Imaging of hematuria patients by CT and MRI: An updated review of the literature

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Abstract:

Background: Hematuria has a wide prevalence rate in the population so it is a common reason for imaging of the urinary tract. Hematuria has many causes from urinary tract infections to malignancy. Imaging has a major role in the investigation of hematuria for determining the underlying cause and influencing management. Computed tomography (CT) and magnetic resonance imaging (MRI) is increasingly valuable tools for assessing the urinary tract in adults and children. However, their imaging capabilities, while overlapping in some respects, should be considered as complementary, as each technique offers specific advantages and disadvantages both in actual inherent qualities of the technique and in specific patients and with a specific diagnostic question.

Use of CT and MRI should therefore be tailored according to the patient conditions and the clinical question.

The present review aim toclarify role of CT and MRI for assessment and diagnosis of causes of hematuria and to study the CT and MRI features of various etiologies causing hematuria.

Key words: Hematuria, CT. MR.

Hematuria has a wide prevalence rate in the population, so it is a common reason for imaging of the urinary tract (**Sharp et al., 2013).**It must be underlined that hematuria may be determined by plenty of causes, many of which are insignificant (renal cyst, exercise, polyps, urethritis, urethrotrigonitis), others are significant and require observation (benign prostatic hyperplasia, papillary necrosis, trauma, arteriovenous fistula), some others are significant and require treatment (urolithiasis, vesicoureteral reflux, ureteropelvic junction obstruction, renal artery stenosis, renal vein thrombosis, renal infections), while the rest are life-threatening (malignancies, abdominal aortic aneurysm) (**Rossi et al., 2014**). Hematuria may be microscopic or gross hematuria. Microscopic is defined by the American Urological Association as 3 or more red blood cells per high power field on properly collected, non-contaminated urinalysis. Gross hematuria is defined as hematuria visible to the physician or patient(**Davis et al., 2012).**Gross hematuria has a high association with malignancy of up to 30-40%, and therefore all patients with gross hematuria need a full urologic workup. Conversely, patients with microscopic have a low risk of malignancy ranging from 2.6-4% (**Sharp et al., 2013).**

Currently there is no universal agreement about the optimal imaging work up of hematuria. The choice of modality to image the urinary tract will depend on individual patient factors such as age, the presence of risk factors for malignancy, renal function, a history of calculus disease and pregnancy, and other factors, such as local policy and practice, cost effectiveness and availability of resources(**Moloney et al., 2014).** Computed tomography (CT) and magnetic resonance imaging (MRI) are increasingly valuable tool for assessing the urinary tract in adults and children. However, theirimaging capabilities, while overlapping in some respects, should be considered as complementary, as each technique offers specific advantages and disadvantages both in actual inherent qualities of the technique and in specific patients and with a specific diagnostic question. The use of CT and MRI should be tailored according to the patient conditions and the clinical question **(Melanie 2011).**

Examination technique and imaging protocols of MDCT in hematuria patients:

CT plays an important role in hematuria investigation and has largely replaced the use of IVU. The emergence of multi-detector CT enables the concept of multi-phasic CTU. Multi-detector CT is capable of providing sub-millimetre-thin section images with higher spatial resolution at a faster rate compared to a single-detector CT. CT also allows three-dimensional (3-D) reconstructions of images, which is helpful to display any complex anatomy for surgical planning. The imaging protocol for CT should be tailored to specific diagnostic goals. In hematuria, commonly used phases with single bolus of contrast media are: (1) precontrast unenhanced phase, (2) nephrogenic phase and (3) excretory phase **(Kee et al., 2016).** The American Urological Association Best Practice Policy guidelines for asymptomatic microscopic hematuria published in 2012 indicates CT urography as the initial test for imaging of the upper tracts thanks to its highest sensitivity and specificity. For patients with relative or absolute contraindications to CTU, magnetic resonance urography is an acceptable alternative approach **(Davis et al,. 2016)**.

