Renal tract ultrasound in children

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Dr J M Stedman
Specialist registrar clinical radiology
Dr K M Park
Consultant paediatric radiologist
Children's Hospital, Oxford
email: jonathanstedman@doctors.org.uk

General considerations
Ultrasound is a safe and non-invasive way of assessing the anatomy of the urinary tract in children. Renal tract ultrasound is one of the most commonly performed imaging examinations in paediatric radiology departments around the UK.

Performing imaging investigations in children is often challenging and, together with the array of specific pathologies that may be encountered, necessitates a dedicated approach to obtain high quality diagnostic images. The majority of imaging in children therefore will be carried out either within a specialist children’s hospital or in a district general hospital by an imaging professional who has a specialist interest and experience in paediatric imaging.

This specific approach begins before the patient arrives at hospital. The bladder should ideally be examined distended with urine although patients who are not potty trained will, of course, not be able to fill their bladder. However as the age of this varies, most parents of patients over the age of two years old will receive advice on bladder filling.

On arrival at the radiology department it is important that children are kept calm as it is likely to be an unfamiliar and potentially frightening environment. A selection of toys for a variety of ages and if possible a play area make the process of waiting much easier and will mean children will be calmer for the examination. Once the patient arrives in the ultrasound room it is essential that the room is equipped properly. Most children’s hospitals will have further toys in the room as well as a selection of distraction devices such as projectors, mobiles, lights and a TV with a DVD player.

Most modern ultrasound machines are capable of interrogating the urinary tract in children. However, specific considerations include the need for a wide variety of transducers to image the variety of sizes of children. The kidneys of a 500 gram pre-term neonate are ideally visualised with a high frequency linear array transducer (we use a 14KHz linear probe in premature neonates) whereas some larger teenagers will require a lower frequency, curvilinear probe for initial analysis followed by a higher frequency probe for more focal interrogation. It is essential to be able to use Duplex, power Doppler and pulse wave Doppler to assess renal vascular anatomy as well as to assess the ureteric jets within the bladder. These functions are now almost universal on modern ultrasound machines.

Organ assessment
We usually assess the bladder first, particularly in children in nappies who may void at any time. Transverse and longitudinal views should be obtained which include the bladder base as well as the distal ureters. Initial views may reveal debris within the urinary bladder which is not an uncommon finding and, in asymptomatic children, does not usually indicate pathology. A further closer inspection should then be made of the bladder wall. Bladder wall abnormalities are uncommon, however, a thickened wall and/or diverticulae may be seen in a chronically obstructed or neuropathic patient. Once the wall has been assessed the operator’s attention should focus on the bladder base; it is important to closely examine this region as most bladder pathologies in children occur here. Distal ureteric dilation is an important finding and should be accurately characterised and the degree of dilation measured, close attention should be paid to looking for a ureteroceles or, less commonly, distal ureteric calculi. A ureteroceles (dilation of the distal ureter) is associated with ureteric duplication in 80% of cases and commonly causes ureteric obstruction. When a ureteroceles is detected it is unusual to find the second, ectopic ureteric orifice. Although not necessary on all examinations, if there is concern about a distal ureteric obstruction or there is difficulty in locating a possible ectopic kidney then the ureteric jets should be assessed with Doppler. A true renal agenesis will only have one jet seen whereas in an occult pelvic kidney or in a cross-fused renal ectopia, two jets will be seen. Once the bladder anatomy has been fully interrogated measurements can be made of bladder volume. Capacity can be approximated as follows: Bladder capacity (in mls) = age of child (years) x 30 +30. This is important when assessing patients who are suffering with recurrent infections and should be performed, if possible, before and after voiding. Low pre-void volumes can be seen in patients with active acute or chronic infection or in children suffering with irritable bladder, however, differentiation between low capacity and poor filling on a particular occasion is important. Incomplete emptying of the bladder (residual volume of >20mls) is an uncommon finding and may predispose to infection. It can also be seen with incomplete or absence of neurological innervation of the bladder wall, most often seen in patients with spinal abnormalities.

The next structure to be examined is the ureter. In a normal examination, the ureters are not normally demonstrated. Unless significantly dilated only the proximal and distal portions of the ureter will be visible. Primary mega-ureter is an uncommon process where the ureter either becomes or is congenitally dilated with no cause found. Much more common, however, is secondary ureteric dilation, which in the majority of cases is due to vesicoureteric reflux secondary to an immature or incompetent vesicoureteric junction. Other causes include vesicoureteric junction obstruction, an obstructing ureteroceles or bladder outflow obstruction. It is important to remember that bladder outflow obstruction may cause only unilateral, and not always bilateral, ureteric dilatation (figure 1).

The proximal ureter and urinary collecting system are frequent sites of pathology in children and therefore must be examined closely. Any dilatation of the renal collecting sys-
tem should be assessed accurately as the degree of dilation is often used in clinical decision and treatment algorithms. Renal pelvic dilation is assessed by measuring the diameter of the renal pelvis as it exits the renal hilum and should be measured in the anteroposterior (AP) plane on transverse section of the kidney. The calyceal pattern should also be examined closely and the degree of dilatation reported. As with the distal ureter, dilation of the proximal ureter is often secondary to another process such as reflux or more distal obstruction. The renal pelvis can also be dilated in isolation in a so-called pelvico-ureteric junction (PUJ) anomaly pattern. This phenomenon is most commonly due to intrinsic abnormalities at the junction of the renal pelvis and ureter but can be secondary to extrinsic factors, such as bands or vessels crossing the proximal ureter causing partial or complete obstruction. Other causes of isolated proximal ureteric dilation are uncommon but can be seen with obstructing stones, for example.

