Original article:

Computed Tomographic urography - A boon to renal enigma

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Abstract:

Objective: Patients with suspected urinary tract disease are often referred for multiple studies such as excretory urography (EU), ultrasound (US), computed tomography (CT) or magnetic resonance imaging (MRI). With the recent development of multislice helical CT, many institutions have started to evaluate the use of CT as a single imaging test that partially or completely replaces EU. This study aims to formulate a protocol for identifying the key imaging features in patients with urinary tract diseases.

Material & Methods: Total 100 patients suspected of having urinary tract disease were evaluated with 64 slice multidetector helical computed tomography (MDCT).

Results: Overall male patients (64%) complained more of urinary tract diseases than females (36%).80% patients had positive CT urographic findings based on clinical symptoms. Of these 100 patients, 32 cases were proved to have renal and ureteric calculi and 2 cases of bilateral nephrocalcinosis(medullary calcification) and computed tomographic urography (CTU) correctly diagnosed 32 of 32 renal and ureteric calculi (100%) and 2 cases of bilateral nephrocalcinosis. 6 of 34 patients (17.6 %) had both uretric and renal calculi. 20 cases were proved to have renal cell carcinoma and CTU correctly diagnosed 20 of 20 cases of renal cell carcinoma(100%). CT urogrphy diagnosed 10 cases of congenital disorder (2 renal agenesis , 4 horseshoe kidneys , 2 ectopic kidney, 2 polycystic kidneys) and 4 patients of infectious disease, emphysematous pyelonephritis.

Conclusion: CT urography is exceptional in diagnosing urinary tract abnormalities, urothelial malignancies, Multiple infectitious diseases, renal transplant kidney &, renal injuries.

Keywords: CT Urography, Nephro-urolithiasis, Urothelial malignancies,Urinary tract congenital anomalies.

Introduction

CT is already widely acknowledged to be superior to EU and US in its ability to detect and characterize renal masses [1, 2]. Recently, its superiority in detecting urolithiasis compared with EU, US and MRI (which cannot directly image calcification) has also been accepted [3, 4]. The last remaining potential limitation of CT for examination of the urinary tract is its perceived limited accuracy in assessment of the mucosal surfaces of the renal collecting systems and ureters.

This study highlights recent developments in the use of multislice CT for complete evaluation of the urinary tract, usefulness of the post processing tools

in CT urography & to formulate a protocol for the evaluation of the urinary tract diseases by identifying the key imaging features.

Methodology:

A detailed prospective CTU of 100 patients suspected of having urinary tract disease conducted at our institute, Geetanjali Medical College and Research Institute, Udaipur.These patients were selected on the basis of clinical criteria, which suggested the presence of urinary tract disease. All the patients were referred from almost all the departments, mainly medicine & surgery and evaluated with
64 slice multidetector helical computed tomography (MDCT) over a period of year from June, 2014 to June, 2015.

Method of examination:

Patient preparation:

History and physical examination of all patients was systematically carried out. All patients were required to be nil by mouth at least for 4 hrs prior to the examination.

Patient position:

Patient was placed supine on the computed tomography table :

Head was immobilized with headrest .

Hands were folded above the shoulder around the head .

Appropriate positioning with the help of laser marker with respect to the field of interest.

Topogram :

A scout topogram was obtained from just above domes of diaphragm up to the symphysis pubis (Region of interest).

Technical consideration:

All patients underwent CT scan at our department , and the following parameters were employed.

Scan parameters

500- 700 MA (miliamperes) / 120- 140 (KV) kilovoltage.

Precontrast contiguous sequential scans and slices of 5 mm thickness were taken .

Post intravenous contrast :

A bolus of 70 ml of non-ionic contrast ultravist (iopromide – 370 mg of iodine/ml) was injected at 2.5ml / sec
via a pressure injector.

