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Efficacy of unenhanced computed tomography features in distinguishing distal ureteric stones from phleboliths

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Abstract

The aim of this study is to evaluate the contribution of unenhanced computed tomography features in the differentiation of distal ureteric stones (DUS) from phleboliths. This retrospective study included 284 DUS and 116 phleboliths in 298 patients whose diagnosis were confirmed by ureteroscopy. The unenhanced computed tomography features of DUS and phlebolith were recorded, including volume, soft tissue rim, comet-tail sign, central lucency, shape, surface, density of pelvic calcifications and bladder volume. The differences between DUS and phlebolith in terms of mean volume and mean density were statistically significant ($p<0.05$). A peripheral rim was detected in 216 (80.3%) out of 269 DUS and in 8 (7.4%) of 108 phleboliths. The comet tail sign and central lucency had a 100% positive predictive value for the diagnosis of phleboliths. For the diagnosis of distal ureteral stones, the geometric shape and irregular surface had a 100% positive predictive value, while the smooth surface had a 100% negative predictive value. The contribution of increased bladder volume in the differentiation of phlebolites from distal ureter stones was significant ($p<0.01$). In the differentiation of distal ureteral stones from phlebolites, the comet tail sign, central lucency, geometric shape, irregular surface, and smooth surface can be used as predictive factors alone. In addition, volume, density, soft tissue rim, shape, and bladder volume are factors that can be used in the differentiation. Using all these features will be useful in daily practice.

Keywords: Distal ureteric stone, computed tomography, phlebolith

Introduction

Distal ureteric stones (DUS) are a common cause of acute pelvic/flank pain in daily practice of urology, emergency medicine, internal medicine, and radiology. An objective diagnosis of DUS is highly important both for the patient and the physician. However, there are some factors complicating the diagnosis of DUS and confusing the physicians, namely non-DUS calcifications located in the pelvic region and phleboliths located close to the distal ureter trace. Phleboliths are small blood clots in a vein that harden over time due to calcification caused by thrombosis. These occurrences are more common in women than in men, and their incidence increases with age [1-3]. In this study, we aimed to evaluate the efficacy of unenhanced computed tomography (UCT) in the diagnosis of DUS and the DUS/phleboliths differentiation.

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Materials and Methods

Patient Selection

This study was approved by Adiyaman University Non-Interventional Clinical Research Ethics Board (approval code: 2020/9-33). We retrospectively evaluated the UCT images of the patients who underwent ureteroscopy (URS) between 2018 and 2020 and were diagnosed with DUS. The UCT images of 600 consecutive patients were retrospectively evaluated by two radiologists with five-year experience (M.Ç. and C.O.). All images were reviewed by the two radiologists independently, and final decisions were reached by consensus. A total of 284 DUS and 116 phlebolith in 298 consecutive patients were included in the study based on the following inclusion and exclusion criteria:

Inclusion criteria

** A diagnosis of DUS achieved by URS
** Having preoperative UCT
** Calcifications located close to the distal ureter trace

Exclusion criteria

** Pelvic opacities greater than 15 mm
** Absence of UCT images prior to URS
** Unconfirmed diagnosis of DUS on URS
** Calcifications located too far from the distal ureter trace

All the UCT examinations had been performed within a maximum of one week before URS. The elimination of DUS was confirmed by evaluating images obtained within a maximum of one month after URS. The presence of calcifications around the ipsilateral ureter was evaluated in the same patients. In total, 116 calcifications were accepted as phlebolith (Figure 1).

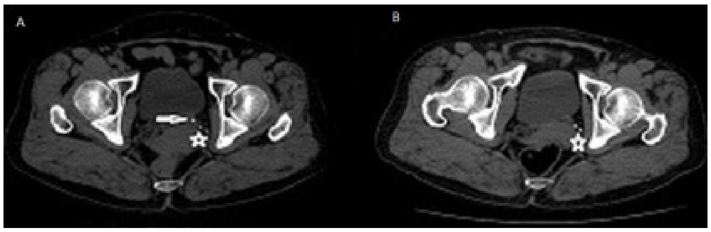

Figure 1. TA) The axial section of the preoperative UCT scan showing a ureteral stone (arrow) and phleboliths (star). B) The axial section of the postoperative UCT scan showing the disappearance of the belonged to the ureteral stone and the persistence of the opacity belonging to the phlebolith