Radiation dose: Current multiphase CT urography protocols can be associated with effective doses as high as 25–35 mSv, depending upon the number of phases included. Substantial dose reduction currently cannot be recommended in cases of intrinsic urinary tract lesions. If the excretory CT phase is performed additionally in the tumor-staging protocol when obstruction of the urinary tract from the outside is suspected, substantial dose reduction may be reasonable. In a population with a high suspicion for or with known malignant disease, radiation dose plays only a relatively small role. However, for patients with benign diseases or for susceptible patient populations, such as children and young or pregnant women, dose is an issue. Strict indications for multiphase

CTU and reduction of the number of phases are important tools to manage this relatively high-dose examination. In consideration of five possible phases of renal CT (unenhanced, arterial, corticomedullary, nephrographic, and excretory phases), a selection has to be made for clinical indications to avoid accumulation of dose **(Rossi et al., 2014).**

Examination technique and imaging protocols of MRI in hematuria patients:

Indications of MRI in cases of hematuria included pregnant women, children, and patients requiring repeated examinations. Useful for patients with renal failure and for diagnosis of prostate cancer **(Lahkim et al., 2015).** Even if computed tomography (CT) is still playing the leader, the role of magnetic resonance imaging (MRI) is increasing, thanks to its better tissue contrast resolution and the absence of radiation exposure. Furthermore, MRI can be used as a problem-solving modality when CT findings are non-diagnostic **(Cova et al., 2014).**

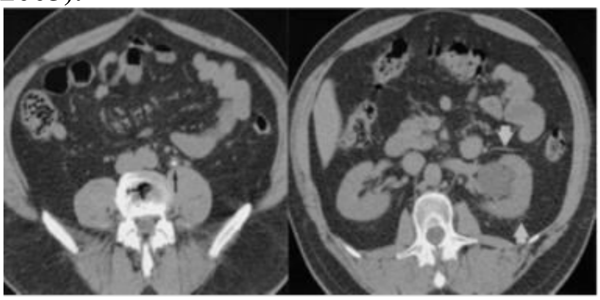
For the exploration of renal masses: Morphological Sq: T1, T2, T2 FS; IP / OP (in search of a fatty component). Gadolinium injection with dynamic Sq ++.

For exploration of the urinary tract: Sq in spontaneous contrast: Sq HASTE T2, T2 EG, T2 SE. Sq with injection of the contrast: Injection of lasix 5min or just before Gadolinium. Injection of gadolinium (0.05 or 0.1 mmol / kg) **(Lahkim et al., 2015)**.

The use of MDCT and MRI for specific clinical indicationsassociated with hematuria:

Urolithiasis:

Renal, ureteral, and bladder calculi are a common cause of hematuria. Twelve percent of people develop kidney stones at some point during their lifetime. The best imaging modality for evaluating calculi is unenhanced helical CT (**Niall et al., 1999**). Because MR is relatively insensitive for the detection of calcification, the diagnosis of ureteral calculi often relies on detecting secondary signs of obstruction such as ureteral dilatation and perinephric fluid; sometimes a persistent filling defect can be identified **(Joffe et al., 2003).**



(A) (B)

Figure (1) Unenhanced multidetector CT urography in a 46-year-old man with hematuria and colicky pain in left flank demonstrates left mid-ureteral calculus (**A**) with "tissue-rim sign" (arrow) and proximal hydronephrosis (**B**) with minimal perinephric fat stranding (arrows) **(Michael et al., 2004).**

Congenital anomalies of the kidney and urinary tract:

Some congenital anomalies of the urinary tract are associated with hematuria, such as polycystic kidney disease. During the work-up of patients with hematuria, anomalies may also be detected incidentally. Many congenital conditions of the urinary tract are demonstrated in utero on antenatal scans, whereas some are only detected in infancy or later due to subsequent complications (**jofee et al, 2003**).

CT arteriography (CTA) is sometimes performed in instances of known horseshoe kidney when surgery is being planned. This is to optimally delineate the multiple vessels that often supply these kidneys before surgery is undertaken. Pelviureteric junction obstruction can usually be diagnosed adequately on US, but a crossing vessel may be demonstrated by MRI, which cannot be visualized by US; in very gross hydronephrosis, MRI may give a better demonstration of the anatomy (**Calder et al., 2007).**

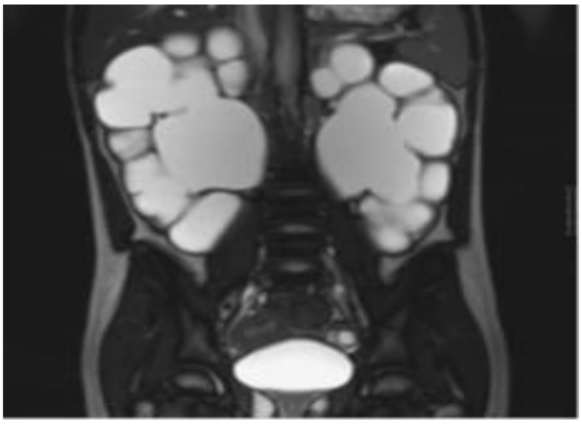


Figure (2) Magnetic resonance imaging: T2-weighted sequence demonstratingthe extent of bilateral pelviureteric junction obstruction, non-dilatation and normal bladder, confirming the obstruction to be at the renal pelvis on both sides **(Calder et al., 2007**).

