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RESEARCH

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Importance of the hounsfield unit value measured by computed tomography in the differentiation of hydronephrosis and pyonephrosis

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Abstract

Background: Acute or chronic obstruction of the urinary tract can be due to a lot of different causes. Patients with pyonephrosis usually complain of a triad of fever, loin pain and elevated white blood cell count in cases of acute obstruction; and they may also have hypotension in severe cases of the disease. These patients have to be treated with appropriate decompression, or they may develop septic shock. The urgency of the need for treatment greatly depends on the differentiation between hydronephrosis and pyonephrosis.

There is a lack of reliable clinical prognosticators of pyonephrosis in patients with obstructive hydronephrosis. Hounsfield unit (HU) measurement is considered as an adequate predictor of pyonephrosis and may aid in the diagnosis and management of this disease that may be fatal.

The use of HU values in differentiation between pyonephrosis from hydronephrosis depends on the fact that the pyonephrotic fluid contains infected material, urine, cellular particles and microorganisms, which when combined can increase the HU values on a computed tomography (CT) study.

This study was done to assess the diagnostic value of the HU measured CT in differentiation between hydronephrosis and pyonephrosis.

Results: Thirty-nine patients were included in this study. All patients had loin pain and were diagnosed with pelvicalyceal dilatation by ultrasonographic examination. They then underwent non-contrast CT examination.

Using CT scan, the degree of PC dilatation was significantly higher among hydronephrosis group as hydronephrosis group had 63.1% severe dilatation of PCs versus 30.8% in pyonephrosis group with p value 0.0001.

Pelvic wall thickness > 2 mm was reported in 10 (76.9%) patients of pyonephrosis group versus in three (7.9%) patients among hydronephrosis group with p value 0.0001.

The mean Hounsfield units were significantly higher among pyonephrosis group compared to hydronephrosis group (16 ± 5.2 versus 1.7 ± 5.5) with p value 0.0001.

Sensitivity analysis showed that Hounsfield units can significantly diagnose pyonephrosis using the cutoff point 6.2 units, with sensitivity 92.3%, specificity 93.3%, area under the curve (AUC) 96.9% and p value 0.0001.

Conclusions: Measuring HU in a NCECT scan of the kidney might be helpful for differentiating between hydronephrosis and pyonephrosis especially upon considering 6.2 HU as a cutoff point.

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Keywords: Pyonephrosis, Hydronephrosis, Hounsfield unit, CT scan, CT attenuation, Obstructive uropathy

Background

Acute or chronic obstruction of the urinary tract can be due to a lot of different causes. Patients with pyonephrosis usually complain of a triad of fever, loin pain and elevated white blood cell count (WBC) in cases of acute obstruction; and they may also have hypotension in severe cases of the disease. [1]. These patients have to be treated with appropriate decompression, or they may develop septic shock. The urgency of the need for treatment greatly depends on the differentiation between hydronephrosis and pyonephrosis [2].

The discrepancy between pyonephrosis and uninfected hydronephrosis is often very difficult. Patients presenting with pyonephrosis may often show the clinical picture of acute infection, weight loss and pain, or with low-grade fever, yet as many as 15% may present with no fever [1].

There is a lack of reliable clinical prognosticators of pyonephrosis in patients with obstructive hydronephrosis. Hounsfield unit (HU) measurement is considered as an adequate predictor of pyonephrosis and may aid in the diagnosis and management of this disease that may be fatal [3, 13].

The use of HU values in differentiation between pyonephrosis from hydronephrosis depends on the fact that the pyonephrotic fluid contains infected material, urine, cellular particles and microorganisms, which when combined can increase the HU values on a computed tomography (CT) study [2, 12].

This study was done to assess the diagnostic value of the HU measured CT in differentiation between hydronephrosis and pyonephrosis.

Methods

Thirty-nine patients who presented with a history of acute or chronic, unilateral or bilateral loin pain in the emergency department or Urology outpatient clinics were reviewed. Twenty-one of these patients were male and 18 were female, their mean age was $52.75 \pm$ SD 16.25 years.

All the patients underwent pelvi-abdominal ultrasound and those who had obstructive uropathy underwent non-enhanced contrast computed tomography on the urinary tract.

