Original Article

Comparison of Imaging Characteristics on Computed Tomography and Magnetic Resonance Urography in Urological Conditions

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Abstract

Introduction: Urinary tract (UT) pathologies are common causes of morbidity presenting mainly as acute flank pain, obstructive uropathy, and hematuria with calculus being the commonest cause. Computed tomography (CT) (noncontrast, contrast enhanced and urography) of the kidney, ureter, and bladder region has been considered as the mainstay in evaluation of patients with UT symptoms. Limitations of radiation exposure and risks of contrast injection in CT have provided space for magnetic resonance urography (MRU) that has recently gain acceptance. However, MRU is limited by its availability and higher cost. Thus, with the aim of evaluating the scope of MRU in various UT pathologies, we planned a comparative study between CT scan and MRU. **Materials and Methods:** Thirty-five patients with UT symptoms (acute flank pain, obstructive uropathy, and hematuria) were evaluated with CT scan and MRU after obtaining approval from Institutional Ethics Committee and written informed consent from the participants of the study. CT scan was performed on 128-slice CT scanner while MRU was performed on 1.5T magnetic resonance scanner using the standard protocol. The data thus recorded in a single-blinded manner were analyzed using appropriate statistical methods and tools. **Results:** Compared with CT scan, MRU had a poor accuracy in detecting UT stones especially <6 mm and without secondary signs of obstruction. However, MRU performed very well in patients with obstructive uropathy and hematuria subgroup with no significant difference in accuracy from CT scan. Overall, MRU had a moderate sensitivity of 76.3%, high specificity of 96.9% and moderately high accuracy of 85.7%. **Conclusions:** Although MRU has lower sensitivity to small sized UT calculus but is very specific to secondary signs of obstruction as well as to causes of obstructive uropathy and hematuria. It can serve as an excellent alternative tool especially in patients with contraindication of contrast injection in CT scan as well as in children, during pregnancy and in conditions requiring repetitive examinations.

Keywords: Acute flank pain, computed tomography, hematuria, magnetic resonance urography, obstructive uropathy

Introduction

Patients with urological diseases present with a myriad of symptoms and signs, the commonest being acute flank pain, hematuria, and obstructive uropathy. Cross-sectional imaging methods such as computed tomography scan (CT scan) and magnetic resonance urography (MRU) have progressively gained value in assessing the urinary tract (UT) in all ages due to their obvious advantages over the existing backbone investigations such as radiography of kidney, ureter, and bladder (KUB) region, intravenous pyelography and ultrasonography.[1]

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In patient with acute flank pain, noncontrast CT (NCCT) KUB is the ideal choice as it not only provides length of the calculus through coronal and sagittal, multiplanar reconstruction images aiding in planning the appropriate mode of management but also provides the information about the composition of calculus indirectly by its attenuation value.[2,3] NCCT is however, limited by its inability to study renal function, differentiating

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acute from chronic obstruction, limited information about inflammation and necrosis and occasional difficulty in distinguishing small calculus in distal ureter from pelvic phleboliths.[3,4] CT urography (CTU) done following injection of iodinated contrast agents may however, fail to opacify the ureter in one excretory phase.[5]

MRU in contrast to NCCT allows optimal evaluation of renal parenchyma details along with its collecting system in a single imaging protocol, providing an additional advantage of no radiation exposure or need of invasive procedure making it suitable for pregnant patients as well.[4] Periureteral edema seen on MRU is highly indicative of acute ureteric obstruction.[1] MRU can be also be considered as a suitable option for patients who might need repeated imaging avoid both radiation exposure as well as risk of contrast agents.[6] However, the role of MRU in acute settings are largely undefined and are yet to gain widespread favor due to high cost.

Another common urological problem in day-to-day practice is hematuria that can be attributed to calculus, infections or malignancies in the UT.[7,8] CTU has established itself as an imaging modality of choice in such conditions but again its utility is limited by pregnancy, deranged renal function and known allergy to iodinated contrast agent.[9] However, we opine patients presenting with hematuria may be directly evaluated with MRU which has the potential of not only saving time and cost especially in high volume centers but also avoids risk of radiation and contrast agents.

