REVIEW ARTICLE

CHOOSING THE APPROPRIATE IMAGING MODALITY FOR PEDIATRIC UROLOGIC DISORDERS

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ABSTRACT

Imaging has important role in diagnosis of urinary tract pathologies in pediatric population. The trend in choosing the imaging modality is towards reduced or no radiation exposure and obtaining combined morphological and functional imaging. Prescribing the appropriate imaging technique by referring physician is as essential as performing and interpreting it by radiologist. One of the annoying issues in radiology is performing inappropriate or less useful imaging studies for suspected urologic disorders prescribed by the referring physicians, so it is of great worth to choose the most convenient radiologic examination considering its indication, specificity, limitation, safety, availability and cost. **OBJECTIVES:** To develop good practice of the first line imaging modalities as well as further imaging strategy in various pediatric urological disorders among the referring physicians in order to choose the most appropriate technique considering its specificity, safety and availability. **METHODS:** This article is based on review of various published papers and articles from international journals. **RESULT:** Ultrasound is universally the modality of choice in pediatric uroradiology. It is inexpensive, immediate, painless, radiation free, widely available and requires no sedation. Magnetic resonance imaging is the second imaging option after Ultrasound in children. It is radiation free modality and provides both morphologic and functional information. Computerized tomography it is less suitable for routine imaging in pediatrics due to its high radiation dose but it is the modality of choice in the context of blunt abdominal trauma and inadequate ultrasound result for urolithiasis. Plain radiography is used to visualize any radio-opaque objects in the urinary tract and to evaluate the position of stents or drains. Voiding cysto-urethrography provides anatomic and functional information about the urinary bladder and the urethra and is the gold standard for detection of vesico-ureteric reflux. Usage of Intravenous Urography is now in universal decline but can still be used as an alternative in the absence of cross sectional imaging facility.Catheter directed angiography has very limited application in pediatric uroradiology due to the invasive nature and is largely replaced by MR Angiography and CT Angiography. Retrograde urethrography and cystogram are essential for evaluation of urethral abnormalities and are replaced by CT cystography in the context of trauma. Nuclear medicine imaging offers functional information about urinary tract. Positron emitted tomography permits the study of organ function by detecting alterations in biochemical processes that suggest disease before changes in anatomy are apparent therefor important in early detection of cancer and evaluation of effects of cancer therapy. **CONCLUSION:** Knowledge of indication, specificity, limitation, availability and patient safety of various imaging modalities in suspected urological disorders in pediatric population is essential for referring physicians in order to achieve the correct diagnosis with less risk and expenses to the patients.

Introduction

Today various conventional[1] (plain film, Ultrasound (US), Intravenous urography (IVU), Voiding cystourethrography (VCUG) and retrograde urethrography (RU)) and advanced[2] (Computed tomography angiography (CTA), Computed tomography urography (CTU) CT cystography, Nuclear medicine imaging, Magnetic resonance urography (MRU), advanced US, (harmonic imaging, Three dimensional (3D), voiding urosonography (VUS) and Positron emitted

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tomography (PET)) imaging modalities are used in pediatric uroradiology.

The trend in choosing the imaging modality is towards reduced or no radiation exposure and obtaining combined morphological and functional imaging.[3] However, even with the use of most sophisticated modern methods and applications, we must accept that some of basic conventional urological imaging methods are still irreplaceable.[4] It this review we will point the appropriate application of each of the mentioned modalities in accordance to clinical context as well as availability, high diagnostic valve and low radiation risk to the patient. (Tab. 1)

Appropriate imaging modalities for specific conditions	
Condition	Imaging modality
Congenital anomalies	US, MRU
Renal function	MRU, NMI, IVU
Urinary tract Calculi	X-ray, US, CTU, IVU
Urinary tract tumors	US, MRU,PET, CTU
PUJ obstruction	US,MRU,IVU
Vesico-ureteral reflux	VCUG, CeVUS, RNC
Urethral pathologies	Urethrograghy
Bladder, diverticula, Ureterocele	VCUG
Posterior urethral valve	VCUG
Post trauma evaluation	CT

Table 1

Ultrasound (US)

Ultrasound is almost universally the modality of choice in uroradiology giving excellent first orienting information then directing the further imaging strategy.[4] It is inexpensive, immediate, painless, radiation free, widely available and requires no sedation or anesthetic.[5]

In children, due to less body fat and relatively superficial location of kidneys and bladder, the urinary tract is easily visualized by ultrasound (Fig 1). Ultrasound allows for repeated follow-up investigations that enable a close monitoring of the course of any diseases.