Patients with history, clinical, laboratory and imaging findings indicated for decompression were sent to the urology department either for uretral catheter or nephrostomy tube insertion.

Then we correlated aspirated or drained fluid from the obstructed kidney with the Hounsfield unit measured in the dilated pelvicalyceal system on the non-enhanced computed tomography study of the patient.

Selection of the patients

Inclusion criteria

Patients who presented with obstructive uropathy in the emergency department (diagnosed by the emergency radiologist by means of an ultrasonographic examination) or Urology outpatient clinics and underwent ureteral catheter or nephrostomy tube insertion for decompression were included. A patient consent to be included in the study was then signed before we proceeded.

Exclusion criteria

Patients who did not show dilatation on ultrasonographic examination, or patients who could not undergo CT examination due to their critical condition and surgical management could not be delayed.

Imaging technique

The NCECT was performed up to 24 h prior to ureteral aspiration, using a 16-row multi-detector CT scanner (Somatom Emotion 16, Siemens Healthcare, Germany). The parameters used in our study were tube current 150 mAs, field of view 300 mm, collimation 5 mm and a matrix of 512×512. A radiologist of 5 years experience measured the mean HU value in the dilated pelvicalyceal systems of all patients using an elliptical region-of interest (ROI) and also measured the renal pelvic anteroposterior diameter, as well as the area of the renal pelvis.

We then categorized the patients with hydronephrosis on the basis of the classification proposed by the Society for Fetal Urology. This classification states that: In Grade 0, there is no dilatation, calyceal walls are apposed to each other; in Grade 1 (mild), there is dilatation of the renal pelvis without dilatation of the calyces (can also occur in the extrarenal pelvis) and there is no parenchymal atrophy; in Grade 2 (mild), there is dilatation of the renal pelvis (mild) and calyces (pelvicalyceal pattern is retained) and there is no parenchymal atrophy; in Grade 3 (moderate), there is moderate dilatation of the renal pelvis and calyces associated with blunting of fornices and flattening of papillae, as well as mild cortical thinning which may be seen; while in Grade 4 (severe), there is gross dilatation of the renal pelvis and calyces, which appear ballooned, loss of borders between the renal pelvis and calyces and renal atrophy seen as cortical thinning [11, 14].

Quantitative measurement of the HU values in the dilated pelvicalyceal system was done by placing an elliptical ROI in the slice with the maximally dilated surface area of the affected kidney in the soft tissue window. We made sure not to include any part of the adjacent renal parenchyma or stones in the areas we measured. In some cases (where it was feasible), we measured up to three ROIs and took a mean value, while in others (where the dilatation was not severe), only one ROI could be measured.

The renal pelvic wall thickness and the renal anteroposterior diameter were then measured in all patients by using the ruler tool at the thickest part that could be identified.

The parenchymal/perinephric inflammatory changes (if any) were noted and recorded for each case. And the cause of obstruction (if could be identified) was diagnosed for each case.

The CT results were then recorded and later on compared with the culture results obtained after drainage among patients diagnosed with hydronephrosis and those diagnosed with pyonephrosis. The radiologists and the urologists working in this study were blinded to the results of each technique to guarantee non-bias in the comparison of the results.

Statistical analysis was conducted using SPSS 22nd edition, and quantitative variables were presented in mean ± standard deviation, means comparison was conducted using Mann–Whitney U test after normality testing. Qualitative variables were presented in frequency and percentages, it was compared using CHI2 test. Sensitivity analysis was conducted to detect the cutoff point for Hounsfield units to diagnose pyonephrosis, also to assess the sensitivity and specificity of this cutoff point. Any p value < 0.05 was considered significant.

Results

A total of 39 patients were included in our final analysis, and all patients were presented with obstructive uropathy. Thirteen of them were finally diagnosed as pyonephrosis with mean age 58.1 ± SD 12.3 years old, while 26 were diagnosed as hydronephrosis with mean age 47.4 ± SD 20.2 years old.

Among the patients of pyonephrosis, 61.5% were females, while 38.5% were males. On the other hand, 38.5% of patients with hydronephrosis were females, while 61.5% were males.

Comparison of demographics between study groups showed female gender was higher among patients with pyonephrosis, while male gender was higher among patients with hydronephrosis.