The renal parenchyma itself can also be affected by disease in children and can be examined in exquisite detail with ultrasound. It is important for the sonographer to be familiar with the normal differences seen in especially young children so as not to confuse them with disease. Persistent fetal lobulation will often be seen in children and the renal sinus fat which is a familiar sight on adult ultrasound will not be seen in neonates and younger children. In neonates, the renal cortex is hyperechoic to adjacent liver until up to 4-6 months of age and the renal medullae are of relatively large volume and markedly more hypoechoic than the bright cortex. This can lead to normal neonatal medullae being confused with hydronephrosis by the inexperienced observer (figure 2). It is also not uncommon to see transient areas of echogenicity at the apices of the renal pyramids in neonates, which is thought to be physiological. Bright medullae, due to nephrocalcinosis, may also be seen in neonates treated with furosemide. Following initial assessment of the renal parenchyma with the patient supine so that the cortical echogenicity can be compared to that of liver and spleen, the bipolar length of the kidney should be assessed, ideally with the patient prone to avoid foreshortening, and the greatest value of three separate measurements taken. Renal lengths should be compared to tables of normal values for age and compared to the contralateral side. A discrepancy of 10% or greater is abnormal and a cause for this should be sought. The most common causes for a larger than normal kidney include the kidney being duplex or obstructed. A unilateral small kidney may have been previously damaged from obstruction or infection or due to a congenital abnormality. The ultrasound operator should then ensure that the entire renal cortex is visible; unusual orientation of the kidneys (the upper pole usually being more medial than the lower pole) and/or failure to visualise the lower pole should alert the sonographer to the possibility of a horseshoe kidney. Once the renal size has been measured, cortical thickness should be assessed for any regions of thinning which may indicate cortical scarring. Any regions of cortical thinning should be closely scrutinised to look for underlying calyceal dilation or stones. In patients suspected of having acute pyelonephritis, renal vascular insufficiency should be assessed using the power Doppler function to look for regions of non-perfusion. Medullary abnormalities are most often seen in systemic diseases such as renal tubular acidosis and hypercalcaemia and give rise to medullary nephrocalcinosis.

Although rare, malignancy does occur in the renal tract in children and is overwhelmingly most common in the kidney itself. It is important the ultrasound operator is familiar with the common mimics of renal parenchymal masses such as the dromedary hump and the cortical bar, however, any cortical or medullary abnormality should be viewed with caution. The commonest renal tumour in children is the Wilms tumour or nephroblastoma (figure 3), it is usually idiopathic but can be seen in conjunction with conditions such as hemihypertrophy or Beckwith-Wiedemann syndrome in up to 10% of cases.

Unlike in adults, renal cysts are unusual in children and require explanation. The majority of cysts seen will be simple, however because they may be associated conditions such as autosomal dominant or recessive polycystic kidney disease (figure 4), follow-up is usually required to ensure they are not increasing in size or number or have concerning features for malignancy.

**Future developments**

Although not widely practised within the UK, some centres around the world have adopted the use of contrast-enhanced ultrasound in the assessment of vesicoureteric reflux in the form of voiding urosonography. In this procedure ultrasound contrast media is instilled into the bladder while scanning over the renal collecting systems to assess for reflux and thus avoiding the use of ionising radiation associated with the more traditional micturating cysto-urethrogram examination.

**Conclusion**

A dedicated approach to renal tract ultrasound in children allows for the vast majority of renal tract pathologies to be imaged accurately and without recourse to ionising radiation. Specialist knowledge and techniques are required to image these patients optimally.

**References**

**Figure 1**  
Term male baby with posterior urethral valves. (A) shows a transverse section through the thick-walled bladder (arrowhead) with bilateral distal ureteric dilation. The right distal ureter (solid thin arrow) contains sonolucent urine whereas the left distal ureter (thin dashed arrow) contains echogenic debris. There is bilateral hydronephrosis, the right kidney (B) shows pelvicalyceal dilation with preservation of the renal cortical thickness, the left kidney (C) is hydronephrotic with cortical thinning and contains echogenic debris.

**Figure 2**  
32-week gestation preterm neonate. Initial scanning of the right kidney through the liver with the baby prone (A) demonstrates the normal lobulated hyper-echoic renal cortex and what could be misinterpreted as a dilated renal calyx (long solid arrow). However, high frequency scanning (B) demonstrates that this is, in fact, a prominent renal papilla (long dashed arrow), which is normal in neonates.

**Figure 3**  
Three-year-old girl with a palpable right-sided abdominal mass. (A) demonstrates a large soft tissue mass (thick straight arrow) arising from the interpolar region of the right kidney. This was confirmed on contrast enhanced CT: Coronal reconstruction (B) demonstrates a large enhancing mass (narrow arrow) that was subsequently proven to be a Wilms tumour.

**Figure 4**  
Seven-year-old boy with a family history of kidney disease. The cortex and medullae contain innumerable foci of high echogenicity in keeping with tiny cysts (arrow) confirming the diagnosis of autosomal recessive polycystic kidney disease.