Pediatric Urologic Interventional Radiology

Luke Linscott, M.D.¹

ABSTRACT

Interventional radiologists are playing an increasingly important role in pediatric urologic intervention, working closely with the pediatric urologist. Interventional radiologists are frequently asked to establish percutaneous access to the renal collecting system prior to nephrolithotomy. Additionally, procedures such as percutaneous nephrostomy, ureteral stent placement and exchange, and renal parenchymal biopsy are frequently encountered requests. This article will review these common procedures and highlight techniques and pathology that are unique to the pediatric population.

KEYWORDS: Pediatric, urologic, interventional radiology, percutaneous nephrostomy, renal biopsy

Objectives: Upon completion of the article, the reader should be able to list the indications and basic approach to commonly encountered pediatric urologic interventions, and have an appreciation for the unique clinical and technical aspects of working with a pediatric population.

Accreditation: Tufts University School of Medicine is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Credit: Tufts University School of Medicine designates this journal-based CME activity for a maximum of 1 *AMA PRA Category 1 Credit*TM. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Application of interventional urologic radiology procedures to the pediatric patient began in the early 1980s with the first case series published in 1986, which established the safety and effectiveness of these procedures.¹ Interventional techniques were adapted from similar procedures performed successfully in adults. Today, the most frequently performed and well-described procedures include percutaneous nephrostomy (often combined with tract dilatation to allow for lithotripsy), ureteral stent placement and exchange, and renal biopsy.²

PERCUTANEOUS NEPHROSTOMY (PCN) PLACEMENT

A percutaneous nephrostomy (PCN) placement is done to relieve an obstructed collecting system or provide a

conduit through which percutaneous lithotripsy may be performed by the urologist. The most common etiologies for upper urinary tract obstruction in children include ureteropelvic junction obstruction (congenital or postsurgical), renal calculi, mycetoma, clot, or extrinsic compression from an abdominal/pelvic mass.² Pyonephrosis is an emergent clinical indication for PCN placement. Additional, less-common indications for PCN include severe reflux related to neurogenic bladder, posterior urethral valves, ureteral trauma, and cystic renal disease.^{3–8} PCN is most often a temporary solution for obstructive uropathy and serves as a bridge to long-term surgical management.³

Evaluation of an obstructed collecting system in children begins with ultrasound and voiding

¹Section of Vascular and Interventional Radiology, Mallinckrodt Institute of Radiology, St. Louis, Missouri.

Address for correspondence and reprint requests: Luke Linscott, M.D., Mallinckrodt Institute of Radiology, Section of Vascular and Interventional Radiology, 510 S. Kingshighway Blvd., Campus box 8131, St. Louis, MO 63110 (e-mail: linscottl@mir.wustl.edu).

Genitourinary Intervention; Guest Editor, Darryl A. Zuckerman, M.D.

Semin Intervent Radiol 2011;28:407–414. Copyright © 2011 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.
DOI: <http://dx.doi.org/10.1055/s-0031-1296083>.
ISSN 0739-9529.

cystourethrography. These two studies together usually identify the etiology of the obstruction.⁹ Diuretic renal scintigraphy is then traditionally employed to quantify the degree of obstruction and plays a major role in determining surgical management.¹⁰ More recently, magnetic resonance (MR) urography has been investigated as a nonionizing modality for anatomic and functional assessment of obstructive uropathy.¹¹

Prior to beginning the procedure, coagulation parameters should be optimized. Antibiotic prophylaxis is mandatory if there is suspicion of an infected collecting system. Many institutions pretreat with antibiotics in all cases, treating all patients as having a potential asymptomatic infection.¹² Conscious sedation and local

anesthesia is sufficient in the majority of cases, but general anesthesia should be considered in unstable or very young patients. The patient is placed prone or semiprone on the fluoroscopy table. Because of children's small size, ultrasound is used almost exclusively for initial access of the collecting system with fluoroscopic guidance used thereafter.