Comparison of study groups showed that fever was more commonly reported in pyonephrosis group with p value 0.0001, while retention was more commonly reported in hydronephrosis group with p value 0.003, bilaterality also was predominant in hydronephrosis group with p value 0.003. There was no significant difference in prevalence of pain, hypertension and hypotension among study groups with p values > 0.05 (Table 1 and Fig. 1).

Comparison of the prevalence of chronic illnesses among study groups showed that there was

Table 1 Clinical characters among the included patients

Clinical picture (symptoms and signs)		Group				P value
		Pyonephrosis		Hydronephrosis		
		Count	%	Count	%	
Pain	No	0	0.0	6	23.1	0.07
	Yes	13	100.0	20	76.9	
Fever	No	3	23.1	24	92.3	0.0001
	Yes	10	76.9	2	7.7	
Hematuria	No	11	84.6	18	69.2	0.30
	Yes	2	15.4	8	30.8	
Retention	No	13	100.0	19	73.1	0.001
	Yes	0	0.0	7	26.9	
Side	Right	9	69.2	9	34.6	0.003
	Left	4	30.8	5	19.2	
	Bilateral	0	0.0	12	46.2	
Hypertension	No	7	53.8	15	57.7	0.81
	Yes	6	46.2	11	42.3	
Hypotension	No	13	100.0	27	103.8	0.48
	Yes	0	0.0	1	3.8	