It is important to know that multifrequency curved and linear array transducers (18-2 MHz) are needed for scanning pediatric patients.

The limitations for ultrasound are that it is entirely operator dependent so for accurate investigation,

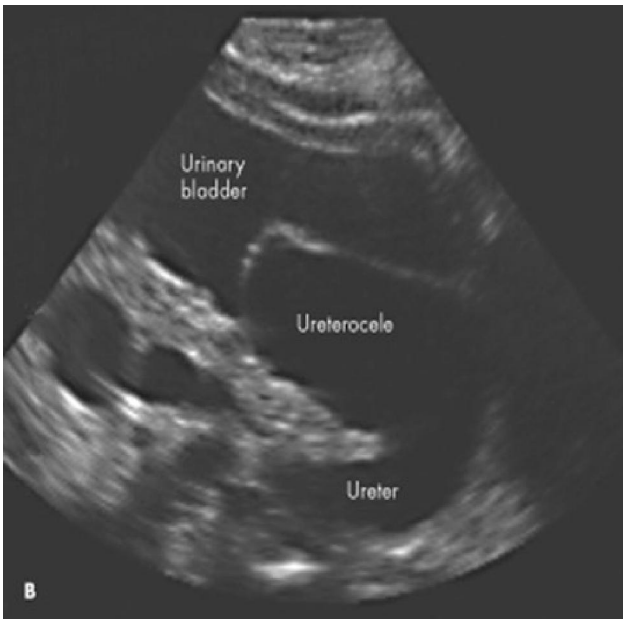

Figure 1: ULTRASOUND IMAGE: Ureterocele in urinary bladder.

operator with high level of skill and knowledge is needed. Meanwhile Still, conventional sonography is poor in anatomical evaluation of the urethra and the ureters and in detecting/excluding of vesicoureteral reflux (VUR)however with the introduction of contrast enhanced voiding urosonography (ceVUS) for diagnosis of vesicoureteric reflux, the spectrum of US applications has substantially broadened.[6]

CeVUS is a relatively new modality in the detection of VUR in children and is a reliable alternative to VCUG and Radionuclide cystography (RNC) with the distinct advantage of avoiding ionizing radiation as well as increasing the detection rate of VUR.

The limitation in evaluation of the urethra may potentially be overcome by attempting of transperineal US examination.US plays an important role in assessment of thickness and length of bulbar urethral stricture.

Magnetic Resonance Imaging (MRI)

When further cross-sectional morphologic examinations and/or functional evaluation of urinary tract are required, MRI becomes the logical and optimal second step.[7] MRI provides comprehensive morphologic and functional information (Fig. 2). The main

Figure 2: MR- T2WI: bilateral PUJ obstruction with normal ureters and bladder.

advantage of MRI is no exposure to radiation, but despite its high diagnostic utility, the need for sedation in infants and small children, availability of MR scanners, and cost are ancillary factors that restrict the widespread use of MR in pediatric uroradiology.

The primary indications for using urinary tract MR imaging are congenital anomalies and renal and bladder tumors. In many European centers, after an US, only MR imaging is used for evaluation of tumors of the urinary tract in children.[7] Infections and vascular anomalies of the urinary tract are less frequent indications for MR imaging.

Computerized Tomography (CT) Scans

As CT delivers a relatively high radiation dose and thus is less suitable for routine imaging in infants and children who have higher radiation sensitivity. According to a study at the children hospital of Philadelphia, 2010, using a 64-channel MDCT scanner for abdominal CTA and abdominal–pelvis CTU in neonates to adolescent patients, average radiation exposures were approximately 1 to 2 mSv with scan times of 1.5 to 4.0 seconds. This radiation dose is equivalent to that of approximately 50 to 100 chest radiographs.[2]

As mentioned before, in an advanced pediatric radiology unit with state-of-the-art imaging, most routine uroradiologic examinations can be performed with US and MR imaging, but there are two main exceptions which make the CT more reliable exam;[6]

A- When following an US study, additional diagnostic imaging for urolithiasis is needed.

B- In the case of severe polytrauma including blunt abdominal trauma.

The need for CT in the first instance is because of the higher diagnostic yield that CT provides, and in the latter, ancillary issues override all other considerations and the point is beyond just diagnostics: CT is much more available and takes short duration of examination.

