ROLE OF MULTIDETECTOR CT UROGRAPHY IN EVALUATING PATIENTS WITH HAEMATURIA

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ABSTRACT

Haematuria is one of the commonest manifestation of urinary tract pathologies and requires thorough diagnostic workup. MDCT urography with its faster speed and multiplanar capabilities has become the investigation of choice in such cases.

OBJECTIVES

Our study was done with the aims of assessing the role of CT Urography in detecting the entire spectrum of urinary tract diseases causing haematuria and also to establish whether this single investigation suffices in directing the right management strategy in all these patients.

MATERIALS AND METHODS

This prospective study of 105 patients presenting with haematuria was done at a tertiary care government hospital at Nagpur over a period of two years. Two phase acquisition protocol (Split Bolus technique) with saline distension was done in the majority of cases. Separate cortico-medullary phase images were acquired in cases of renal neoplasms for their better characterization. Images were viewed in axial as well as with 3D reformatted coronal planes.

RESULTS

Split bolus MDCT Urography with saline distension provided at least 50% opacification of urinary tract in about 94.8%. Major causes of haematuria in our study were urolithiasis (25.7%), Urothelial tract and bladder neoplasms (23.8%) followed by renal neoplasms (16.2%). Developmental anomalies, infections and trauma were some other aetiologies. The overall sensitivity for upper urinary tract evaluation was 100%, while that for lower urinary tract was 88.4%. The overall positive predictive value was 97.4% in diagnosing haematuria by MDCT Urography.

CONCLUSIONS

CT Urography is highly accurate in evaluation of haematuria and definitely has potential to be one stop shop in evaluation of patients with haematuria. With the use of properly tailored protocols, the issue of radiation exposure can be addressed.

KEYWORDS

MDCT Urography, Haematuria.

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INTRODUCTION

Haematuria is one of the most common presentations of urinary tract pathologies and always warrants serious concern, both to the patient as well as the treating physician.[1,2] The advanced multidetector CT scanners.[3,4] with its superior spatial resolution, higher speed and isotropic reconstruction capability has ushered in a revolution in diagnostic imaging of urinary tract disorders. MDCT urography provides a detailed anatomic depiction of the entire urinary tract in a single breath hold, thus allowing patients with haematuria to be evaluated comprehensively.[5] The superior spatial resolution allows excellent 3D multiplanar reformats.[6] Lately, it has almost supplanted the conventional urography in evaluation of the urinary tract.[3,4,5,6,7]

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AIMS AND OBJECTIVES

- To study the accuracy of CT urography in identifying various pathologies of urinary tract causing haematuria.
- To study the spectrum of imaging findings in patients presenting with gross as well as microscopic haematuria.
- To study whether with a single investigation of CT Urography can assist in formulating the right management strategy in every patient of haematuria.

MATERIAL AND METHODS

Study Design

Prospective study, hospital-based study of patients with haematuria was done at a tertiary care institute.

Study Settings: Dept. of Radiodiagnosis, IGGMCH, Nagpur.

Study Period: Sept. 2009-August 2011.

Study Population: 105 patients of all ages referred by the clinicians.

Inclusion Criteria

1. Complaints of gross haematuria.
2. Documented unresolving microscopic haematuria with associated significant risk factors for developing urologic disease.

3. Patients with haematuria who were suspected to have some urinary tract pathology on other modalities and were then referred for CT Urography.
4. Patients whose complete medical or surgical treatment follow-up was available.

Exclusion Criteria

1. Patients lost to follow-up.
2. Patients whose haematuria resolved on subsequent clinical and post medical treatment follow-up.
3. Patients whose serum creatinine value was above 1.5 mg/dL.
4. Patients known to be allergic to ionic or non-ionic contrast media.
5. Pregnant patients.

Equipment

1. Somatom Emotion Duo CT Scanner; Siemens Medical Systems, Forchheim, Germany.
2. Medrad Vistron Pressure Injector.

CT Urography Protocol

- Patient is advised to be nil by mouth six hours before the study.
- Water (800-1000 mL) was given as negative contrast medium.
- An initial supine AP scout film with 100 mA was obtained to confirm the tomographic plane.
- Precontrast scan was done in supine position using 5 mm collimation (100 mA, 120 Kv, pitch 6) from the domes of diaphragm to the base of the bladder.