A single-stick or double-stick technique may be used. Obstructive uropathy in children often presents with massively dilated kidneys and thin, mobile renal cortices. In the presence of a dilated collecting system, a single-stick technique is recommended as the thin, mobile renal cortex makes multiple guidewire and sheath exchanges difficult with potential loss of access.² In this

Figure 1 A 17-year-old girl 30 weeks pregnant with moderate right hydronephrosis and pyelonephritis. (A) A 21-gauge micropuncture needle and wire are used to access the dilated system under ultrasound guidance. (B) A 5-French (Fr) sheath is placed to allow for placement of a stiff wire. (C) Dilation to 10 Fr is performed over the stiff wire. (D) The 10-Fr cope loop catheter is advanced over the stiff wire, ensuring that the radiopaque marker is within the renal pelvis.

Figure 1 (Continued) (E) Final fluoroscopic images show the cope loop within the renal pelvis.

case, a three-step approach is recommended: (1) initial access with an 18-gauge needle, (2) installation of a stiff guidewire to at least the level of the pelvicaliceal junction, and (3) placement of the catheter over the guidewire. If the renal parenchyma is normal, without thinning, a standard technique using multiple sheath and guidewire exchanges is acceptable (Fig. 1). Catheter sizes range from 5 to 10 French (Fr) and choice depends on patient size and the character of the urine, with larger catheters used when sediment or pyuria are present.¹² 5-Fr catheters may be placed over a stiff guidewire without prior dilatation, but dilatation should be performed prior to insertion of larger catheters.²

In a nondilated system, such as in preparing for percutaneous lithotripsy, the double-stick technique may be advantageous. Any part of the collecting system may be identified for initial puncture using a 22-gauge needle. In smaller patients, this can usually be accomplished with ultrasound. If stones are visualized on fluoroscopy, they may also be used as a target. If initial attempts are unsuccessful, the 22-gauge needle can be advanced beyond the expected region of the pelvis or calyx, and slowly retracted while injecting small amounts of contrast. Once the collecting system is identified, it can be distended with contrast and/or air. At this point, the target calyx can be identified using fluoroscopy and accessed with an 18-gauge needle with the remainder of the technique being similar to the single-stick technique.²

Following the procedure, the catheters should be placed to gravity and sutured to the skin. Padding of the insertion site will prevent catheter kinking and improve patient comfort. This procedure can be safely performed on an outpatient basis in select patients.¹² As mentioned earlier, PCN is rarely a long-term treatment for children

as it often is in adults. In children, PCN usually serves as a bridge to more definitive surgical management, which should be scheduled and performed as soon as possible to avoid potential problems associated with tube maintenance in the pediatric population.¹²

Major complications of this procedure range from 0–4% and include bleeding, arterial injury, sepsis, and injury to the renal pelvis.^{4–8} Overdistension of the collecting system and extensive guidewire manipulations should be avoided to reduce the risk of sepsis, especially in cases of suspected pyonephrosis. Minor complications are more common and include hematuria, urinary tract infection, and catheter displacement.^{3–8}

PERCUTANEOUS NEPHROLITHOTOMY

Although renal stone disease is much less common in children compared with adults, it remains one of the most common indications for percutaneous nephrostomy tube placement. Options for treatment of upper tract calculi include extracorporeal lithotripsy, percutaneous nephrolithotomy (PCNL), or a combination of the two. In those children with a large stone burden, PCNL provides the best chance for complete stone removal. Rates of stone clearance range from 68% to 100%.¹³

In contrast to adults, nearly half the children in developed countries have an identifiable metabolic predisposition to nephrolithiasis.¹⁴ Imaging evaluation of suspected upper-tract stones always begins with ultrasound in children. Computed tomography (CT) is less frequently utilized in children due to concern for radiation dose. MR urography is a helpful technique as it can simultaneously evaluate stone burden, pelvicaliceal anatomy, and functional obstruction.¹¹