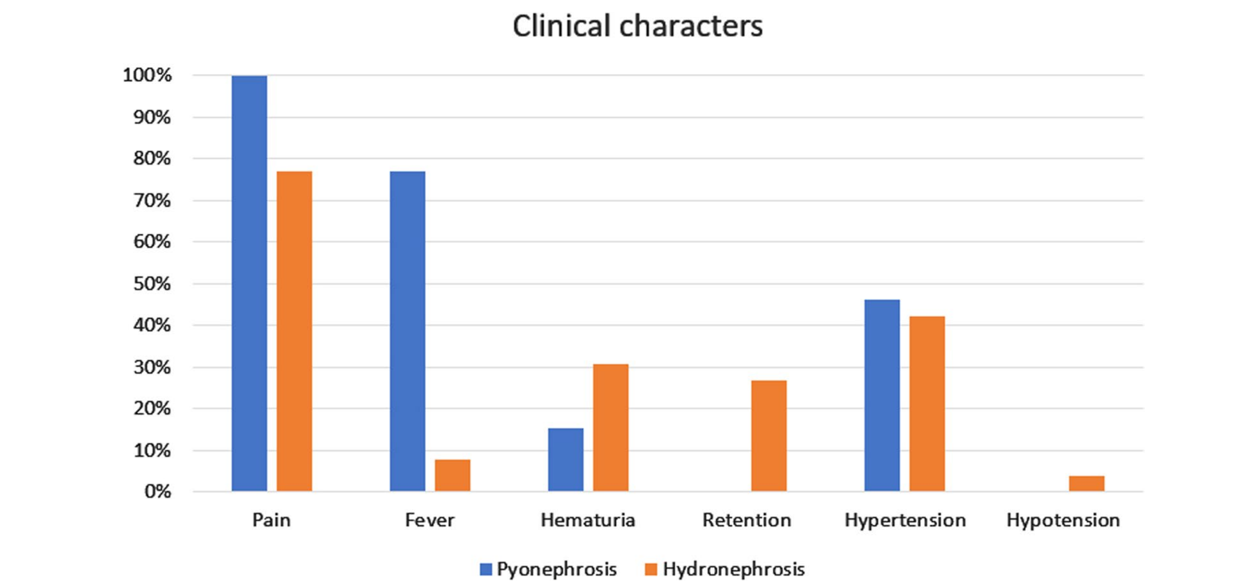

Fig. 1 Bar chart showing clinical symptoms among study groups

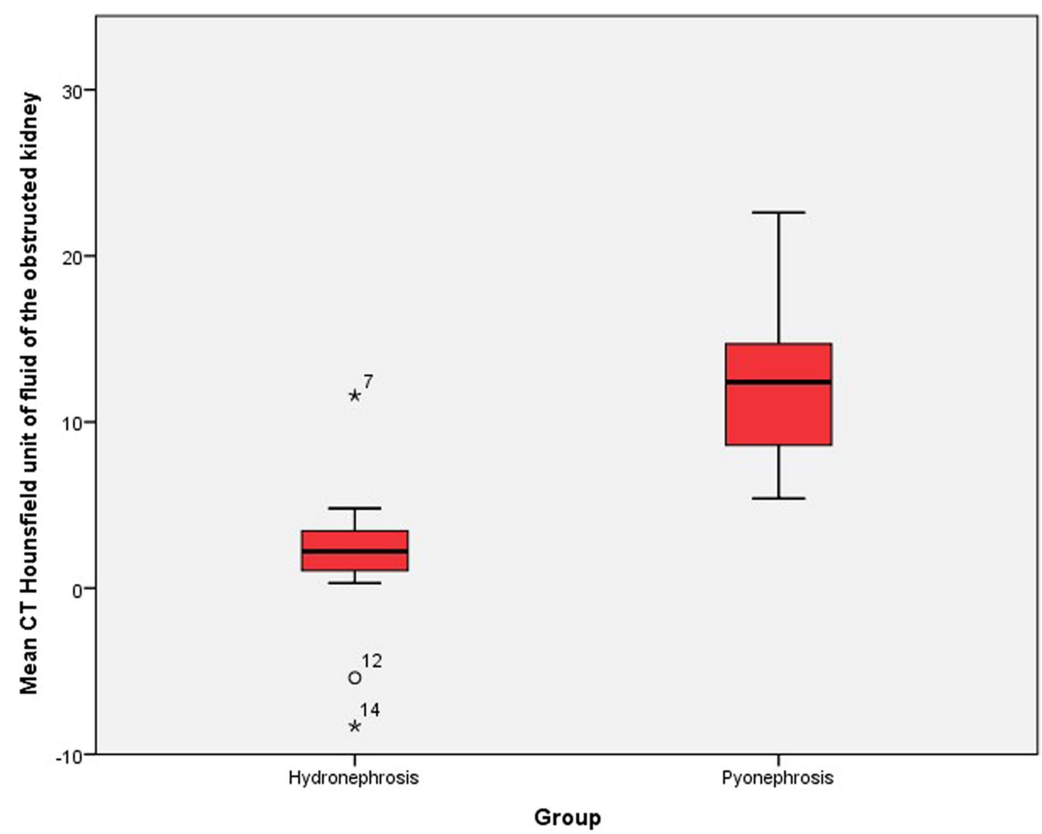

Fig. 2 Box plot showing Hounsfield units distribution among study groups

Table 2 Laboratory findings among the study groups

		Group				P value
		Pyonephrosis		Hydronephrosis		
		Count	%	Count	%	
CBC	Normal TLC	1	7.7	15	57.7	0.003
	High TLC	12	92.3	11	42.3	
Kidney Function Tests	Normal	3	23.1	12	46.2	0.16
	Elevated	10	76.9	14	53.8	
Culture and Sensitivity	Negative	0	0.0	14	53.8	0.001
	Positive	13	100.0	12	46.2	

Table 3 Ultrasound findings among study groups

		Group				P value
		Pyonephrosis (13 renal unit)		Hydronephrosis (38 renal unit)		
		Count	%	Count	%	
1.Degree of dilatation of PCs	Mild	0	0.0	0	0.0	0.047
	Moderate	9	69.2	14	36.9	
	Severe	4	30.8	24	63.1	
2. Hyperechoic debris	Yes	6	46.2	6	15.8	0.029
	No	7	53.8	32	84.2	
3.Fluid–fluid levels	Yes	8	61.5	0	0.0	0.0001
	No	5	38.5	38	100.0	

no statistically significant difference of the associated comorbidities between study groups with p value 0.89 Fig. 2.

Prevalence of high TLC was significantly more prevalent in pyonephrosis group compared to hydronephrosis with p value 0.003. As well, positive culture was positive in 100% of pyonephrosis cases compared to 46.2% in hydronephrosis group despite the clean appearance of drained urine with p value 0.001 (Table 2).

The degree of pelvicalyceal system dilatation, detected by the ultrasound examination, was significantly more severe in hydronephrosis groups with p value 0.0001. Fluid–fluid levels was reported in eight (61.5%) patients of pyonephrosis group versus 0.0% in hydronephrosis group with p value 0.0001 (Table 3).