Renal and urinary tract infection:

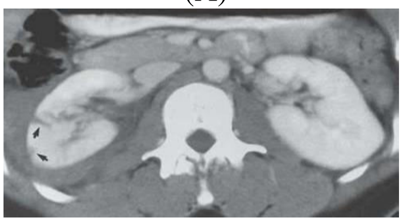
If US cannot answer the diagnostic question, further cross-sectional imaging may sometimes be useful. In the acute setting, with a very ill patient and suspected sepsisrelated to the urinary tract, CT may add further information regarding, for example, abscess rupture or retroperitoneal fluid (or pus) collections. CT is useful in showing calcification and extrarenal complications in xanthogranulomatous pyelonephritis, if this has not already been confirmed by US. MRI may be of value after the acute episode for demonstrating underlying structural anomalies if these have not been determined by US **(Melanie 2011**).

Figure (3) Multidetector CT urography study in a 75-year-old man with uncontrolled diabetes mellitus, left flank pain, hematuria and fever. A large staghorn calculus (arrow) with hypodense, nonenhancing parenchymal mass is seen in the left kidney suggestive of xanthogranulomatous pyelonephritis **(Melanie 2011).**

Renal and urinary tract trauma

CT is usually performed straight from the emergency room. CT will demonstrate direct trauma to the kidney and to any other intra-abdominal organs and may show retroperitoneal injuries or complications better than US **(Lee et al., 2007**). MRI has no indication in the acute setting of trauma. Very occasionally, it may have some value in the follow-up of renal trauma, but in children, this would usually be by US **(Melanie 2011**).

(A)



(B)

Figure (4) Renal laceration with intrarenalHematoma. A; CT scan through the right kidney shows an intrarenal hematoma (H) .B; More caudal section shows two small lacerations (arrow) and a small perinephric hematoma (**Dunnick et al., 2013**).

Genitourinary tumors

Are a common etiology for hematuria and their detection can frequently be challenging, occasionally requiring multiple diagnostic tests. Contrast-enhanced (CE) computed tomography (CT) and conventional magnetic resonance imaging (MRI) are established imaging techniques for the work-up of genitourinary tumors **(Mouli et al., 2012).** Multidetector CT remains the most widely available and primary imaging modality for detecting and characterization of renal lesions. The role of MRI in the evaluation of renal masses is ever increasing. The use of advanced MRI techniques such as diffusion-weighted imaging and ADC measurements has increased the diagnostic capability of the method in assessing renal masses. Therefore, MRI can be used when the CT findings are nondiagnostic. Furthermore, MRI can be used when optimal CT cannot be performed, as in the case of compromised renal function, severe iodinated contrast allergy or pregnancy where radiation exposure is a problem **(Wang et al., 2010**).