The technical approach to PCNL is similar to standard percutaneous nephrostomy placement, except that it is performed under general anesthesia and usually in the operating room (Fig. 2). The choice of calyx is made to optimize nephroscopic access to the target stones. The PCNL tract should be discussed in detail with the urologist to create an optimal approach to stone removal. At the beginning of the procedure, a ureteral catheter is placed by the urologist. This ureteral catheter may be used to opacify the collecting system, obviating the need for a double-stick technique. An 18-gauge sheathed needle is used to access the collecting system and a stiff guidewire is placed well into the ureter. The tract is then dilated to 18- to 28-Fr for nephroscopic access. An additional safety wire is often placed to the level of the bladder to maintain access throughout the procedure. Lithotripsy is then performed and stones removed. A percutaneous nephrostomy tube and/or double-J nephroureteral stent are often left in place following the procedure. Removing the nephrostomy tube has been shown to be safe and effective in adults.¹⁵

Figure 2 A 13-year-old girl with a large left staghorn calculus. (A) Under fluoroscopic guidance, an upper pole calyx is accessed between the 11th and 12th ribs after consultation with the urologist regarding the optimal nephroscopic approach. Note the large staghorn calculus filling most of the renal pelvis and calyces. (B) A guiding catheter and Bentson guidewire are passed to the level of the urinary bladder. (C) An 8/10 dilator set was used to pass a second superstiff guidewire over which an 8-mm balloon was used to dilate the nephrostomy tract. (D) A 24-French Amplatz sheath was then placed, its tip in the upper pole calyx. Guidewires are left in place and the procedure turned over to the urologist.

Recent reports suggest that removing the nephrostomy tube in selected pediatric patients is also safe.¹⁶

Complication rates are significantly higher (8–43%) than standard percutaneous nephrostomy due to the large serial dilations and trauma to the collecting system related to the lithotripsy and stone removal.² Major complications include hemorrhage requiring transfusion (24%)¹³ and urinary leak (7%)¹⁶. Minor complications include fever (30%)¹³, urinary tract infection, and residual stones. Increased stone burden and sheath size are

associated with increased complication rates.¹³ At our own institution, we report one case of peritoneal perforation resulting in large volume ascites and right hydrothorax requiring pleural and peritoneal drain placement (Fig. 3).

URETERAL STENT INSERTION AND EXCHANGE

Internal ureteral stents are an important alternative to external drainage and share many of the same indications

Figure 3 An 8-year-old boy with cystinuria and 2-cm right renal calculus. Following complicated percutaneous lithotripsy, the patient developed abdominal distension. A chest x-ray (CXR) following the procedure demonstrated a large right hydrothorax, which required chest tube placement. Computed tomography (CT) demonstrated a retroperitoneal hematoma and large volume ascites. The ascites resulted from peritoneal perforation and passage of nephroscopic irrigation fluid into the peritoneal cavity. The ascites resulted in abdominal compartment syndrome and required percutaneous drainage. (A) CXR shows a large right hydrothorax. (B) Noncontrast CT shows a right retroperitoneal hematoma (white arrow), large volume low-attenuation ascites (black arrow), and double-J ureteral stent.

as percutaneous nephrostomy. Urologists place the majority of ureteral stents in a retrograde fashion. However, when this is not possible, an antegrade approach may be accomplished by the interventional radiologist. Indications for antegrade ureteral stent insertion include failed pyeloplasty, postoperative ureteral stenosis/obstruction, ureteral injury, ureteral fistula, and tumor compression.^{2,17,18}

The preprocedural preparation is similar to the previously described urologic procedures, with many

institutions administering prophylactic antibiotics in nearly all cases.¹⁷ The technical approach is similar to that in adults with initial access performed using a single- or double-stick method. Middle- or upper-pole calyces are chosen to allow straight access to the pelvis and upper ureter, which greatly assists in passing a guidewire into the ureter and performing dilations without buckling the wire. In cases of ureteral stricture or excessive tortuosity of the ureter, standard guidewires often buckle in the renal pelvis or ureter. In these cases, a hydrophilic guidewire is very helpful to pass the wire into the urinary bladder. Additionally, once a stricture is bypassed with a wire, it may be dilated using an angioplasty balloon.¹⁹

After a stiff guidewire is advanced well into the urinary bladder, a peel-away sheath is placed over the wire. Given the highly variable length of children's ureters, a variable length silicone ureteral stent is best used in the young pediatric population.² In teenagers, fixed-length ureteric stents work well; the procedure requires measuring the ureter length prior to insertion. The tapered end of the double-J stent is placed over the wire and passed into the ureter. A pusher with a radiopaque marker is then used to advance the distal stent tip to the level of the bladder and the proximal stent tip into the region of the renal pelvis. The proximal stent tip contains a safety suture, which may be used to draw the stent tip back to the level of the renal pelvis if it has been advanced too far into the ureter. After proper positioning of the stent loops, a nephrostogram should be performed to document patency of the stent. The safety suture may then be cut and removed (Fig. 4).

