Current Practice

Imaging in paediatric nephrourology

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Imaging of the renal tract in infants and children is constantly evolving but continues to rely heavily on ultrasound and nuclear medicine studies. Functional assessment is undertaken by nuclear medicine studies with the Tc 99m DTPA/MAG3 dynamic renogram being used to evaluate differential function and drainage and the Tc 99m DMSA scan to assess the renal parenchyma. The role of intravenous urography (IVU) is limited mainly for specific problems primarily relating to calyceal anatomy and solving problems of urolithiasis. The conventional micturating cystourethrogram (MCUG) remains crucial especially in the evaluation of male urethra and vesicoureteric reflux (VUR). Cystograms have changed so that the radiation burden is markedly reduced with the use of direct isotope cystography (DIC). There is growing experience with magnetic resonance urography (MRU). Angiography is reserved for special clinical situations and although invasive with a high radiation burden, it still remains the gold standard for renal artery stenosis. Interventional procedures need specific indications and require special expertise in specialized units[1].

Each imaging technique has its strengths and weaknesses which should be borne in mind. A guiding principle in paediatrics is to choose the least invasive, but appropriate, imaging technique with the lowest radiation dose whenever possible. Consequently, almost all genitor-urinary (GU) studies in children should start with an ultrasound (US). The parents /guardian can frequently help the child to overcome anxiety and most parents should be encouraged to remain with their child throughout the examination[1].

Techniques

Ultrasound (US)

Ultrasound is non invasive and easy to perform in most children. The information provided is independent of function of kidneys showing anatomical detail of the retroperitoneal, intra abdominal and pelvic structures[2]. Simple measurement of bipolar renal length is particularly important in assessing kidney growth. Any child who requires imaging of the kidney and the urinary tract should undergo an US examination as the first investigation. There are no contraindications for US.

Strengths

- US is very sensitive in detecting upper tract dilatation whether calyceal, renal pelvic or ureteric.
- Kidney size and the bladder are well demonstrated.
- A post micturition bladder US is a simple method of assessing adequacy of bladder emptying in a toilet-trained child.
- High resolution scanners are sensitive in assessing renal calculi and nephrocalcinosis.
- In a cooperative child information regarding the vasculature can be ascertained from Doppler evaluation of the arterial and venous waveforms.
- If an abdominal mass is present US can define the origin and determine whether it is cystic or solid.

Weaknesses

- US cannot reliably detect focal renal scarring, VUR or renal arterial abnormalities.
- Accurate comparison of small changes in renal pelvic dilatation on sequential US is difficult as changes may be related to altered bladder volume or hydration at the time of the examination.

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- US assessment of the renal arterial blood flow velocity and the spectral waveform lacks sufficient sensitivity and has been disappointing in renovascular hypertension.

Micturating cystourethrogram (MCUG)

This is the definitive method of assessing the lower urinary tract and VUR. It may reveal upper tract pathology if VUR is present.

Strengths

- MCUG is the superior method for demonstrating the anatomical detail of the male urethra, the bladder and the vesicoureteric junction. It is necessary in all boys in whom urethral pathology is suspected.

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Weaknesses

- MCUG requires bladder catheterization and entails a high radiation dose to the gonads especially in girls.

Urography (Plain film and IVU)

A plain abdominal radiograph is essential before every IVU. The spine warrants careful evaluation. The frequency of performing an IVU has decreased dramatically over the past decade in all departments involved in paediatric renal imaging. Plain radiograph and IVU are especially useful when US has detected /suspected urinary calculi to confirm the number of stones and their exact location. Due to the widespread availability of good-quality US equipment a plain film is not necessary in the routine investigation of children with urinary tract infections.

Strengths

- IVU has the ability to show detailed anatomy of calyces, ureters and bladder.

Weaknesses

- IVU has a low sensitivity in the detection of renal scars.

- There is a potential reaction to contrast medium and a high radiation dose compared to dynamic and static isotope scans.

- IVU provides only a coarse index of renal function.

Contraindications

- IVU is contraindicated in neonates and young infant in addition to renal failure at any age.

Nuclear medicine

Cystography

Direct isotope cystography (DIC)

DIC is indicated in those who need follow up cystography to exclude renal reflux. There are no contraindications.

Strengths

- DIC has a high sensitivity for reflux because of continuous monitoring rather than the limited intermittent fluoroscopy with conventional MCUG.

- It has a lower radiation dose compared to MCUG[3].

Weaknesses

- Catheterization is still required.

- Anatomical detail of the vesicoureteric junction and urethra is poor.

- Degree of VUR cannot be graded.

- Reflux into a dilated ureter behind the bladder or into a pelvic kidney may be missed since the isotope in the bladder will obscure pathology posteriorly.

Indirect radioisotope cystogram (IRC)

IRC is undertaken following the intravenous injection of TC 99m DTPA/MAG3. Once majority of the isotope is in the bladder, child is asked to micturate in front of the gamma camera[4]. It is indicated in follow up cystography in the older toilet trained child when renal reflux needs to be excluded.

Strengths

- IRC provides information about renal function, excretion, bladder emptying and reflux in normal voiding conditions without the necessity for bladder catheterization and bladder function without an increase in radiation dose above the

routine renogram. Therefore this is the only cystogram that is physiological.

Weaknesses

- IRC has all the weaknesses of DIC except the need for bladder catheterization.
- Renal reflux can be missed due to the high urine flow rate from the kidneys as a diuretic is used for the study.
- VUR can be difficult to interpret in the presence of hydronephrosis and hydroureter and caution in interpretation of results is necessary.
- It is time consuming and cannot be undertaken in departments with heavy workload.