CT findings

Using CT scan, the degree of PC dilatation was significantly higher among hydronephrosis group as hydronephrosis group had 63.1% severe dilatation of PCs versus 30.8% in pyonephrosis group with p value 0.0001 (Fig. 3, 4 and 5).

Pelvic wall thickness > 2 mm was reported in 10 (76.9%) patients of pyonephrosis group versus in three (7.9%) patients among hydronephrosis group with p value 0.0001.

Parenchymal\perinephric inflammatory changes were insignificantly higher among the pyonephrosis group (46.2%) compared to hydronephrosis group (21.1%) with p value 0.36.

Underlying cause of obstruction was mainly renal stones in both study groups with no significant difference (p value 0.87).

The mean Hounsfield units were significantly higher among pyonephrosis group compared to hydronephrosis group (16 ± 5.2 versus 1.7 ± 5.5) with p value 0.0001 (Fig. 2).

Mean anteroposterior diameter of kidney was 28.4 ± 10.1 mm in pyonephrosis group versus 31.1 ± 14.4 mm in hydronephrosis group with p value 0.49.

Renal pelvic area was 628.51 ± 433.1 mm2 in pyonephrosis group versus 745.14 ± 470.6 mm2 in hydronephrosis group (p 0.45).

Sensitivity analysis showed that Hounsfield units can significantly diagnose pyonephrosis using the cutoff

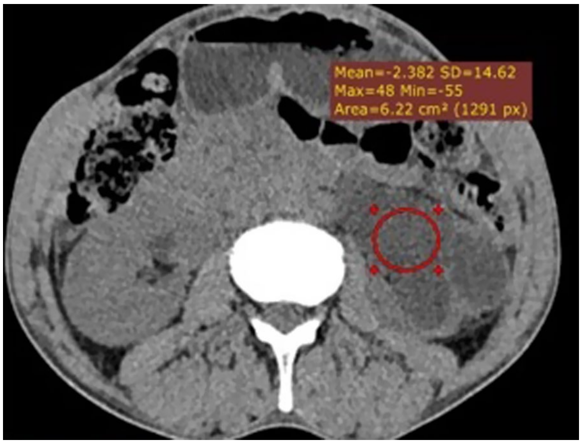

Fig. 3 Axial CT scan showing marked dilatation of the left PCS with thinning out of the renal parenchyma. Mean HU within the dilated pelvicalyceal system = -2.3 HU indicating the diagnosis of hydronephrosis

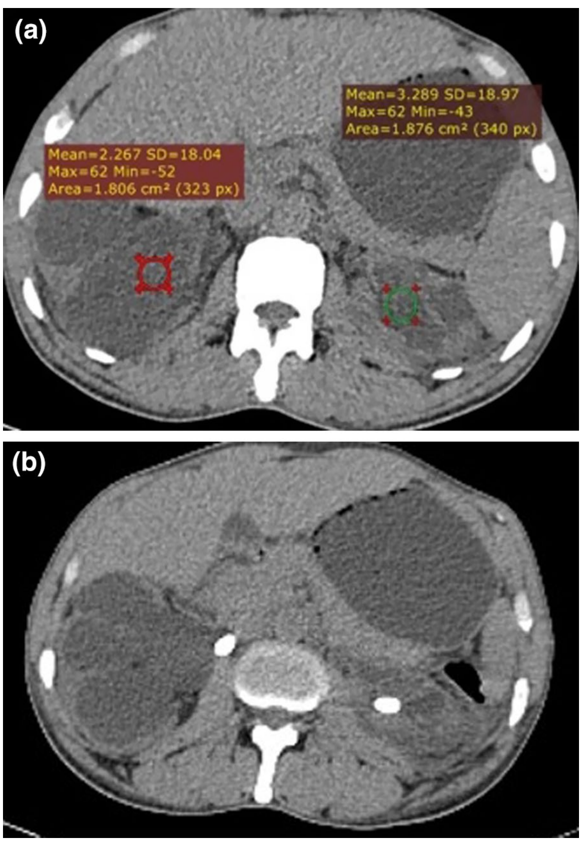

Fig. 4 **a** CT scan showing markedly dilated both pelvicalyceal system and ureters with thinning out of the renal parenchyma. Mean HU within the dilated right pelvicalyceal system = 2.2 indicating the diagnosis of hydronephrosis. Mean HU within the dilated left pelvicalyceal system = 3.2 indicating the diagnosis of hydronephrosis. **b** Axial CT scan of the same patient showing bilateral pelvic renal stones