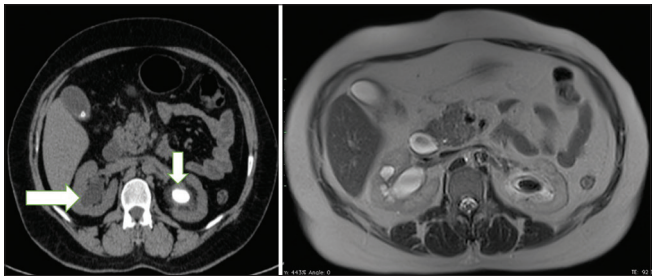

Figure 1: Axial non-contrast computed tomography image (left) shows hydronephrosis in right kidney with large calculus in left renal pelvis with secondary hydronephrosis (white arrows) with similar findings in corresponding T2W axial magnetic resonance image (right)

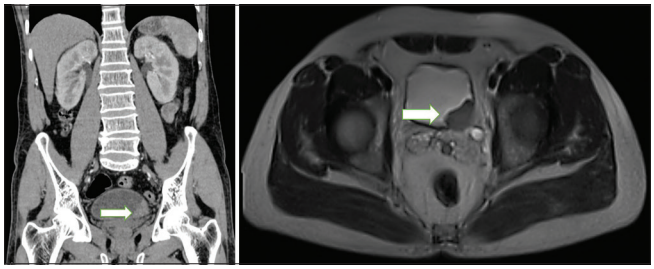

Figure 3: Coronal multiplanar reconstructions contrast-enhanced computed tomography image (left) shows vesical tumor in left posterolateral location (arrow) with similar findings on axial T2 weighted magnetic resonance image (right-arrow)

Similarly, obstructive uropathy can be due to pelviureteric junction (PUJ) obstruction, ureteral strictures (benign or malignant) and urethral obstruction due to calculi or stricture.[10] Though the role of CTU in intravesical obstruction is severely limited except in case of obstructing urethral stone but the ability of MRU to evaluate whole of UT provides a striking substitute, even in patients with deranged renal function thus avoiding contrast-related nephrotoxicity.[10]

Considering the above, we planned a comparative study on CT scans and MRU in above common urological conditions to gain more objective information on the utility and diagnostic performance of MRU with the following aims and objectives.

Aims

To compare the imaging characteristics of CT scan and MRU in following urological conditions:

- Patients presenting with acute ureteric colic
- Patients presenting for hematuria
- Patients presenting with obstructive uropathy.

Objectives

- To conduct NCCT KUB and MR-Urography in patients presenting with acute flank pain and comparing the imaging characteristics
- To conduct contrast-enhanced CT (CECT) KUB and MRU in patients presenting with hematuria and comparing their imaging characteristics
- To conduct CECT scan and MRU in patients presenting with obstructive uropathy and compare their imaging characteristics.

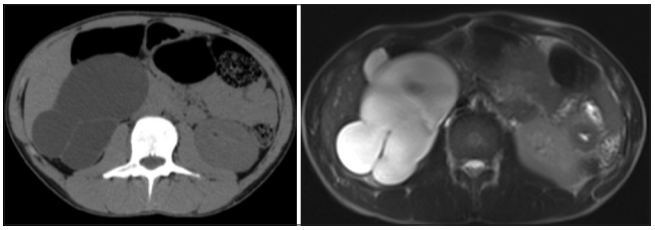

Figure 2: Axial non-contrast computed tomography image (left) shows Grade-4 hydronephrosis with pelviureteric junction obstruction on right side with similar findings on axial T2W magnetic resonance image (right)