A. The Two Phase (Pre-Contrast and Combined Nephropyelographic and Excretory Phase or "Split Bolus" Post Contrast) Acquisition Protocol.[5,8,9,10,11]

- Initially, a bolus of 30 mL of 300 mg/mL iodinated non-ionic contrast (Inj. Iomeron Bracco, Italy) given intravenously.
- After this, 250 mL of normal saline was administered intravenously over the next 8-10 minutes for better delineation.[11] and opacification of ureters.
- Dynamic contrast enhanced scanning using 3 mm collimation (mAs 150, kV 120) was now performed following administration of additional 80 mL contrast at 2.3 mL/second after a start delay of 80 seconds.

This split bolus two-phase CT Urography technique allowed acquisition in the nephropyelographic phase and was done in the majority of patients.

Parameters	Value
Collimation	3 mm
Reconstruction Increment	1 mm
mAs	150
KV	120
Table Feed	4 mm

B. The Three Phase Protocol: Separate Cortico-Medullary, Nephro-Pyelographic and Excretory Phase Acquisition.[12]

(For Renal Masses, Trauma Cases and those with Suspected Vascular Anomalies we followed this Protocol).

- Initial bolus dose not given.
- Instead, a total of 100 cc of 300 mg/mL intravenous contrast was administered at a rate of 2.3 mL/sec by a pressure injector after a start delay of 24 seconds, 80 seconds and 180 seconds for acquisition of the above phases respectively.
- All the other technical parameters were kept similar to that in the two-phase protocol.

Post Processing and Image Analysis

Coronal and sagittal reformation of the images was done using Maximal Intensity Projection (MIP), Multiplanar Reformation (MPR) and Volume Rendering Technique (VRT).

The axial as well as reformatted coronal and sagittal images were viewed on a workstation for evaluation.

The images were converted from Dicom to JPEG format using E-film software for storage.

Follow-Up

A meticulous follow-up of all 105 patients was kept. The standard of reference included all available, clinical, lab results, histopathological and operative findings as well as other imaging modalities like Ultrasound as well as cystoscopy, ureteroscopy, DSA, etc.

The M/T strategy was determined by the clinical judgement of the referring physician.

RESULTS

Sl. No.		No. of Cases	Percentage
1.	Number of abnormal scans	93	88.6%
2.	Number of normal scans	12	11.4%
	Total	**100**	**100%**

Table 1: Incidence of Abnormalities on CT Urography

Final Diagnosis	Modality Used	No. of Patients
TCC Bladder	Cystoscopic Biopsy	3
TCC Lower Ureter	Ureteroscopic Biopsy	1
Intrarenal Arterio-Venous Malformation	Digital Subtraction Renal Angiography	2
Indeterminate	Relevant According to Clinical Presentation	6
Total		**12**

Table 2: Final Diagnosis of Haematuria Cases with Normal CT Urography

Thus, the sensitivity of CT Urography in identifying a pathology for haematuria was 93.93% and the positive predictive value was 100%, while the specificity was also 100% and the negative predictive value was 50%.

Sex	No. of Cases	Percentage
Male	68	64.8%
Female	37	35.2%
Total	**105**	**100%**

Table 3: Gender Distribution of Cases

Pathologies	Gross Haematuria	Microscopic Haematuria		Total
		Asymptomatic	Symptomatic	
Urolithiasis	9	0	18	27 (25.7%)
Urothelial Tract and Bladder Neoplasms	10	6	9	25 (23.8%)
Renal Parenchymal Masses (Benign and Malignant)	8	5	4	17 (16.2%)
Developmental anomalies	1	4	2	7 (6.7%)
Infection	2	0	5	7 (6.7%)
Trauma	5	0	1	6 (5.7%)
Vascular Malformations	0	2	0	2 (1.9%)
Extraurinary Tract Pathologies	2	0	0	2 (1.9%)
No Cause Found	1	11	0	12 (11.4%)
Total	**38**	**28**	**39**	**105**

Table 4: Distribution of Pathologies According to the Type of Haematuria on CT Urography

Calculus disease was most commonly encountered in young and middle age group (16-45 years), 17 (63%) cases out of 27.

Non-neoplastic lesions were more common in younger age group (<45 years), while neoplastic lesions were common in older age group (>45 years). Urothelial tract and bladder neoplasms were significantly more common in males, 20 cases (80%) out of 25 as compared to in females, 5 cases (20%).