Rather than these, CT needs to be considered as a secondary option if US and/or MR imaging are inadequate, unavailable or cannot be performed and the clinical suspicion warrants further imaging clarification.

State of the art CT technology offers two advanced imaging protocols for pediatric urological applications: CT angiography (Fig. 3) and CT urography (CTU). Direct CT cystography may be necessary for evaluation of bladder rupture.[6]

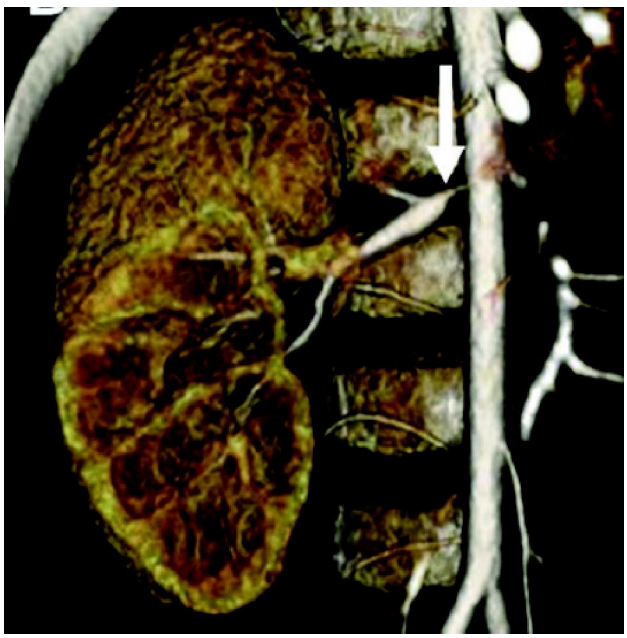

Figure 3: CTA Coronal 3D VRT: Right renal artery short-segment high-grade stenosis

Plain Radiography

However less, but still has indications in pediatric uroradiology: the main indications tor a KUB are:

- To visualize any radio-opaque objects in the urinary tract.
- Evaluate the structure of the spine and bony pelvis
- Evaluate retroperitoneal air and fat-fascial planes (abscess, infection, perforation)
- Detect air in the urinary tract or free air in the abdomen
- Detect retained foreign bodies
- Evaluate the position of stents or drains[1]

Intravenous urography (IVU) or Intravenous pyelography (IVP)

Initially it was the only method allowing assessment of renal anatomy and function, but with the addition of new methods, it is now in universal decline.[4] IVU becomes an alternative primarily in the absence of cross sectional imaging facility. In such cases the IVU needs to be more focused with as few exposures as achievable and with as low as possible radiation dose.[3]

Dehydration, elevated creatinine, and allergic reactions to contrast media are relative contra-indications for IVU.Meanwhile this examination should be delayed until at least the 4th week of life better the 6th week of life as the glomerular filtration rate is very low at birth and the tubules are even more immature than the glomeruli. These physiological factors explain why IVU in the neonate is charac-terized by poor visualisation of the kidneys.

The indications for IVU can be

- Hematuria and colic, or other signs or symptoms that suggest a urinary calculus, with indecisive US result.
- Symptomatalogy suggest certain congenital abnormalities, (suspected ectopic ureter)
- Recent urinary tract surgery, when the urinary tract will be at risk for future deterioration, or preoperative anatomic assessment;
- Abnormal findings on a renal US that may indicate the need for IVU (e.g. calyceal diverticulum)
- History of papillary necrosis, tuberculosis of GU tract, medullary sponge kidney.[4]

Voiding cystourethrography (VCUG) or Micturating cystourethrography (MCUG)

VCUG is still considered the gold standard for detection of vesico-ureteric reflux (VUR) and evaluation of urethra.[4] It provides anatomic and functional information about the urinary bladder (bladder capacity, VUR, trabeculations, diverticula or ureteroceles) (Fig. 4) and the urethra (valves, stric-tures, incomplete relaxation of the sphincter or prostatic utricle). VCUG is the only diagnostic imaging modality that can reliably directly demonstrate posterior urethral valves.[1]However, a significant radiation dose, particularly to the ovaries, persists that implies a strict indication for performing VCUG.[4] As mentioned above, ceVUS can be a good alternative for VCUG in evaluation of VUR.

Figure 4: VCUG oblique images: ectopic ureter inserting into urethra.