Computed Tomography Procedure and Image Interpretation

On pre-and post-operative UCT imaging, 3-mm-thick images were obtained using a Toshiba Acquilion 64-slice CT device with the patient in the supine position. Scanning and reconstruction parameters included 16 x 0.75 mm beam collimation, 90-120 kV tube voltage, 50-110 mAs effective tube current-time product. The scanning boundaries were extended from the lung base to the upper thigh. The field of view was 400 - 500 mm. Sagittal and coronal reformatted images were created, and a 3D evaluation of pelvic calcifications was performed. The transverse (T), longitudinal (L), and anteroposterior (AP) dimensions of pelvic densities were determined and the analysis of the images were performed using the institutional database system (Oracle database V1.10.43.134). Once the dimensions were obtained, the volumes were calculated using the ellipsoid formula TxLxAPхл / 6 defined by Sorokin et al. [4]. The minimum, mean, maximum, and standard deviation (SD) calculations of the Hounsfield units (HU) of DUS and phleboliths were performed using the same database system. The calcifications' size was evaluated in the bone window setting (window level 350 HU/window width 1300 HU).

Features of Distal Ureteric Stones and Phleboliths

All DUS and phleboliths were also evaluated in terms of peripheral rim, comet tail, and central lucency. A peripheral rim was defined as a soft-tissue appearance around the calcification on UCT and was evaluated according to linear soft tissue adjacent and extending with calcification as the comet-tail sign (Figure 2, 3). The comet-tail sign was evaluated in the soft tissue window setting (45/450 HU). The central lucency was defined as the presence of lower density in the calcification and was evaluated as a non-dense area in the bone window setting (window level 350 HU/window width 1300 HU) (Figure 4).

Figure 2. The axial section of the UCT scan showing a geometric shaped stone with a soft tissue rim sign in the left distal ureter (circle)

Figure 3. The coronal section of the UCT scan showing a comet-tail sign near the phleboliths

The shape of each calcification (round, oval, geometric) was evaluated in the bone window setting (window level 350 HU/ window width 1300 HU) to decide whether they could be used in the DUS/phlebolith differentiation. The calcifications was described as round when the anteroposterior and transverse dimensions were equal. Those described as ovalhad long and short axis, and the shape was described as geometric in the cases with non-oval and non-round calcifications (Figure 5).

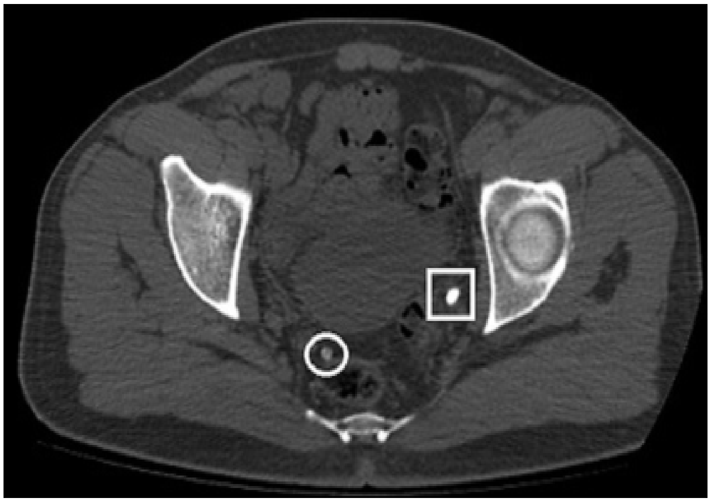

Figure 4. The axial section of the UCT scan showingthe central lucency in the phlebolith (circle) and also high density of the stone (square)

Figure 5. The coronal section of the UCT scan showing a geometric shaped stone in the left distal ureter (arrow)

The increased bladder volume is known to have a diagnostic value in the diagnosis of DUS [5]. In the present study, the bladder volume was determined using sagittal UCT images to evaluate its contribution to the DUS/phlebolith differentiation.

Statistical Analysis

Statistical analyses were performed to compare the DUS and phlebolith groups. Thedescriptive statistics for the categorical variables were given as numbers (n) and percentages. The continuous variables were summarized as mean, standard deviation and minimum-maximum. The normal distribution of the results was checked by the Kolmogorov-Smirnov test. According to normality test, the results were analyzed using the independent samples t-test or Mann Whitney's U test. The categorical variables were compared using the Pearson's chi-squared test. All statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) software, version 23.0 (IBM, New York, NY, USA) and significance level was considered $p<0.05$.

Results

Volume and Density

The mean volume of DUS was 76.25 mm3 (range, 15-405 mm^3), and the mean volume of phleboliths was 18.64 (range, 3-141) mm^3. The Mann-Whitney U test indicated a significant difference between these two volumes ($p<0.05$).

The mean density of DUS was 966 (range, 532-1,460) HU, and the mean density of phleboliths was 372 (range, 144-696) HU. Similarly, a significant difference was found between these two volumes ($p<0.05$). Only 14 (12%) out of 108 phleboliths had a higher density than 532 HU, while all the DUS had a density of higher than 532 HU (Table 1).