Dynamic Renogram

Tc99m DTPA or TC99m MAG3 is used with a diuretic in the presence of a dilated collecting system. Renal pathophysiology that can be assessed includes renal perfusion, differential renal function and drainage of the collecting system. The differential renal function (DRF) of each kidney is expressed as a percentage of the sum of the right and left kidneys.

Indications

- To assess DRF and drainage in suspected obstruction before any surgery of the collecting system.
- Postoperative evaluation of the collecting system for indirect cystography.
- Following renal transplantation.
- Renography with captopril stimulation for renovascular hypertension.

Strengths

- Quantification can be undertaken routinely.
- Serial renography is reliable in the long-term follow up.

Weaknesses

- Anatomical detail of the calyces is not as clear as that seen with IVU.

There are no contraindications to the study. However high quality dynamic isotope scans are best achieved when some renal maturity has occurred and should ideally be delayed until the child is at least 4 weeks of age.

Static renal scan

Tc99m DMSA binds to the proximal convoluted tubules and results in an unchanging image for many hours. The delayed static images after intravenous (IV) injection represents functioning cortical mass and an accurate image of renal parenchymal outline.

Indications

- In urinary tract infection (UTI) to diagnose renal involvement in the acute phase if needed to continue antibiotic treatment.
- The exclusion of a scar needs a normal DMSA study.
- When only one kidney has been identified and doubt exists about the presence of a second kidney.
- In the follow up of reflux nephropathy.
- The assessment of focal parenchyma abnormalities in the presence of hypertension.
- In the presence of renal failure and/or gross bilateral dilatation (e.g. prune belly syndrome) where assessment of drainage is not possible but differential renal function is required to find out whether both kidneys are equally involved or if all the function is from one kidney. There is no minimum age in such clinical situations to undertake a DMSA scan.

Strengths

- Low in radiation burden compared to IVU.
- With an ectopic kidney differential renal function is more reliably assessed than with a dynamic renogram.

Weaknesses

- It is time consuming.
- It has a higher radiation burden compared to dynamic renography.

Computed tomography (CT)

CT has a limited but specific role to play in the evaluation of paediatric GU tract. Use of contrast medium is necessary in certain clinical problems.

Indications

- In suspected malignant renal or pelvic lesion or abscess a study with IV contrast enhancement.
- In the follow up of known malignant tumours.
- Major abdominal trauma.
- In suspected renal or ureteric calculi and nephrocalcinosis. CT is more sensitive than US or plain radiography for calcification and calculi.

Strengths

- CT provides good anatomical detail.
- With newer multislice scanners, scanning time is very short and excellent reconstructed images are possible in coronal and sagittal planes, very helpful in planning surgery and radiotherapy.

Weaknesses

- CT involves a large radiation burden.
- Younger children may need sedation to lie still.

Contraindications

- Renal failure or known allergy to contrast medium.

Magnetic resonance imaging (MRI)

The previously limited role of MRI in paediatric uroradiology is beginning to undergo substantial change. With special sequences it is possible to yield a magnetic resonance urogram (MRU) comparable to the IVU in terms of anatomical detail. MRU can be performed independently of the renal function[5].

Indications

- Children with neuropathic bladder or an abnormal spinal radiograph require exclusion of spinal cord pathology which is best achieved by MRI.
- Many centres are increasingly relying on MRI to stage intra-abdominal extent of Wilms tumours.
- MRI is superior to CT in the evaluation of pelvic tumours due to the multiplanar imaging capability.
- Could replace an IVU if the facility is available at the centre.

Strengths

- Lack of ionizing radiation and multiplanar imaging capability.

Weaknesses

- Expensive and not freely available.
- Relatively long scanning time.
- Most children below 7 years need sedation or anaesthesia.
- Renal function cannot be assessed in comparison to isotope renography.

Contraindications

- A pacemaker is an absolute contraindication.

Interventional procedures

Angiography

Angiography with its high radiation dose and invasive nature is reserved for special clinical situations. This is best undertaken by an experienced operator using digital equipment.

Indications

- Hypertension with a high suspicion of renovascular disease and suspected vasculitis especially polyarteritis nodosa.
- Before interventional procedures viz. embolization of arterio-venous malformations (AVM), balloon dilatation of renal artery stenosis, testicular vein embolization for varicocele obliteration.

Strengths

- No other imaging modality can match the high-resolution detail of renal vasculature provided by angiography.

Weaknesses

- Invasive and needs general anaesthesia in children.
- High radiation burden.

Contraindications

- Known allergy to contrast medium.

Antegrade pyelogram

It is carried out by an experienced operator in the radiology department or in the operating theatre to provide anatomical detail of the renal pelvis and/or ureter unavailable from US or IVU. Contrast medium is injected under US guidance directly into the renal pelvis and radiographs obtained to show the exact site of obstruction for surgery.

Nephrostomy drainage

The procedure is similar to that of an adult. Following an antegrade pyelogram a pig tail catheter is placed in the dilated renal pelvis or ureter for drainage of the obstructed system.

Retrograde pyelogram

This is carried out by a urologist in the operating theatre under anaesthesia. Contrast medium is introduced into the ureter by a catheter placed in it following cystoscopy to demonstrate the exact site and cause of obstruction in the ureter not demonstrated by US or IVU.

Almost all GU studies in children should start with an US. There is difference of opinion with regard to the radiological investigation of UTI. It is important to bear in mind that US is not reliable in detecting VUR and renal scarring and a normal US scan does not exclude either. When the US findings are abnormal the radiologist will suggest further radiological investigation according to the child's clinical problem. In complex clinical problems the case should ideally be discussed with the radiologist. It is important that a child is not made to follow strict protocols, but the protocols be adjusted to suit each child's clinical problem.

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