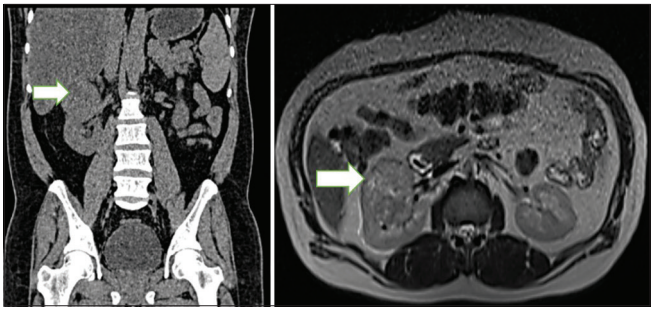

Figure 4: Coronal multiplanar reconstructions noncontrast computed tomography image (left) shows isodense renal carcinoma at upper pole of right kidney (arrow) with similar findings on axial T2W magnetic resonance image (right) with better information about internal matrix (arrow)

Materials and Methods

This hospital-based, observational, comparative, and blinded study was performed on 35 patients visiting the Department of Radiodiagnosis following approval from Institutional Ethics Committee (Ref. No: TMMCandRC/IEC/18-19/071dated: 27/12/2018) and after obtaining written informed consent using the following criteria:

Inclusion criteria

- Patients presenting with acute flank pain, hematuria, and obstructive uropathy.

Exclusion criteria

- Previous history of contrast allergy, if CECT KUB is indicated
- Deranged renal function (serum creatinine > 1.3 mg/dL or estimated glomerular filtration rate < 60 ml/min)[11] in case of CECT KUB
- Any contraindication to magnetic resonance imaging (MRI).

The study population was divided into three different groups as follows:

a. NCCT KUB versus MRU in patients presenting with acute ureteric colic
b. CECT KUB versus MRU in patients presenting with hematuria
c. CECT KUB versus MRU in patients with obstructive uropathy.

All patients were evaluated on 128-Slice, multidetector, helical, Philips Ingenuity, CT scanner using one or all the following phases:

- Noncontrast (NCCT-unenhanced)
- Nephrographic (CECT-enhanced)
- Urographic (CECT-Delayed).

Intravenous iodinated contrast agent namely Iohexol containing 300 mg% Iodine was used in the dosage of 1–2 ml/kg body weight for obtaining CECT scans.

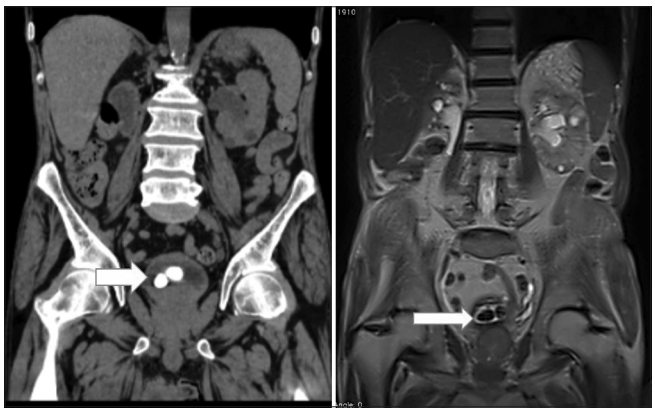

Figure 5: Coronal multiplanar reconstructions noncontrast computed tomography image (left) shows two hyperdense vesical calculus (arrow) while corresponding coronal T2-weighted magnetic resonance image (right) shows two hypointense filling defects (arrow)

MRU was performed on Siemens Magnetom Avanto, 1.5Tesla, MR scanner utilizing breath holding sequences – heavy T2-weighted and fat suppressed T2-weighted image sequences.

Data from CT scan and MRU were recorded in predesigned pro forma by radiologist in a single blinded manner. Appropriate statistical tools were applied to evaluate the results.

Results [Figures 1-5]

Majority of the patients in our study, nearly one-third (11/35) were in 31–40 years of age group and majority (68.5%) were male (24/35).

Majority of the patients in our study (32/35) had unilateral disease while rest (3/35) had bilateral disease. Among the unilateral, the left side was more commonly involved (19/32).