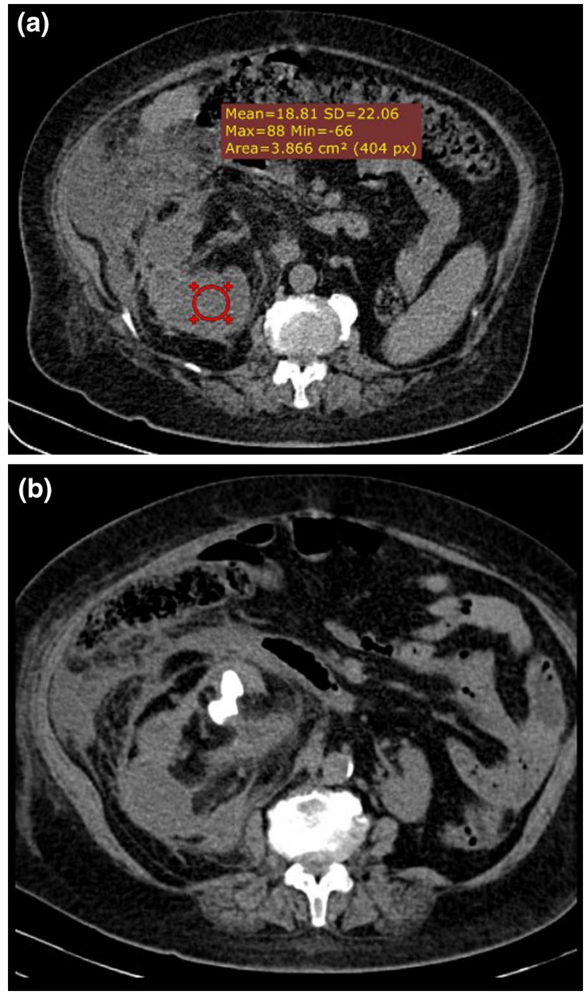

Fig. 5 **a** Axial CT scan showing swollen right kidney showing markedly dilated right pelvicalyceal system with marked smudging of perinephric fat planes. Mean HU within the dilated pelvicalyceal system = 18.8 indicating the diagnosis of pyonephrosis. **b** Axial CT scan of the same patient showing right large renal stones and marked smudging of the perinephric fat planes

point 6.2 units, with sensitivity 92.3%, specificity 93.3%, AUC 96.9% and p value 0.0001 (Table 4).

Discussion

Several earlier studies assessed factors associated with pyonephrosis in patients diagnosed with urinary stones. Patodia et al. studied a group of 91 patients with pyonephrosis and 410 patients without pyonephrosis and revealed that there are risk factors that increase the incidence of pyonephrosis including the stone size, the severity of hydronephrosis, the time of presentation, and the function of the kidney [6]. Our results corroborate some of these findings (although not the same points of evaluation in our study), where we found that

Table 4 CT findings among the study groups

		Group				P value
		Pyonephrosis (13 renal unit)		Hydronephrosis (38 renal unit)		
		Count	%	Count	%	
Degree of dilatation of the PCs	Mild	0	0.0	0	0.0	0.047
	Moderate	9	69.2	14	36.9	
	Severe	4	30.8	24	63.1	
Pelvic wall thickness > 2 mm	Yes	10	76.9	3	7.9	0.0001
	No	3	23.1	35	92.1	
Parenchymal\perinephric Inflammatory changes	Yes	6	46.2	8	21.1	0.084
	No	7	53.8	30	78.9	
Possible causes of obstruction	Urinary stones	9	69.2	28	73.7	0.729
	Tumors	2	15.4	6	15.9	
	Stricture	0	0.0	2	5.2	
	Congenital anomaly	2	15.4	2	5.2	
Mean CT Hounsfield unit of fluid of the obstructed kidney		16.0	5.2	1.7	5.5	0.0001
A-P diameter		28.45	10.1	31.13	14.4	0.535
Renal pelvic area		628.51	433.1	745.14	470.6	0.435

patients with delayed presentation and poor renal function (76.9%) are more likely to develop pyonephrosis compared to the hydronephrosis group.