Site	No. of Patients
Renal Pelvis	4 (16%)
Ureter	4 (16%)
Bladder	14 (56%) (1 benign, 13 malignant)
Multifocal	3 (12%)
Total	**25 (100%)**

Table 5: Distribution of Urothelial Tract and Bladder Neoplasms

TCC was the commonest histopathological type of bladder malignancy encountered constituting 96% of the total, while only one case (4%) was of squamous cell carcinoma and 1 case (4%) was of bladder papilloma.

Urothelial tract thickening was more common in pelvicalyceal system lesions, 2 (66.7%), while endoluminal filling defect was common in ureteral lesions, 3 (100%). We encountered 3 lesions with an infiltrative pattern of growth; 1 lesion at the pelviureteric junction was included in the pelvicalyceal system lesions. Out of the 5 ureteral neoplasms, 3 were in the lower ureter, while 2 in the upper. Thus, there were 6 upper tract and 3 lower tract neoplasms in all; 1 out of 5 ureteric neoplasms was multifocal with another lesion in bladder.

We could identify 9 out of 10 urothelial tract malignant lesions on CT urography; 1 lesion was diagnosed as lower ureter TCC on ureteroscopic biopsy performed in a patient of haematuria with normal CT Urography examination out of the 9 lesions diagnosed to be malignant on CT Urography, 1 lesion in the lower ureter turned out to be a blood clot on ureteroscopic biopsy and another lesion was an inflammatory focal thickening in the renal pelvis on histopathology).

Thus the overall sensitivity, positive predictive value, specificity and negative predictive value in identifying a urothelial tract neoplasm in our study was 87.5%, 77.8%, 66.7% and 80% respectively. These values were 100%, 83.3%, 75% and 80% respectively for upper tract tumours and 66.7%, 50%, 66.7% and 50% for lower tract tumours respectively.

	Type	No. of Patients	Percentage	Total
Malignant	RCC	5	29.4%	11 (64.7%)
	Wilms'	3	17.6%	
	Lymphoma	2	11.8%	
	Sarcoma	1	5.9%	
Benign	AML	2	11.8%	6 (35.3%)
	Complex cyst	3	17.6%	
	Oncocytoma	1	5.9%	
	Total	**17**	**100%**	

Table 6: Distribution of Renal Parenchymal Neoplastic Lesions

In our study, we could identify all renal parenchymal benign and malignant lesions which were a potential cause of haematuria of varying degrees in these patients. We could also stage the malignant lesions with fair degree of accuracy. We could identify one subcentimeter sized RCC's and one subcentimeter sized lymphoma in our study. One patient with renal cell sarcoma actually had a high-grade TCC on histopathological examination. We had 100% sensitivity and 94.1% positive predictive value in diagnosing renal parenchymal masses by CT urography.

Sl. No.	Developmental Anomaly	Actual Cause of Haematuria	No. of Cases	Total
1	Horseshoe Kidney	Neoplasm	1	5
		Trauma	1	
		Calculus	1	
		No Cause	2	
2	PUJ Obstruction	Calculus	2	5
		Trauma	1	

		Infection	1	
		No Cause	1	
3	Duplication	Calculus	1	2
		No Cause	1	
4	Adult polycystic Kidney	-	2	2
5	Ectopic Kidney	No Cause	1	1

Table 7: Spectrum of Developmental Anomalies Encountered

Horseshoe kidney and pelviureteric junction obstruction were most commonly seen anomalies. The above table shows that 8 of the 15 patients with developmental anomalies had some predisposing cause for haematuria.

	No. of Patients	Percentage
PCS Rupture	4	66.7%
Parenchymal Laceration	5	83.3%
Ureteric Laceration	1	16.6%
Perinephric Collection	5	83.3%
Periureteric Collection	1	16.6%
Parenchymal Devascularisation	4	66.7%
Pedicle Avulsion	0	0

Table 8: Findings in Patients with Urinary Tract Trauma (N=6)

Parenchymal laceration and perinephric collection were most commonly encountered, both occurring in 83.3% of trauma cases. Parenchymal devascularisation suggested by non-enhancing areas was seen in 66.7% of the patients.