In our study, patients with acute flank pain formed the major group [Table 1].

In our study, all 35 participants had two UT units as there was no case with renal agenesis or postnephrectomy status, hence our findings accounted for seventy UT units. Out of total 70, 38 UT units had urological disease (3 cases had bilateral pathology) which were further subgrouped into five categories based on etiology, namely calculus with obstruction, calculus without obstruction, noncalculus obstruction, urinary bladder tumor and renal tumor.

Table 2 shows the comparison with CT scan and MRU findings in different patient group in our study. It is evident from the Table 2 that though MRU is inferior to CT scan in detecting calculus, but it is equally good in detecting the noncalculus cause of obstructive uropathy as well as UT tumors.

Table 1: Patient distribution based on the chief complaint

Complaint	Frequency (%)
Acute flank pain	16 (45.7)
Obstructive uropathy	11 (31.4)
Hematuria	8 (22.8)
Total	35 (100)

Table 2: Comparison between the frequency and percentage of computed tomography and magnetic resonance imaging in cause of the pathology

Cause/diagnosis	CT scan, *n* (%)	MRU, *n* (%)	χ^2, *P*
Calculus with obstruction	23 (32.85)	14 (20.0)	85.19, 0.01
Calculus-without obstruction	4 (5.71)	5 (7.14)	
NCO	9 (12.85)	9 (12.85)	
Urinary bladder tumor (TCC)	1 (1.42)	1 (1.42)	
Renal tumor (RCC)	1 (1.42)	1 (1.42)	

MRU: Magnetic resonance urography, CT: Computed tomography, TCC: Transitional cell carcinoma, RCC: Renal cell carcinoma, NCO: Noncalculus obstruction

Table 3: Comparison of computed tomography scan and magnetic resonance urography based on level/location of pathology

Part of urinary tract involved	Level of obstruction	CT scan, *n* (%)	MRU, *n* (%)	χ^2, *P*
Ureter	Distal ureter	10 (26.31)	4 (13.33)	85.19, 0.01
	Middle ureter	4 (10.52)	3 (10.00)	
	Upper ureter	3 (7.89)	3 (10.00)	
Kidney	Upper pole	2 (5.26)	2 (6.66)	
	Middle pole	6 (15.78)	5 (16.66)	
	Inferior pole	1 (2.63)	1 (3.33)	
	Renal pelvis	3 (7.89)	3 (10.00)	
	Pelvic ureteric junction	7 (18.42)	7 (23.33)	
Urinary bladder	Vesicoureteral junction	1 (2.63)	0	
	Left posterolateral bladder wall	1 (2.63)	1 (3.33)	
Total		38 (100)	30 (100)	

MRU: Magnetic resonance urography, CT: Computed tomography

Table 3 shows the comparison with CT scan and MRU in various urological conditions based on the level or location of pathology. From Table 3, it is evident that MRU is significantly inferior to CT scan in detecting the lesions in distal ureter with nearly similar accuracy in the rest of the locations.

Table 4 shows MRU is nearly as accurate as CT scan in diagnosing the Grade II and IV of hydronephrosis in patients with obstructive uropathy with slight errors in diagnosing Grade I and III hydronephrosis.

Table 5 shows the comparison of CT scan and MRU in detecting lesions based on their size. It is evident from the table MRU is slight inferior to CT scan in detecting the smaller lesions.

Table 6 shows the comparison with CT attenuation values and MR intensity of calculus detected in our study population. The table reveals that calculus with CT attenuation value of more than 970HU will have a MR intensity of <515SI thus indicating an inverse relationship, meaning thereby that the harder calculus has less SI and hence appear more hypointense.

Table 7 shows the comparison of CT scan and MRU in diagnosing different pathologies in different subgroups of our study population. It quite evident from the table that except for cases with calculus causing obstruction where the sensitivity of MRU was lower than CT scan but with an accuracy of more than 85%, in the rest of the pathologies including calculus without obstruction the overall sensitivity and accuracy of the MRU was more than 95% and 100% in cases of tumors in the UT. The overall reliability of MRU was also moderate to high.