Pitch - 1.375:1

Reconstruction interval - 0.625 - 1mm

Region scanned - from just above domes of diaphragm to symphysis pubis

Phases of acquisition :

Precontrast scan : Precontrast scan was performed from just above diaphragm to the symphysis pubis .

Post contrast scan : Three phases were acquired .

Cortico-medullary phase (25-70 sec)

Nephrographic phase(90-180 sec)

Excretory phase (> 180 sec , at 450 & 750 sec)

Excretory phase scans were taken at 450 and 750 secs for the complete opacification of the ureters.

Tailoring the examination to the working clinical diagnosis by optimizing constituent factors (e.g. timing of acquisition , oral contrast used , rate of contrast material administration , collimation and table feed.) Multiplanar reconstruction (MPR) and post processing was done in all cases.

A systemic approach was adopted while evaluating scans. All the scans were evaluated to

1. Localize the lesions , define extent and identify site of origin.
2. Characterize the nature of lesions.
3. All the lesions were followed up , correlated with clinical history , hematological and biochemical

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investigations. Per-operative / histological confirmation was achieved wherever needed.

The lesions were classified into congenital, infective, neoplastic and other acquired diseases.

A valid surveillance protocol was formulated. **(Table1)**

Table I

Protocol for CT urography

	64 ROW MULTISLICE CT SCANNER
Area scanned	Unenhanced- abdomen and pelvis Enhanced – abdomen and pelvis
Kvp/ mAs/ rotation per second	120-140/ 300/ 0.5
Section thickness	5 mm both in the precontrast and post contrast scan
Pitch	1.375:1
Reconstruction level	0.625- 1mm
Intravenous contrast media /dose	ultravist – 370mg iodine/ml of iodine / 70 ml
Injection rate per sec	2.5 ml / sec
Scan delay	25 -70sec for cortico-medullary phase 90-180 sec for nephrographic phase > 180 sec for excretory phase At 450 & 750 sec
3D technique	Volume rendering and maximum intensity projection

Observations and results

We have prospectively studied 100 cases of CTU at our institute over a period of year. Results can be summarized as follow:

Overall male patients (64%) complained more of urinary tract diseases than females.(36%).

80% patients had positive CT urographic findings based on clinical symptoms**.(Table 2).**

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Table-2

Imaging diagnosis

CT UROGRAPHY DIAGNOSIS	TOTAL NO OF PTS	PERCENTAGE
ECTOPIC KIDNEY	2	2%
HORSESHOE KIDNEY	4	4%
RENAL AGENESIS	2	2%
POLYCYSTIC KIDNEYS	2	2%
PUJ OBSTRUCTION	2	2%
ONLY RENAL CALCULI	14	14%
ONLY URETERIC CALCULI	12	12%
RENAL + URETRIC CALCULI	6	6%
BILATERAL NEPHROCALCINOSIS	2	2%
EMPHYSEMATOUS PYELONEPHRITIS	4	4%
RENAL CELL CARCINOMA	20	20%
URINARY BLADDER MALIGNANCY	8	8 %
URINARY BLADDER PAPILLOMA	2	2%
NORMAL	20	20%

Of these 100 patients, 32 cases were proved to have renal and ureteric calculi and 2 cases of bilateral nephrocalcinosis(medullary calcification) .CTU correctly diagnosed 32 of 32 renal and ureteric calculi (100%) and 2 cases of bilateral nephrocalcinosis **.** 6 of 34 patients (17.6 %) had both uretric and renal calculi. 20 cases were proved to have renal cell carcinoma

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. CTU correctly diagnosed 20 of 20 cases of renal cell carcinoma(100%). Renal diseases were more identified than the other urinary tract diseases.