Soft Tissue Rim Sign

A peripheral rim was detected in 216 (80.3%) out of 269 DUS and in 8 (7.4%) of 108 phleboliths. The sensitivity and positive predictive value (PPV) of UCT in the diagnosis of the peripheral rim were 80% and 96% in DUS and 7.4% and 3.57% in phleboliths, respectively. This difference was statistically significant ($p<0.05$) (Table 2).

Comet-Tail Sign

The comet-tail sign was observed in 24 (22%) out of 108 phleboliths, whereas no comet-tail sign was observed in any DUS. The difference was found to be statistically significant $p<0.05$). The comet-tail sign had a sensitivity of 22% and a specificity of 100% in the differentiation of phleboliths from DUS (Table 2).

Central Lucency

The central lucency was detected in 18 (16.7%) patients with phlebolith, while no central lucency was detected in the patients with DUS. The central lucency had a PPV of 100% and a sensitivity of 16.7% for the differentiation of phleboliths from DUS (Table 2).

Shape and Surface

Of all phleboliths, 46% had a round shape, 54% had an oval shape, whereas no phlebolith was observed to have a geometric shape. In contrast, 18% of DUS had a round shape, 24% had an oval shape, and 58% had a geometric shape. The geometric shape had a PPV of 100% for the diagnosis of DUS. On the other hand, all the phleboliths had a smooth surface, while 64% of DUS had a smooth surface, and 36% had an irregular surface. In a similar way to the geometric shape, the irregular surface also had a PPV of 100% for the diagnosis of DUS (Table 2).

Bladder Volume

The DUS/phlebolith differentiation was achieved in 70 (94.6%) out of 74 patients with a high-volume convex bladder, in 133 (82.6%) out of 161 patients with a moderate-volume flat-middle bladder, and in 100 (72.5%) out of 138 patients with a low-volume concave bladder. The DUS/phlebolith differentiation became more difficult as the bladder volume decreased. Moreover, the effect of high bladder volume in the differentiation of DUS from phlebolith was significant ($p < 0.001$). On the other hand, very low bladder volume (concave bladder) was found to have a significant effect in not differentiating DUS and phlebolith ($p < 0.001$). In addition, moderate bladder volume did not contribute significantly to differentiating stones from phleboliths($p = 0.274$) (Table 3).

Table 1. Mean volume and mean density values of distal ureter stones and pelvic phleboliths

	DUS (n=269)	Phleboliths (n=108)	P*
Mean volume (mm3)	76.25 mm³ (15-405 mm³)	18.64 mm³ (3-141 mm³)	< 0.05
Mean density (HU)	966 HU (532-1460 HU)	372 HU (144-696 HU)	< 0.05

* Mann-Whitney U test, DUS: Distal ureteric stones, HU (Hounsfield unit)

Table 2. Contribution of features used in differentiation distal ureter stone from phleboliths

Features	**DUS(n=269)**	**Phleboliths (n=108)**	**Sensitivity***	**Specificity***	**PPV***	**NPV***
Soft tissue rim	216 (80%)	8 (7%)	80%	92%	96%	65%
Comet-tail sign	0 (0%)	24 (22%)	22%	100%	100%	76%
Central lucency	0 (0%)	18 (16%)	16%	100%	100%	74%
Round shape	48 (18%)	50 (46%)	46%	82%	51%	79%
Oval shape	65 (24%)	58 (54%)	53%	75%	47%	80%
Geometric shape	156 (58%)	0 (0%)	57%	100%	100%	48%
Smooth surface	172 (64%)	108 (100%)	100%	36%	38%	100%
Irregular surface	97 (36%)	0(0%)	36%	100%	100%	38%

Table 3. Contribution of bladder volume used in differentiation distal ureter stone from phleboliths

Bladder volume	Successful differentiation	Unsuccessful differentiation	P
Convex bladder	70 (94.6%)	4 (5.4%)	< 0.001
Middle bladder	133 (82.6%)	28 (17.4%)	0.274 (NS)
Concave bladder	100 (72.5%)	38 (27.5%)	< 0.001

NS: Non- significance

Discussion

The differentiation of the calcifications in the pelvic area with UCT provides an important advantage for the diagnosis and treatment of patients. Moreover, employing additional diagnostic techniques such as intravenous pyelography requires higher doses of contrast media and leads to increased radiation exposure for the patient. Additionally, unnecessary interventional procedures performed for therapeutic purposes bring additional burden to both the patient and the healthcare system. UCT can be effectively used to diagnose DUS and their differentiation from phleboliths, as demonstrated in the present study.