Summing up all the above conditions, MRU had an overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 76.3%, 96.88%, 96.67%, 77.5%, and 85.7% respectively [Table 8]. The subgroup with highest accuracy of MRU was that of obstructive uropathy followed by hematuria and least with acute flank pain [Table 9].

Table 4: Comparison of grade of hydronephrosis[1] on computed tomography scan and magnetic resonance urography

Grade of hydronephrosis	CT, *n* (%)	MRU, *n* (%)	χ^2, *P*
I	7 (21.21)	6 (18.18)	86.04, 0.001
II	12 (36.36)	12 (36.36)	
III	8 (24.24)	9 (27.27)	
IV	6 (18.18)	6 (18.18)	

CT: Computed tomography, MRI: Magnetic resonance imaging

Table 5: Comparison of computed tomography scan and magnetic resonance urography based of size of lesion[2,12]

Size of calculus/mass (mm)	CT, *n* (%)	MRU, *n* (%)	*P*
<6	9 (23.6)	7 (18.4)	0.001
>7	29 (76.3)	22 (57.8)	

CT: Computed tomography, MRI: Magnetic resonance imaging

Table 6: Comparison of computed tomography scan and magnetic resonance urography based on density/intensity of calculus[13]

CT density (HU)	MRI intensity (SI)	Frequency, *n* (%)
>970	<515	18 (66.6)
<970	>515	9 (33.3)

CT: Computed tomography, HU: Hounsfield unit, MRI: Magnetic resonance imaging, SI: Signal intensity

Discussion

In our study, most of the patients were 31–40 years with male predominance (24/35). This age and gender distribution was similar to Ahmad *et al*.[4] However, our study did not exhibit any correlation of diagnosis on CT scan and MRU with age or gender.

In our study, out of 23 cases of calculus with obstruction on CT scan with mean size of 13.7 mm, 14 were detected by MRU (60.8%). All the cases had calculus located either at PUJ or in ureter except for one case with additional vesical calculus, well visualized on MRU. The study by Semins *et al*. (2013)[14] revealed nearly 50% detection of obstructing stones by MRI with sensitivity and specificity of 84% and 100% respectively based on detection of calculus, dilatation

Table 7: Agreement of magnetic resonance urography with computed tomography scan in diagnosing condition based on different subgroups

	MRU versus CT scan	*n*	Diagnostic performance of MRU	Percentage	*K*	*P*
Calculus with obstruction	True-positive result (sensitivity)	14	Sensitivity	60.8	0.67	0.001
	False-positive result	0	Specificity	100		
	False-negative result	9	PPV	100		
	True-negative result (specificity)	46	NPV	83.6		
	Reliability	-	Accuracy	86.9		
Calculus without obstruction	True-positive result (sensitivity)	4	Sensitivity	100	0.36	0.001
	False-positive result	1	Specificity	98.4		
	False-negative result	0	PPV	80		
	True-negative result (specificity)	65	NPV	100		
	Reliability	-	Accuracy	98.5		
NCO	True-positive result (sensitivity)	9	Sensitivity	100	1.00	0.001
	False-positive result	0	Specificity	100		
	False-negative result	0	PPV	100		
	True-negative result (specificity)	61	NPV	100		
	Reliability	-	Accuracy	100		
Urinary bladder tumor	True-positive result (sensitivity)	1	Sensitivity	100	1.00	0.001
	False-positive result	0	Specificity	100		
	False-negative result	0	PPV	100		
	True-negative result (specificity)	69	NPV	100		
	Reliability	-	Accuracy	100		
Renal tumor	True-positive result (sensitivity)	1	Sensitivity	100	1.00	0.001
	False-positive result	0	Specificity	100		
	False-negative result	0	PPV	100		
	True-negative result (specificity)	69	NPV	100		
	Reliability	-	Accuracy	100		

