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Pediatric Urologic Imaging

Lane S. Palmer, MD[a,b,*]

[a]*Division of Pediatric Urology, Schneider Children's Hospital of the North Shore-Long Island Jewish Health System, New Hyde Park, NY, USA*
[b]*Departments of Urology and Pediatrics, Albert Einstein College of Medicine, Bronx, NY, USA*

There have been significant advances made over the past decade in imaging the genitourinary tract in children. Ultrasound, voiding cystourethrography (VCUG), and diuretic renography currently dominate the radiographic imaging of children with urologic complaints or anomalies. Prenatal diagnosis of urologic anomalies has improved with advances in ultrasound technology [1]. The use of ^{99mTc}-mercaptoacetyl glycyl^3 (MAG_3), greater uniformity in performing the diuretic renography [2], and SPECT imaging have improved the diagnostic quality of nuclear imaging.

Improvements in CT and MRI now offer better adjunctive studies and in some cases a definitive study. Spiral CT has improved imaging for stone disease and tumor staging because of its rapidity and reduction in motion artifact and the need for sedation. Finally, MRI continues to grow as an imaging study for complex anomalies but also may have a role in evaluating obstruction and infection [3–5]. In this article, the discussion will focus on ultrasound, VCUG, and nuclear studies; however, the other imaging modalities will be discussed when pertinent.

Imaging modalities in children

Ultrasound

Ultrasound is the most commonly performed study of the urinary tract. It is performed routinely prenatally as a screening tool for congenital anomalies, the first study performed following urinary tract infections [6], and the primary study of the acute scrotum in many institutions [7]. When evaluating the urinary tract, the study should include the kidneys and the bladder. Ultrasound images of the kidneys are taken in longitudinal and transverse views assessing renal length (well-established nomograms exist [8]), degree of hydronephrosis (using the Society for Fetal Urology grading system [9]), renal scarring (although nuclear studies and MRI are more sensitive), and the presence of duplication anomalies, cystic renal disease, and dilation of the proximal ureter. Bladder ultrasound assesses bladder volume and the efficacy of bladder emptying and the presence of ureteroceles, bladder masses, dilated distal ureters, or other abnormalities of the pelvis. Testicular ultrasound with Doppler is user-dependent and requires probe placement over the painful area; however, it avoids radiation, is readily available, assesses symmetry and architecture, and carries sensitivity and specificity similar to nuclear scintigraphy that previously was the standard study for evaluating the acute scrotum.

Contrast voiding cystourethrography

The second most common study in pediatric urology is the VCUG. When properly performed, the contrast VCUG provides an excellent view of the anatomy and some sense of function of the bladder and urethra. The plain film taken before catheterization may detect sacral or bony abnormalities, spinal dysraphism, and abnormal bowel gas patterns suggestive of a mass effect. Once catheterization is established and contrast is instilled, an early anteroposterior film will visualize a ureterocele or bladder tumor best. To evaluate

* 1999 Marcus Avenue, M 18, Lake Success, NY 11042, USA
E-mail address: lpalmer@nshs.edu.

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for vesicoureteral reflux, steep oblique images are then taken of the bladder and renal fossae just before voiding and again during voiding. The bladder images also assess bladder emptying and urethral anomalies. The urethral catheter need not be removed during voiding. Post void films complete the study [10].

Nuclear imaging

Kidney

The static renal scan assesses cortical abnormalities such as infection and scarring using ^{99m}Tc-dimercaptosuccinyl acid (DMSA). The diuretic renogram involves intravenous injection of a radiotracer that is reabsorbed by the tubules (MAG_3 or DTPA), timely injection of a diuretic (furosemide, 1 mg/kg), and bladder catheterization. Hydration (oral or intravenous) before injection prevents artificially poor tracer uptake. Differential renal function is measured in the first 2 minutes after initial injection. The reduced background activity seen with MAG_3 has led to its preference over DTPA at many institutions. Finally, tracer drainage from the collecting system is assessed after timely injection of furosemide (typically at the peak of tracer uptake or at 20 minutes after injection of the tracer). The time needed for drainage of 50% of the tracer correlates with the obstructive state of the kidney.

Bladder

Radionuclide cystography provides some of the information described for contrast VCU with less exposure to ionizing radiation but without providing adequate anatomic detail. The tracer is instilled into the bladder, and the appearance of tracer in the area of the renal fossa is evaluated. The presence of reflux is graded as mild, moderate, and severe. The role of radionuclide cystography is more limited than contrast VCUG.

Scrotum

99mTc-pertechnetate is injected intravenously, and blood flow to the testes is evaluated immediately and by delayed images.

Renal anomalies

Hydronephrosis

Renal pelvic dilation is the most common ultrasound abnormality of the kidney seen on prenatal or postnatal ultrasound [11]. In the prenatal period, dilation of the renal pelvis in the anteroposterior dimension is measured in millimeters, with the risk of a significant uropathy increasing with the time of detection [12] or size of the pelvis [13]. In the postnatal period, dilation is divided into broader grades such as the system offered by the Society for Fetal Urology (Fig. 1). In the highest grade, renal parenchymal thinning will be seen. Hydronephrosis needs to be distinguished from the normal renal pyramids. The pyramids are small noncommunicating hypoechoic ovoid or round structures that are distributed radially around the kidney. They have no relation to hydronephrosis, so they will remain present in the face of a dilated renal pelvis.

Hydronephrosis may be primary and either obstructive or nonobstructive; or it may be secondary to other processes, many of which are described in this article. Thus, VCUG is indicated to assess for vesicoureteral reflux or other pathology. Diuretic renography is performed to determine obstruction and differential renal function. Some authors advocate for the MRI reporting comparable functional and drainage information to nuclear scintigraphy but with an anatomic image without radiation [4,5].

Renal cystic diseases (Fig. 2)

Multi-cystic dysplastic kidney

The characteristic findings on ultrasound are of multiple cysts of variable size that do not communicate and a paucity of renal parenchyma. The noncentral location of the largest cyst helps to distinguish the multi-cystic dysplastic kidney (MCDK) from the severely hydronephrotic kidney. Notwithstanding this difference, it can be very difficult to distinguish between the two entities. Documenting the lack of function by nuclear scintigraphy using either DMSA or MAG_3 may help to make the distinction. CT or MRI may improve the imaging of the nature of the parenchyma between the cysts. The cysts of a MCDK often involute, and the renal unit contracts or disappears; this phenomenon can be followed by ultrasound. Abnormalities may be found in roughly 40% of the contralateral kidneys such as duplication, hydronephrosis, and obstruction on ultrasound. Because vesicoureteral reflux also can be seen into the stump of the MCDK or in the contralateral kidney, a VCUG is indicated [14].

Autosomal recessive polycystic kidney disease

The diagnosis of autosomal recessive polycystic kidney disease is made easily on ultrasound.