The two leading causes of pyonephrosis are obstruction and infection; hence any risk factor increasing the incidence of urinary tract infections (UTI) could also lead to pyonephrosis [7]. In our study, we found that patients with pyonephrosis had comorbid conditions (especially diabetes in 38% of cases), and they were more frequently of the female gender compared to those seen in the hydronephrosis group (61.5% vs 38.5%).

Hydronephrosis and sometimes its underlying cause are best depicted by CT as the investigation of choice in adults. CT examination should be compulsory in cases where ultrasound examination was non-diagnostic and to diagnose the presence of any extrarenal extension of the pathology. However, differentiation of simple hydronephrosis from pyonephrosis may be difficult on CT as it is mostly diagnosed by the presence of indirect signs. The imaging of obstruction can be performed with NCECT with an accuracy of 97% in the detection of stones within the ureters, although contrast-enhanced CT scans are more suitable to detect infection, in addition to any parenchymal or functional changes [7].

CT scan in cases of hydronephrosis can detect the indirect signs of pyonephrosis which are renal pelvic and ureteral wall thickening, kidney enlargement, perinephric fat stranding and a renal parenchymal striated nephrogram, which are usually more severe in pyonephrosis than in simple hydronephrosis. A study done by Basmaci et al. showed that pelvic wall thickening has a sensitivity of 76% for pyonephrosis. On the other hand, bridging septa and thickening of the renal fascia are indicative but nonspecific of pyonephrosis, since they are frequently seen in association with other conditions such as inflammation, trauma, retroperitoneal neoplasms, infarction, or peritonitis [2, 15].

In a study done by Gnannt et al. who used the measurement of HU values, as well as clinical and laboratory assessments, it is suggested that they were the most useful in the differentiation between infected and non-infected fluids. Also, the HU values could discriminate between exudates and transudates [8]. This is in accordance with the results of our study showing that the mean HU value of the pyonephrosis group was significantly higher than that of the hydronephrotic group (16 ± 5.2 versus 1.7 ± 5.5) with p value 0.0001.

In another study done by Yuruk et al., there was a statistically significant higher HU value in patients with pyonephrosis compared to those with hydronephrosis. In their study, they diagnosed cases with pyonephrosis with a sensitivity of 65.96% and specificity of 87.93%, when they used a cutoff value of HU > 9.21, [9, 10]. Likewise, in our study, the HU value was significantly higher in patients in the pyonephrosis group compared to the hydronephrosis group (16 ± 5.2 versus 1.7 ± 5.5) with p value 0.0001; with sensitivity 92.3%, specificity 93.3% in the diagnosis of pyonephrosis. However, in that study, the authors used contrast-enhanced CT in some of their cases. In contrast, we believe to have attained a more uniform group by undergoing only NCECT for all our patients.

Conclusions

From this study, we conclude by examining the fluid in an obstructed kidney by measuring its HU using a single NCECT scan, we can differentiate its contents being infected or clear (pyonephrosis or hydronephrosis). We found a cutoff value of 6.2 HU can potentially predict the presence of pyonephrosis in patients with obstructive uropathy.

Making the diagnosis of pyonephrosis earlier and in a precise method will allow physicians to make a proper management plan to avoid any complications of this pathology.

Abbreviations

AP: Anteroposterior; ARF: Acute renal failure; AUC: Area under the ROC Curve; CRP: C-reactive protein; CT: Computed tomography; DJ: Double J; DM: Diabetes Mellitus; ESR: Erythrocyte sedimentation rate; GFR: Glomerular filtration rate; HU: Hounsfield unit; HYDRO: Hydronephrosis; KFT: Kidney function tests; Mm: Millimeter; PPV: Positive predictive value; PYO: Pyonephrosis; ROC: Receiver operating characteristic curve; SNR: Signal-to-noise ratio; US: Ultrasonography; WBC: White blood cells.

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Author contributions

NRB contributed to manuscript writing. AK contributed to idea of the research, collecting cases, manuscript writing, results and statistics. SYS contributed to revising manuscript and results. SSM contributed to revising the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of the Faculty of Medicine at Cairo University in Egypt. Written informed consent was signed by all patients who participated in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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