MRU: Magnetic resonance urography, CT: Computed tomography, NCO: Noncalculus obstruction, PPV: Positive predictive value, NPV: Negative predictive value

Table 8: Agreement of magnetic resonance urography with computed tomography scan in all urological conditions

	MRU versus CT scan	*n*	Diagnostic performance of MRU	Percentage	*K*	*P*
Urinary tract pathology	True-positive result (sensitivity)	29	Sensitivity	76.32	0.71	0.001
	False-positive result	1	Specificity	96.88		
	False-negative result	9	PPV	96.67		
	True-negative results (specificity)	31	NPV	77.50		
	Reliability	-	Accuracy	85.71		

MRU: Magnetic resonance urography, CT: Computed tomography

Table 9: Comparison of diagnosis on computed tomography scan and magnetic resonance urography in symptomatic subgroup

Symptoms	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy	*K*	*P*
Acute flank pain	64.7	100	100	71.4	81.2	0.63	0.001
Obstructive uropathy	91.6	90	91.6	90	90.9	0.79	0.001
Hematuria	77.7	100	100	77.7	87.5	0.75	0.002

PPV: Positive predictive value, NPV: Negative predictive value

of collecting system and perinephric edema which was similar to our study.

In calculus without obstruction subgroup, all the 4 cases of renal calculus were correctly diagnosed on MRU with a sensitivity of 100% and specificity of 98.4%.

In our study, out of 4 cases of calculus with size <6 mm, only 2 (50%) were detected on MRU while out of 23 calculus with size >6 mm, 16 (70%) were detected correctly on MRU. This result is in line with a study of Kalb *et al*.[15] that demonstrated that sensitivity of MRI increases with the size of calculus.

However, this is unlikely to affect the management as <6 mm are usually managed conservatively. Fielding *et al*.[12] described the significance of ureteric calculus size in management, stating that a ureteric calculus of <6 mm in length is well managed conservatively by its spontaneous expulsion while those with length more than 6 mm require intervention. Min *et al*.[2] in a study on 360 patients with UT stones also concluded that significantly higher incidence of urological intervention was seen in patients with calculus in upper ureter and in those with calculus >5 mm width and >6 mm length. Thus, in 20/27 (nearly 75%) patients, MRU could predict the future course of management. The calculus in distal ureter were the ones that escaped detection.

Ouzaid *et al*.[13] proposed that the attenuation value of 970 HU suggests inability to achieve stone disintegration with a lithotripter. In our study, we tried to correlate calculus attenuation on NCCT with intensity on MRU which revealed a SI of <515 for corresponding density of >970 HU.

In noncalculous obstruction group, all the 9 cases were correctly diagnosed by MRU including 8 cases with PUJ obstruction and one with ureterocele with 100% sensitivity and specificity. In a comparative study of NCCT scan and MRU done by Shokeir *et al*.[16] on 108 patients with hydronephrosis without calculus, 54 patient had ureteral strictures, out of which NCCT diagnosed 28% against 83% on MRU distinct advantage of MRU in UT strictures. Another study on patients with obstructive uropathy by Bafaraj[10] revealed that MRU accurately detected all causes of obstruction except calculus <3.8 mm thus inferring that though CT scan is more sensitive in detecting stones but MRU is superior in not only analyzing other pathologies as well as the evaluation of anatomic and vasculature details where contrast studies could not be performed.

In acute flank pain subgroup, out of 17 UT units only 11 cases (64.7%) were diagnosed by MRU showing a sensitivity and specificity of 64.7% and 100% respectively with calculus being the main cause. Our results are slight lower than that of Sudah *et al*.[1] with a minimum sensitivity of 93.8% and specificity of 100.0% primarily because they used MR contrast agent to perform excretory urography while be used heavy noncontrast, heavy T2W images.