Calculus diseases were more seen as compared to the other urinary tract diseases. Renal calculus disease was slightly more than the other calculus disease. CT urogrphy diagnosed 10 cases of congenital disorder (2 renal agenesis **[Figure 1]** , 4 horseshoe kidneys**[Figure 2]** , 2 ectopic kidney**[Figure 3]**, 2 polycystic kidneys**[Figure 4]**) and 4 patients of infectious disease, emphysematous pyelonephritis. **[Figure 5]**

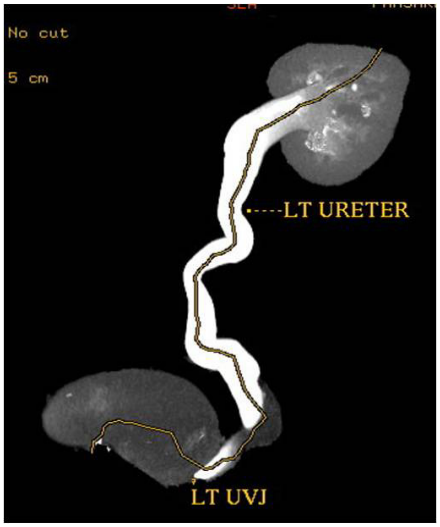

Fig.1 : Right renal agenesis

Fig.2 : Horse-shoe kidney

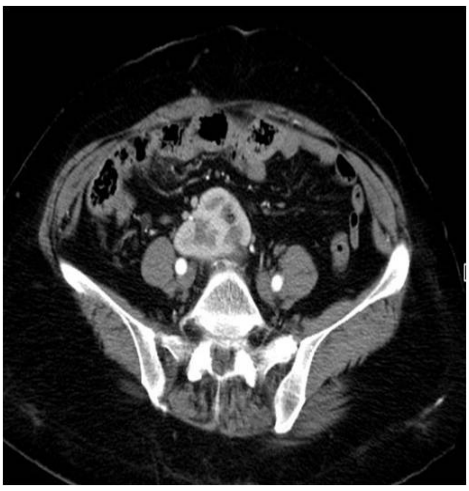

Fig. 3 : Ectopic kidney

Fig.4 : Polycystic kidney

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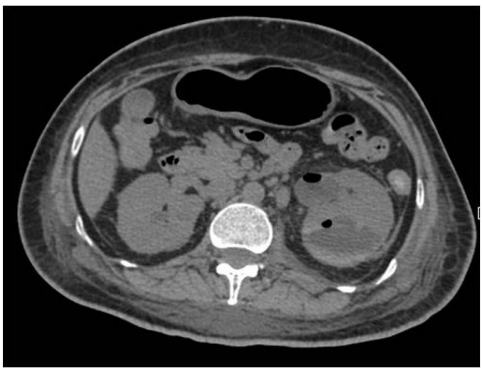

Fig. 5 : Small pockets of gas seen in the pelvis and renal parenchyma : Emphysematous Pyelonephritis .

Overall chances of malignancy increases significantly with increase in the age incidence .Most of the renal tumors showed predominant enhancement in the corticomedullary phase of the contrast study. & most of the urinary bladder tumors showed homogenous contrast enhancement . Almost all the CT urographic diagnoses were matched on per-operative / histopathological examination.

Discussion

Concept of urinary tract imaging include *(a)* unenhanced axial CT of the kidneys, *(b)* enhanced CT of the abdomen and pelvis, and *(c)* excretory phase enhanced images of the urinary tract obtained with axial CT images.

Detection of urothelial abnormalities with excretory phase enhanced CT requires visualization of the optimally distended and opacified collecting system as traditionally seen at EU. It is difficult to obtain a single set of images on which the collecting systems are completely opacified due to normal physiologic peristalsis of the intrarenal collecting systems and ureters. Several studies have shown that CT acquisition performed with abdominal compression improves opacification of the collecting system when compared to CT scans obtained without compression. [5,6] We performed maximum intensity projection and 3D reformatted CT urography images from axial thin-cut multi-slice images of 0.625 -1mm thickness , we were able to differenciate all the uroliths from the pelvic uroliths adjacent to the ureter. Hence 3D reformatted CT urography can provide more information in distinguishing phleboliths from renal stones than can conventional axial CT scan, by viewing the anatomic relationship with multiplanar images. Urinary stones can nearly all be seen on CT with the exception of stones due to protease inhibitors such as indinavir [7,8].