Type	No. of Patients	Percentage
Tuberculous	3	42.9%
Gram Negative	4	57.1%
Total	**7**	**100%**

Table 9: Aetiology of Infections Encountered in CT Urography

Pelvicalyceal thickening along with ureteric thickening were the most common findings and were noted in all three patients with tuberculous infection. Other findings were focal caliectasis in two patients, parenchymal and ureteric calcification and ureteric calcification, ureteric stricture and infundibular stenosis leading to phantom calyx and caseous abdominal lymph node seen in one patient each.

Focal parenchymal hypodensity and mucosal thickening are seen in 50% of cases with gram negative infection of the urinary tract. Ureteric thickening and Caliectasis were seen in one patient each. In all four patients, urine culture and microscopy established the diagnosis.

Anomaly	No. of Patients
Small Pseudoaneurysm of Intrarenal Artery	1
Isolated Right Renal Vein Thrombosis	1
Total	**2**

Table 10: Spectrum of Vascular Anomalies on CT Urography

In two patients presenting with asymptomatic microscopic haematuria, one of which was a post biopsy status, CT revealed a small traumatic pseudoaneurysm of the lower pole intrarenal segmental artery, while another patient had an isolated renal vein thrombosis, later found out to be due to Protein C deficiency causing hypercoagulable state. The patient later also developed left lower limb deep venous thrombosis.

Pathology	No. of Patients
Advanced Malignancy of Cervix with Direct Extension to the Base of Bladder	1
Metastatic Retroperitoneal Lymph Nodal Mass Directly Invading the Kidney	1
Total	**2**

Table 11: Spectrum of Extraurinary Tract Pathologies causing Haematuria

Sl. No.	CT Urography	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
1.	Urolithiasis	100%	-	100%	-
2.	Urothelial Tract Tumours				
	a. Upper Tract	100%	75%	83.3%	80%
	b. Lower Tract	66.7%	80%	66.7%	80%
	c. Overall	86.5%	76.7%	77.8%	80%
3.	Urinary Bladder Tumours	80%	-	75%	-
4.	Renal Parenchymal Masses	100%	-	94.1%	-
5.	Asymptomatic Microscopic Haematuria				
	a. Upper Tract	91.7%	100%	100%	85.7%
	b. Lower Tract	60%	100%	100%	60%
	c. Overall	77.3%	100%	100%	54.5%
	Overall Accuracy in Identifying a Pathology	**93.9%**	**100%**	**100%**	**50%**

Table 12: Statistical Analysis

DISCUSSION

Haematuria is a common clinical problem with prevalence rate of 9-18% and can originate from any site along the urinary tract and whether gross or microscopic may be a sign of serious underlying disease including malignancy. The incidence of asymptomatic microscopic haematuria in general population varies from 0.9% to 21%.[13] Although ultrasound is very effective in detecting renal cystic lesions, this modality also has poor sensitivity for detecting solid renal lesions less than 3 cm.[13] MRI has been recently used to evaluate the urinary system.[14] However, the inability of MRI to pick up calcification is an inherent drawback of this modality in its utility in diagnosing urinary pathologies. Also the cost and lack of easy availability restricts its use. At present the use of MR urography is limited to children, pregnant women, in renal insufficiency and in patients with contrast allergy.[14]

The ability of CT urography to evaluate the renal parenchyma as well as the urothelium in a single investigation has prompted many authors to moot it as a potential one stop investigation for the spectrum of urinary tract disorder with haematuria.[5,8,9] During this prospective study, 105 patients with haematuria underwent CT Urography at the Department of Radiodiagnosis of our institute over a period of 24 months from November 2009 to October 2011.

Out of the 105 patients referred for CT Urography (CTU), 93 were found to have positive findings on CT urography concerning the high percentage of identifying pathological findings (Sensitivity 93.9%, positive predictive value 100% and specificity 100%) among the patients with haematuria in our study, it should be under consideration to have CTU as the first line diagnostic tool.

CT Urography is the best diagnostic tool for detection of urolithiasis.[15,16] and can accurately diagnose the complications associated with the same as well as adequately comment on renal excretory function, which is of prime importance for the treating urologist.

Our CT urography protocol was 87.5% sensitive and 77.8% positively predictive for urothelial tract malignancies with these values being 100% and 83% for upper tract and 66.7% and 80% for lower tract, thus establishing the fact that CT Urography is a highly accurate modality of investigation for upper urothelial tract pathologies with propensity to detect even subtle urothelial tract thickening and hence facilitating detection of malignancies in their early stages. For lower urinary tract, however, the sensitivity of examination would approach nearly 100% if CT is combined with ureteroscopic examination. The poor sensitivity of CT Urography would be due to relatively poor distension and opacification of lower ureters in some patients. Further refining of CT urography protocols and newer scanners with more detector rows and faster scan times by improving the spatial resolution may settle the issue to some extent.