Volume and Density

In studies investigating the density of DUS and phleboliths, the mean HU value of DUS has been reported to be higher than that of phleboliths due to the presence of central lucency, a low density of the central part of phleboliths and the decreased HU value of the whole density [6,7]. In studies comparing the volumes of DUS and phleboliths, however, the mean volumes of DUS have been reported to be higher than those of phleboliths, which could be attributed to the difference in the formation mechanisms and anatomical locations of DUS and phleboliths [6,7]. Tanidir et al. reported that the mean volume of DUS and phleboliths was 352.7 and 32.4 mm3, respectively. In the same study, the mean HU value of DUS and phleboliths was 398 and 922.7 HU, respectively [6]. Akdamar et al. reported that the volume and density values of DUS were higher than those of phleboliths [7]. In our study, the measurement of volume and density had a significant contribution to the DUS/phlebolith differentiation.

Soft Tissue Rim Sign

In our study, a peripheral rim was detected in 216 (80.3%) out of 269 cases of DUS and in 8 (7.4%) of 108 cases of phleboliths. Similarly, Heneghan et al. detected a peripheral rim in 8% of phleboliths and in 77% of DUS [8]. However, Akdamar et al. did not detect any soft tissue around phleboliths and attributed this outcome to the UCT technique used in the study. In the same study, a peripheral rim was detected in 67% of DUS, similar to our results [7]. As revealed in our study, phleboliths may have a peripheral rim, though rarely.

Comet-Tail Sign

The comet-tail sign consists of a soft tissue interrupted by phleboliths, located right next to the calcification and showing a linear extension from the calcification [9]. As demonstrated in our study, this sign has 100% specificity in diagnosing phleboliths. Similarly, some previous studies have found no comet-tail sign in any DUS and reported that the comet-tail sign had a PPV of 100% in the diagnosis of phleboliths [8,10,11].

Central Lucency

Central lucency is the hallmark sign of phlebolith, with a remarkably high PPV for its diagnosis. Bell et al. and Arac et al. found similar PPV values [9,10]. In our study, no profile analysis of calcifications was performed, and only 16% of phleboliths were found to have central lucency by visual evaluation. Arac et al.performed a profile analysis and detected central lucency in 60% of phleboliths [10]. Traubici et al. detected central lucency in 1% and 66% of phleboliths using CT and KUB X-ray, respectively [2]. Based on these findings, we consider that our rates might have been higher if CT and KUB X-ray had been used for the evaluation of pelvic calcifications.

Shape and Surface

The PPV values of round and oval shapes for the diagnosis of phlebolith have been reported to vary between 54% and 91%, while the reported PPV of the geometric shape for the diagnosis of DUS was 100% [7,9]. In our study, the PPV values of the shapes were similar to those reported in the literature. Additionally, the surface evaluation we added to our study showed a PPV value of 100% for the diagnosis of DUS. Nevertheless, although a consensus was reached by the two radiologists regarding surface evaluation, it is a subjective assessment.

Bladder Volume

Avanesov et al. reported that increased bladder volume is associated with a higher risk of distal DUS at the ureterovesical junction [5]. Our findings indicated that increased bladder volume contributes to the DUS/phlebolith differentiation. Accordingly, we consider that bladder volume should be optimized by continuous hydration before the CT scan.

In the present study, the parameters that were used in the literature were employed to differentiate DUS from phleboliths. To our knowledge, there has been no comprehensive study in the literature using all these parameters for differentiating DUS from phleboliths. Accordingly, our study is of a high value due to its comprehensive and inclusive character. The strength of our study is that all the patients underwent URS, which is the gold standard in the differentiation of DUS from phleboliths. Additionally, the numbers of DUS and phleboliths evaluated in this study were higher than those reported in other studies. On the other hand, the main limitation of our study was that the volumes of DUS and phlebolithswere small, as we did not limit the size of pelvic calcifications included in the study. Moreover, no profile analysis was performed for the evaluation of central lucency, thus we were not able to assess central lucency in those with lower density and volume values.

Conclusion

Our findings indicated that the differentiation of DUS from phleboliths via UCT is highly valuable both for the patients and the healthcare system since it prevents unnecessary additional examinations. The most important strength of our study was that all DUS or phleboliths were detected by URS. Additionally, the evaluation of volume, density, peripheral soft-tissue rim, comet-tail sign, central lucency, shape, surface, and bladder volume was found to contribute to the DUS/phlebolith differentiation. The use of these parameters in daily practice will provide valuable information both for the diagnosis and differential diagnosis of DUS and phlebolith.

Conflict of interests

The authors declare that they have no competing interests.

Financial Disclosure
All authors declare no financial support.

Ethical approval
This study was approved by Adiyaman University Non-Interventional Clinical Research Ethics Board (approval code: 2020/9-33).

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