Renal and urinary bladder tumours:

CT urography also has good potential for diagnosing neoplasms in the urinary tract. In our 20 patients with clinical manifestations of urinary tract disorders, CT urography correctly detected 28 out of 30 patients with urinary tract tumors (20 renal cell carcinoma,8 transitional cell carcinoma of the urinary bladder).Two cases were given as papilloma on CT urography due to its morphology which was proved transitional cell carcinoma by cystoscopic biopsy .

Renal mass evaluation

MDCT detected 20 of 20 cases of renal cell carcinoma (100%).

The key imaging features were arterial phase enhancement of the tumor in the cortico-medullary phase with neovascularisation .

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MDCT identifies most renal masses missed on IVU or ultrasound. Furthermore, in patients scheduled to undergo partial nephrectomy or enucleation of a cortical mass, the relationship between the mass and the collecting system can be precisely evaluated by CT urography using the maximum intensity projection images or volume rending images . (Table 8).

Table 8

Differential diagnosis of solid renal lesions

Benign renal lesions: Noninvasive, no extracapsular extension	
Pseudotumor	Same enhancement pattern as renal cortex (renal columns, fetal lobulation, parenchymal scars)
Angiomyolipoma	Fatty areas (<-20 HU) accompanied by areas of soft-tissue attenuation
Lipoma	Fat attenuation only (<-80 HU)
Oncocytoma	Stellate central scar, nonhomogeneous enhancement pattern; differential diagnosis: renal cell carcinoma
Adenoma	<3 cm, nonspecific enhancement pattern; differential diagnosis: renal cell carcinoma; lesions 3 cm or larger are potentially malignant
Fibroma ,Hemangioma	<3 cm, nonspecific
Papilloma	Like renal pelvic carcinoma, but noninvasive; often multifocal (differential diagnosis: renal pelvic carcinoma

Malignant renal lesions: Invasive, possible extracapsular extension (grade T3 or higher)	
Renal cell carcionma	Usually hypervascular, rarely hypovascular; tends to infiltrate the renal vein
Nephroblastoma	Children; nonhomogeneous hypervascularity; often very large; tends to infiltrate the renal vein
Sarcomas	May be hypervascular; liposarcoma contains nonhomogeneous fatty components
Metastasis	Usually hypovascular, often bilateral, multifocal; primary tumor?
Renal pelvic carcinoma	Located in renal sinus; frequent pyelocaliceal obstruction; drop metastases
Lymphoma	Bilateral > unilateral; diffuse infiltration is common; abdominal lymphadenopathy; hypovascular

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However, CT urography is limited in detecting early neoplasms arising from the urothelial epithelium, which can be better demonstrated on uretero-cystoscopy

Congenital conditions:

Polycystic kidney disease:

We encounterd two cases of polycystic kidneys on CT urography. The key imaging features were bilateral enlarged kidneys with multiple cysts (10-30 HU) in the bilateral kidneys (size range 0.2 - 6 cm) . All the cysts were almost completely replacing the renal parenchyma . As the creatinine was high (3.1) , the contrast was not administered .

Multiple reformation images were obtained in the coronal , saggital and axial planes for the evaluation of the ureter and kidneys . However the optimal MIP images could not be achieved as the most of the field of view of ureters was obscured with the multiple cysts , non-contrast CT urography and non-dilated bilateral ureters.

Horse-shoe kidney :

CT urography detected 4 cases of horse shoe kidneys The key imaging features were fusion of the lower pole of the both kidneys in the midline joined by the enhancing renal parenchymal isthmus at the level of L3-L4 vertbrae.