Our study was 80% sensitive and 75% positively predictive in the detection of bladder tumours. Although CT has been shown to detect bladder lesions with sensitivities up to 90–95% using specialized virtual cystography and reconstruction techniques, our protocol was not routinely performed on patients with haematuria at our institution. Small tumours at the ureteral orifices were missed, possibly due to the normal protrusion that is often seen in that region. Mixing artifacts within the bladder can also result in false-positive and false-negative interpretations. Despite the improvements in CT spatial resolution, the use of an anatomic imaging approach will not provide the ability to identify the presence of flat bladder tumours, such as carcinoma in situ. Conventional cystoscopy still remains the gold standard for evaluation of the bladder urothelium and patients with haematuria should ideally undergo both CT urography and conventional cystoscopy.

The split-bolus protocol also accurately detected all instances of renal cell carcinoma, which were not previously diagnosed or suspected clinically suggesting that synchronous acquisition of nephrographic and excretory phases does not compromise the ability to visualize the renal parenchyma. However, we also made use of the triple phase protocol with initial acquisition in cortico-medullary phase, so as to stage the tumours once they are detected and such patients did not require any additional study for staging.

However, the benefit of reduced radiation dose to most patients who had no malignancy outweighs the inconvenience of possible reimaging with triple phase protocol to the few patients with malignancy.[5]

We have found that it remains imperative that the axial source images are viewed and interpreted and that appropriate tailored window and level settings be used when evaluating the collecting system and ureters, so that dense intraluminal contrast material does not obscure fine urothelial detail and potentially small urothelial lesions. Having said so, the 3D reformatted images are imperative in making a diagnosis and also to convey information to the referring clinicians in a more user friendly manner.

Developmental anomalies of the urinary tract along with their complications are very well depicted by CT urography. CT urography precisely grades urinary tract trauma playing a crucial role in the management of such patients.

CT urography plays an important role in detecting the features as well as complications of both tuberculous and pyogenic infections of the urinary tract.

In summary, we have shown that a split-bolus protocol for CT urography can be used successfully to evaluate for urinary tract calculi, renal abnormalities and urothelial lesions in one simple, non-invasive examination. Although this study did not include a direct comparison between this technique and other MCDT urography protocols, our data suggests that the sensitivities and specificities in detecting a variety of abnormalities are comparable to other protocols. The split-bolus protocol reduces radiation dose to patients and results in a smaller number of images for interpretation compared with other MDCT urography protocols. Given the significant advantages of this protocol, we believe that it has potential as an alternative to existing MDCT urography protocols and IVU for the evaluation of the urinary tract.

LIMITATIONS

1. Lack of adequate contrast opacification and distention of the urinary tract. In such cases, subtle intrinsic lesions causing tiny filling defects may be missed. Though various modifications to increase ureteric opacification are being tried, a consensus is yet to be reached regarding the best method.
2. Radiation dose remains a concern for multiphase CT urography.[16] However, two phase CT urography protocol used in this study significantly reduces the radiation dose.

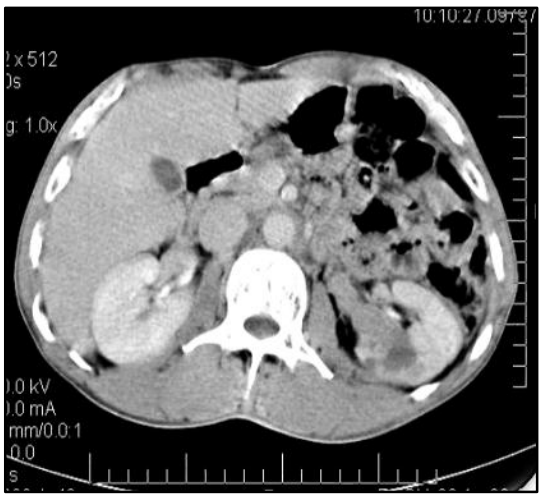
3. Accuracy is limited for lower urinary tract pathologies.