Out of 12 UT units in obstructive uropathy, 11 disease units were diagnosed by MRU except a single case of calculus in distal ureter and one false positive case of distal ureteric calculus with a sensitivity and specificity of 91.6% and 90% respectively. Kadam *et al*.[17] in their study on 100 patients with obstructive uropathy concluded that MRU is better for diagnosis of mild to severe dilatation of Pelvic Congestion Syndrome (PCS) and can detect more than 85% UT stones in addition to other advantages.

In hematuria subgroup, 6/8 patients had obstructive calculi while one each had renal cell carcinoma and transitional cell carcinoma of urinary bladder. MRU could diagnose these patients with sensitivity of 77.7% and specificity of 100%. Sudah *et al*.[18] in their prospective study on 20 patients concluded that CT scan and MRU have equal diagnostic potential for both benign and malignant UT tumors. They also stated that MRU is excellent for imaging of ureter simulating excretory phase with no risk of radiation exposure. Martingano *et al*.[8] in their comparative study on CTU and MRU in claimed that though CTU provides better resolution of urothelial structures while but MRU permits greater diagnostic confidence with difficulty in distinguishing a calculus from tumor without contrast studies. However, they maintained that MRU has a potential role in UT imaging.

In our study, using CT scan was considered as gold standard similar to Semins *et al*.,[14] the analysis revealed the sensitivity of 76.32% and specificity of 96.88% in overall diagnosis of UT pathologies by MRU with an accuracy of more than 85%.

Although we have not included contrast MRU in our study, but Rouviere *et al*.(2020) [19] in a recent study have provided standardized protocols for the same as MRU is gaining more and more acceptance over CTU. In another recent by Damasio *et al*. (2019),[20] functional MRU have been found equivalent to renal scintigraphy in evaluation of UT in congenital anomalies of UT. All these recent studies add further value and uniqueness to our study as to the best of our knowledge, no other study had included the three subgroups together. Analyzing only single group based on patient complaint or symptoms does not highlight the complete diagnostic capability of any modality.

Limitations of the study

- The sample size for the study was small due to time-bound nature
- Number of patients in each group were small
- Causes of UT obstruction and hematuria other than calculus, like UT tumors were limited
- Surgical correlation was not done in our study.

Conclusions

- Males outnumbered females in presenting with urological diseases with maximum in 31–40 years of age group
- Acute flank pain is the most common complaint with hematuria being the least common
- Calculus in the UT is the most common cause of urological symptoms. CT scan is more sensitive in detecting urinary stones compared to MRU. Though sensitivity of MRU for detection of calculus is moderate (66.7%) but specificity is very high being 97.7%
- In noncalculus obstruction as well as in UT tumors, CT scan and MRU are equivalent in diagnostic accuracy
- Though detection of small calculi on MRU is difficult but presence of secondary signs of obstruction like proximal dilatation, thickening of ureter or perirenal edema are better evaluated on MRU
- Though the overall sensitivity of MRU in different subgroups is moderate (76.3%) but its specificity very high being 96.9%.

Summary

Urological diseases present with numerous complaints, mainly grouped into acute flank pain, obstructive uropathy and hematuria. Although CT scan is the imaging modality of choice in acute flank pain due to its exquisite ability to detect even tiny calculus but is limited by its radiation concerns and risk of contrast injection.

In recent, there is a growing awareness of utilizing MRU in UT pathologies as it has the advantage of being noninvasive without the risk of contrast injection and radiation exposure allowing it to be performed in young children as well as in pregnant females. In addition, MRU is very accurate in detecting the consequences giving better information about dilatation of PCS, perirenal edema and fat stranding.

Both CT scan and MRU are equally accurate in UT pathologies other than calculus such as PUJ obstruction, ureterocele, and UT tumors not only for diagnosis but also in follow-up. In fact, many studies including ours show that MRU should be used as the only investigation in patients with obstructive uropathy and hematuria.

Although in developing country like India, the accessibility and expenses may be significant restraining factors for MR urography but in a tertiary healthcare centers, its judicious use would allow timely management of patients.

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Conflicts of interest

There are no conflicts of interest.

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