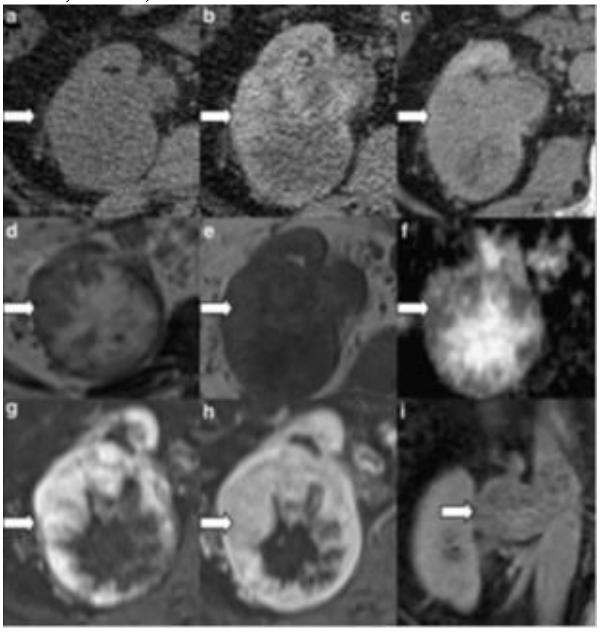


Figure (5) Multimodal presentation of a common type RCC on CT and MRI: CT (upper row): isodense in the native phase (arrow in a), hypervascular in the arterial phase with areas of necrosis (arrow in b) and early wash-out in the venous phase (arrow in c). MRI (middle and lower row): heterogeneous appearance on T2-weighted (arrow in d) and T1-weighted native (arrow in e) because of haemorrhage and necrosis, heterogeneous pattern on the ADC map (arrow in f), hyperenhancement in the arterial phase with areas of necrosis (arrow in g), early wash-out in the venous phase (arrow in h), and a tumour thrombus with contrast media enhancement reaching the renal vein and inferior vena cava (arrow in i) **(Novara et al., 2007**).

Computed tomography (CT) urography is the preferred imaging modality for the evaluation of hematuria (common presenting symptom), detection and staging of urothelial cancer. Magnetic resonance imaging (MRI) can be considered for appropriate indications, as the case of compromised renal function, severe iodinated contrast allergy, or pregnancy (to whom radiation exposure is better to be avoided), although it is considered superior to CT in demonstrating the extent of bladder wall invasion **(Mouli et al., 2012).**

Figure (6) Multiplanar reconstruction (MPR) CT image shows a soft tissue mass (asterisk) in a bladder diverticulum (arrow) in 68-year-old man **(Verma et al., 2012**).

Both CT and MRI cannot detect microscopic invasion of perivesical fat (stage T3a). In patients with invasive bladder cancer, the goal of CT or MR imaging is to detect T3b disease or higher, which may help to stratify patients into those who might benefit from neoadjuvant chemotherapy before definitive cystectomy and those who should undergo radiotherapy rather than radical surgery **(Cowan et al., 2010).** For local staging of bladder tumors, the role of a multiparametric MRI approach with conventional and functional sequences (diffusion-weighted images and dynamic contrast material techniques) is evolving and has not yet been fully established **(Laspas 2014).**

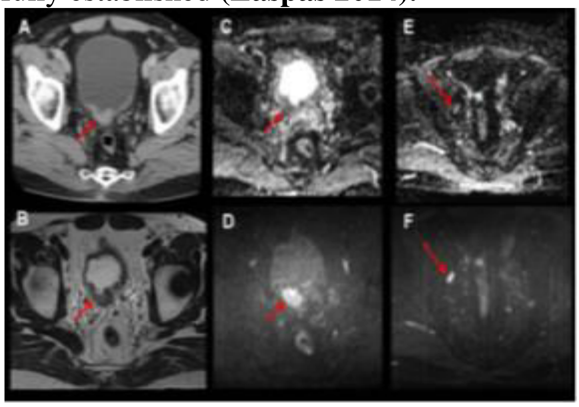


Figure (7) Bladder tumor at dorsal bladder wall visualized by CT as a wall thickening with contrast enhancement (A). Of note, soft tissue contrast is superior in MRI compared to CT (B, T2w axial). Additional diffusion weighted imaging (DWI; C–F) improves delineation of the tumor mass as a hyperintense mass in the b-value images (D, b800 image) and allows evaluating apparent diffusion coefficient (ADC) values (C) as potential marker of tumor cellularity.(**Laspas 2014**).

Vascular disease of the urinary tract:

Both CT and MRI can give excellent information with respect to normal vascular supply to the kidneys and wider urinary tract and in the context of vasculopathies. CT will give better spatial resolution with the CT scan being performed in the arterial phase and allows 3D reconstruction of the vascular tree but at a considerable radiation dose. MRI is increasingly able to offer detailed vascular information with no radiation dose, and this should be considered as an entirely valuable alternative **(Melanie 2011).**

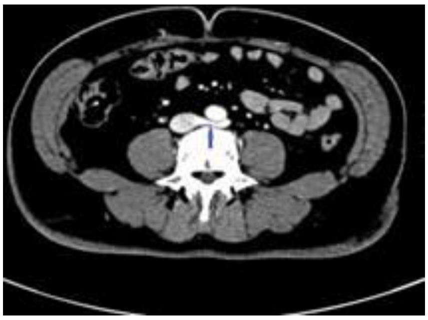


Figure (8) Left retroaortic renal vein entrapped between aorta and vertebra **(Deepa et al., 2013**).

Conclusion:

CT and MRI are accurate imaging techniques for diagnosis and management of hematuria patients, their indication and protocol of imaging should be tailored according to patient conditions and clinical questions.

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