Retrograde urethrogram (RUG) and Cystogram

They are mainly indicated in the evaluation of urogenital trauma, however most cystograms in trauma patients are now CT cystograms. Urethrogram

is also essential in defining the extent and nature of urethral stricture disease.[1] To evaluate the whole length of urethra, retrograde as well as antegrade urethrography must be done. Anterior urethra is studied by RUG and posterior urethra is studied by antegrade urethrography.
In patients with history of multiple urethroplasties for a hypospadiac urethra, RUG can delineate the existing urethral anatomy prior to reconstructive surgery.

Catheter Directed Angiography

Due to the invasive nature of this imaging modality it has very limited application in pediatric uroradiology and largely replaced by CT angiography and MR angiography.
Its advantage is that it can be both diagnostic and therapeutic permitting selective embolization of injured vessels in certain instances of renal trauma with segmental artery bleeding.[1]

Nuclear Medicine Imaging

Nuclear Medicine Imaging offers functional information that is not attainable with traditional radiographic imaging. The most common nuclear imaging studies include radionuclide cystography (RNC), cortical renal scintigraphy and diuretic renography. Indications for each of them are described below:

Radionuclide cystography (RNC):

- Family screening for vesicoureteral reflux
- Follow-up of known VUR
- Follow-up of patients after anti-reflux surgery

Diuretic Renography

- Evaluation of hydronephrosis as it can distinguish obstructive conditions from physiological hydronephrosis (secondary to either Ureteropelvic junction obstruction or urterovesical junction obstruction) (Fig. 5).

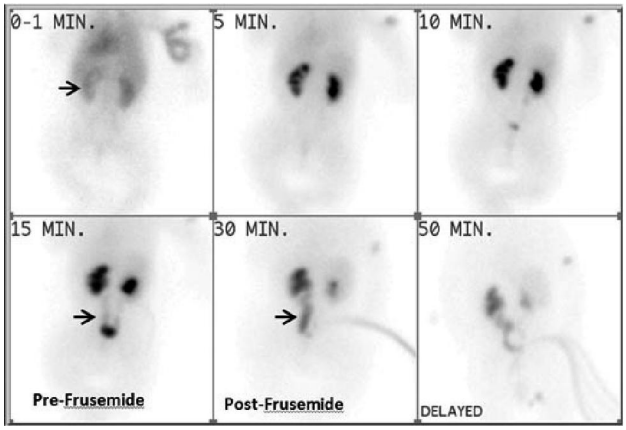

Figure 5: Tc-99m MAG-3 study shows hydronephrotic left kidney with tortuous ureter and hold up of tracer in left collecting system and incomplete clearance after frusemide stress (15 min) and post-void. Right kidney is normal functioning with no evidence of obstruction.

Renal cortical scanning

- Identify anomalies of the upper urinary tract that affect renal function e.g. multicystic dysplasia and pyelonephritic scarring.
- Diagnosis of acute pyelonephritis (Fig. 6).

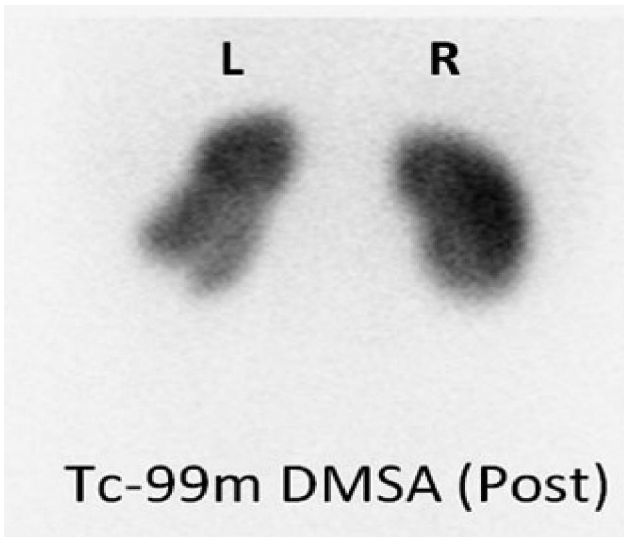

Figure 6: Tc-99m DMSA posterior shows a cortical scar over left lower pole.

Positron Emitted Tomography (PET) Scan

PET permits the study of organ function by detecting alterations in biochemical processes that suggest disease before changes in anatomy are apparent with other imaging tests, such as CT or MRI.
PET is used to detect cancer and to examine the

effects of cancer therapy by characterizing bio-chemical changes in the cancer. It is also useful in evaluation of retroperitoneal tumors and renal tumors in the pediatric GU patient.

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