If there is any question about the proper function of the stent or there is anticipated need to reaccess the collecting system in the near future, two options are available: (1) a separate nephrostomy catheter may be left in place; or (2) the double-J internal ureteric stent can be removed and a single percutaneous nephroureterostomy stent may be placed.

Complications include technical failure, stent malposition, stent infection, and rarely, pelvis or ureter injury. Internal double-J ureteral stents must be exchanged every 4 to 8 weeks.² The frequency of stent exchange depends on the degree of encrustation of stents at the time of exchange. Encrustation is a particular problem in those patients prone to stone formation. A conservative approach is to start with a short exchange interval of 4 to 6 weeks and lengthen the subsequent exchange interval if there is no significant encrustation evident.

Although urologists usually perform internal ureteral stent exchanges, the procedure can also be performed by the interventional radiologist in female patients. At our institution, this process involves cannulation of the female urethra with guidewire and angled catheter. A sheathed (coaxial) catheter is then exchanged

Figure 4 A 3-year-old boy with right ureteropelvic junction obstruction and recent trauma, with clinical concern for forniceal rupture. A percutaneous nephrostomy (PCN) placement was performed initially, and the patient then presented for conversion to an internal double-J ureteric stent. (A) PCN in the right renal pelvis. (B) The PCN has been removed over a wire. The guidewire is passed to the level of the bladder and a peel-away sheath advanced into the renal pelvis. (C) Internal double-J stent exchanged over the wire. (D) Peel-away sheath and wire removed with the proximal and distal loops properly placed within the renal pelvis and bladder, respectively.

over the wire and the distal ureteral catheter loop is snared using a nitinol snare. The distal ureteral catheter, coaxial catheter, and snare are brought to the surface through the urethra. A guidewire is then passed through

the ureteral catheter and coiled in the renal pelvis. The old stent is then exchanged over the wire for a new internal ureteral stent, with positioning confirmed by fluoroscopy.

RENAL BIOPSY

Renal biopsy is performed in children with renal parenchymal disease to initially establish a diagnosis and monitor disease progression and response to medical therapy. Importantly, in the age of pediatric renal transplantation, percutaneous renal biopsy has become an integral tool in evaluating for rejection and plays a key role in posttransplant medical management. Preprocedural steps include optimization of a patient's coagulation status and review of prior imaging. Routine antibiotic prophylaxis is not recommended. Conscious sedation and local anesthesia are usually sufficient to perform the procedure, but general anesthesia is sometimes required for younger children. Native kidneys are best approached with the patient in the prone or semi-prone position, whereas transplant kidneys may be approached with the patient in the supine position.²

The types of biopsy devices used to obtain tissue samples are varied, but semiautomated devices are recommended as they have been shown to obtain optimal tissue samples with few reported complications.^{20–25} Ultrasound is used almost exclusively for imaging guidance due to children's small size. CT may only be helpful in obese teenagers for which ultrasound guidance is not possible. Many approaches have been recommended. In native kidneys, the lower pole is usually most easily visualized and can be accessed from a posterior or lateral approach. In transplant kidneys, a lateral approach is recommended to avoid the peritoneum. Initial puncture of the renal capsule should be done under realtime

Figure 5 A 6-year-old girl with hematuria and proteinuria following an episode of Henoch-Schönlein purpura (HSP). Note the needle guide markers that show the approximate course of the biopsy needle. Three passes were made with an 18-gauge semiautomatic biopsy needle. No complications were identified. Surgical pathology demonstrated HSP nephritis.

