones (812 ± 135) and uric acid stones (413 ± 143) [22]. Stone size was omitted from our analysis which may have predictive value in stone appearance under fluoroscopy.

6. Conclusion

This study confirmed that in stones with density up to 400 HU, the likelihood that it will not appear on fluoroscopy is 91.2% which can be used as a cutoff level for doing KUB radiograph on patients presenting with ureteric stones and planned for treatment by ESWL or URS, and the patient presenting with a stone of a density more than 400 HU is deemed to be radio-opaque and there is no need to request KUB for them before ESWL or URS.

Recommendations

Operating ESWL machines with CT guided will be very valuable for localization, as shown by the visibility of all stones on CT KUB but not on fluoroscopy until then the CT value of 400 HU can be used for the prediction of visibility of stones at ESWL.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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