Contrast-enhanced CT scanning has a high degree of accuracy in defining the structural abnormalities of horseshoe kidney, including the degree and site of fusion, the degree of malrotation, associated renal parenchymal changes (eg, scarring, cystic disease), and collecting system abnormalities (eg, duplex system, hydronephrosis). It can also be used to differentiate a parenchymal isthmus from a fibrous isthmus and to show the relation of the isthmus to surrounding structures.

Unilateral Renal Agenesis

CT urography detected two cases of renal agenesis . The key imaging features were complete absence of the right kidney and ureter with compensatory enlargement of the left kidney. The left ureter was dilated , however no acquired cause of calculus / stricture was discerned .

Ectopic kidney (pelvic kidney)

CT urography detected two cases of pelvic kidney .The key imaging features were absence of the right kidney in the right renal fossa and presence of normally located right adrenal gland.Post processing (maximum intensity projection , saggital and coronal) images were obtained which confirmed the pelvic location and aberrant renal vessels and insertion of right ureter .

Acquired puj obstruction (partial)

The CT urography detected two cases of acquired left partial PUJ obstruction.The key imaging features were dilated right pelvis with smooth tapered narrowing at the pelviureteric junction. The caliber of ureter distal to obstructon was normal.No calculus was seen at the pelvi-ureteric junction. On post contrast excretory phase contrast ,the right pelvis was dilated and contrast was seen in the ureter below the obstruction with normal caliber of the ureter.Most of the adults present with episodic loin pain. In some younger patients the pain may be located in periumbilical region. In many children, however the lesion is found incidentally.

Emphysematous pyelonephritis:

CT urography detected 4 cases of the emphysematous pyelonephritis.

The key imaging features were areas of bubbly air collection in the renal parenchyma , renal pelvis and in the perinephric space .CT is the modality of choice for emphysematous pyelonephritis..

In addition to above mentioned observed urinary tract diseases, many other urinary tract disorders can also be identified.

Ureteral duplication. CT urography can depict not only opacified ureters but also unopacified ureters not shown on IVU. Furthermore, CT urography can identify the location of ectopic ureteral insertion.

Medullary Sponge Kidney

The hallmark urographic finding of medullary sponge kidney is parallel striations of contrast material that extend peripherally from the surface of the papilla into the medulla and persist on delayed views . Excretory phase enhanced CT can demonstrate such striations particularly with thin-section scanning but is less sensitive than urography.

Urothelial Tumors

The urographic findings of ureteral transitional cell carcinoma include *(a)* a nonfunctioning kidney secondary to high-grade urinary obstruction (46%), *(b)* hydronephrosis with or without hydroureter (34%), *(c)* single or multiple ureteral filling defects with or without hydroureter and hydronephrosis (19%), and *(d)* fixation of the ureter with irregular narrowing of the lumen and nontapering. [9, 10]

Renal donor & transplant kidney evaluation and renal trauma

CT urography along with CT angiogram is an important indication for the assessment of the renal vessels and pelvicalyceal system for kidney donor and renal transplant patients . Renal injuries , mainly the pedicular injuries are well assessed by multi detector CT.

Limitations in interpreting multislice CT urography

The most common and perplexing problem that limits the diagnostic quality of multislice CT urography is **lack of adequate contrast opacification and distention of the upper urinary tract.** Ureteral non-opacification is a more significant problem when the unopacified segment is not dilated. This problem is not uncommon. It usually occurs as a result of peristalsis and is generally more common in the distal ureters. Another potential problem relates to the layering of contrast-enhanced urine dependent to unopacified urine in bladders and or full/dilated renal collecting systems. **Urothelial abnormalities are more difficult to detect if they are not outlined by opacified urine**. This problem could be reduced or eliminated by having the patient roll over several times to facilitate mixing of enhanced and unenhanced urine. This study shows that CT urography is exceptional in diagnosing urinary tract abnormalities, congenital anomalies, evaluating urothelial malignancies with synchronous or metachronous spread except in patients with deterioration of renal function or allergic history of contrast medium.

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