CONCLUSIONS

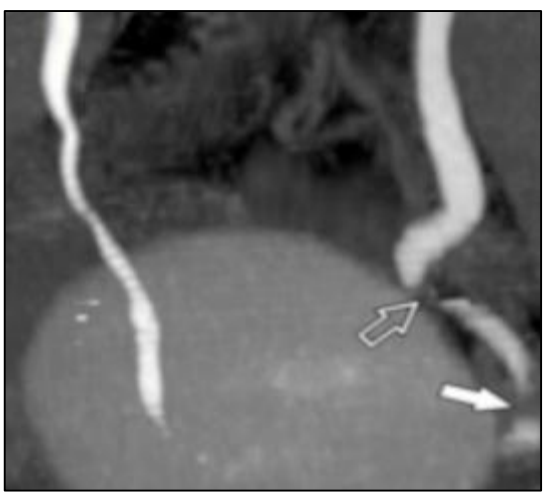
- Multidetector CT urography detects with high accuracy the entire spectrum of urinary tract pathologies causing haematuria.
- The two phase protocol evaluates both the renal parenchymal and urothelial pathologies in a single investigation reducing significantly the radiation dose to the patient.
- Thus, multidetector CT urography has the potential to become a one stop shop for evaluation of urinary tract, especially in cases of haematuria.[17]

Case 1: 3D Reformatted Coronal MIP Image showing the Right Ureteric Calculus, causing Upstream Obstructive Hydronephroureterosis and Normal Excretion of Right Kidney Normal Excretion of Right Kidney

Case 2: Acute Obstruction due to Left Ureteric Calculus

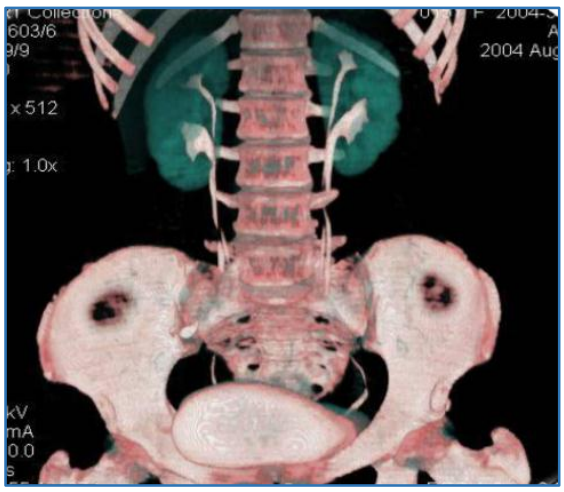


Case 3: Axial Image in Patient showing Infiltrating Left Renal Pelvic Hypodense Lesion with Deranged Excretory Function Renal Pelvicalyceal TCC



Case 4: Coronal Reconstructed Thin MPR Image showing Stenosing Lesion of the Left Ureter with Periureteric Soft Tissue (White Arrow). Ureteric Peristalsis shown by Open Arrow. Ureteric TCC

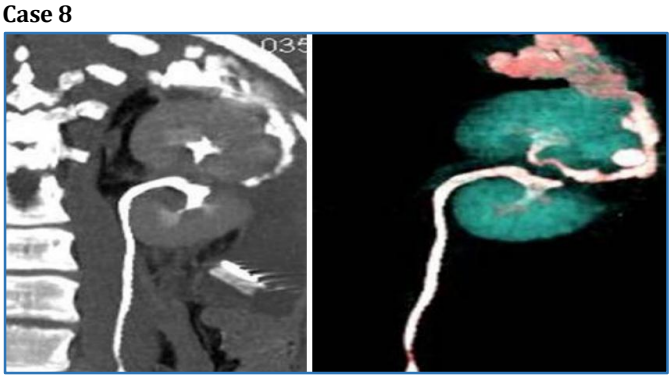
Case 5: Coronal Reformatted MPR Image showing Two Nodular Hypodense Lesions at the Base of Bladder Multifocal Papillary TCC



Case 6: Double Moiety of Ureters as seen on VRT Images

Case 7: Oblique MPR Image showing Hydronephrotic Kidney with Parenchymal and Ureteric Calcifications

Case 8



Left Renal Trauma

a) Coronal MPR image showing a laceration through the interpolar region with contrast extravasation and perirenal haematoma.

b) Volume rendered coronal reformatted image of the same. AAST Grade III renal injury. (AAST - American Association of Surgery in Trauma).

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