Figure 6 An 8-year-old boy with proteinuria underwent renal biopsy with an 18-gauge semiautomatic biopsy needle. After the procedure, a moderate to large perinephric hematoma was identified (white arrows).

ultrasound guidance during a patient breath hold. Once the biopsy needle tip is within the renal capsule, it should be angled such that the needle travels along the trajectory of the renal cortex. This trajectory is important for two reasons: (1) to avoid injury to renal vessels, and (2) to provide the best possible pathologic specimen with the greatest number of glomeruli. Each throw of the biopsy needle should be performed under real-time ultrasound guidance. The ideal number of specimens may differ from institution to institution. A discussion with the referring nephrologists as well as pathologists regarding optimal specimen collection is recommended (Fig. 5).

In a large case series, minor and major complications occurred in ~14% and 3.4%, respectively. Minor complications include gross hematuria and subcapsular hematoma (Fig. 6). Major complications include bleeding requiring transfusion, renal hematoma, and arterial injury.²⁶ Percutaneous transplant renal biopsy has a similar complication rate to native kidney biopsy.^{27–29} Same-day outpatient renal biopsy appears to be safe in selected native and transplant renal biopsies.^{26,28}

CONCLUSION

Urologic interventional procedures have been shown to be safe and effective in the pediatric population. The interventional radiologist plays an integral role in the management of many congenital and acquired urologic conditions. Specific considerations and technical tricks are helpful in the pediatric age group. Special consideration needs to be given to the safe sedation of small children. Choose equipment and devices appropriate to

the variable body size of the pediatric population. Adequate communication of proper postprocedure care to parents and referring clinicians is critical.

REFERENCES

1. Ball WS Jr, Towbin R, Strife JL, Spencer R. Interventional genitourinary radiology in children: a review of 61 procedures. *AJR Am J Roentgenol* 1986;147(4):791-796
2. Barnacle AM, Wilkinson AG, Roebuck DJ. Paediatric interventional urology. *Cardiovasc Intervent Radiol* 2011;34(2):227-240
3. Yavascan O, Aksu N, Erdogan H, et al. Percutaneous nephrostomy in children: diagnostic and therapeutic importance. *Pediatr Nephrol* 2005;20(6):768-772
4. Laurin S, Sandström S, Ivarsson H. Percutaneous nephrostomy in infants and children. *Acad Radiol* 2000;7(7):526-529
5. Stanley P, Diamant MJ. Pediatric percutaneous nephrostomy: experience with 50 patients. *J Urol* 1986;135(6):1223-1226
6. O'Brien WM, Matsumoto AH, Grant EG, Gibbons MD. Percutaneous nephrostomy in infants. *Urology* 1990;36(3):269-272
7. Stanley P, Bear JW, Reid BS. Percutaneous nephrostomy in infants and children. *AJR Am J Roentgenol* 1983; 141(3):473-477
8. Winfield AC, Kirchner SG, Brun ME, Mazer MJ, Braren HV. Percutaneous nephrostomy in neonates, infants, and children. *Radiology* 1984;151(3):617-619
9. Kim YS, Do SH, Hong CH, Kim MJ, Choi SK, Han SW. Does every patient with ureteropelvic junction obstruction need voiding cystourethrography? *J Urol* 2001;165(6 Pt 2):2305-2307
10. Houben CH, Wischermann A, Börner G, Slany E. Outcome analysis of pyeloplasty in infants. *Pediatr Surg Int* 2000;16(3):189-193
11. Perez-Brayfield MR, Kirsch AJ, Jones RA, Grattan-Smith JD. A prospective study comparing ultrasound, nuclear scintigraphy and dynamic contrast enhanced magnetic resonance imaging in the evaluation of hydronephrosis. *J Urol* 2003;170(4 Pt 1):1330-1334
12. Hogan MJ, Coley BD, Jayanthi VR, Shiels WE, Koff SA. Percutaneous nephrostomy in children and adolescents: outpatient management. *Radiology* 2001;218(1):207-210
13. Zeren S, Satar N, Bayazit Y, Bayazit AK, Payasli K, Ozkeçeli R. Percutaneous nephrolithotomy in the management of pediatric renal calculi. *J Endourol* 2002;16(2):75-78
14. Cameron MA, Sakhae K, Moe OW. Nephrolithiasis in children. *Pediatr Nephrol* 2005;20(11):1587-1592 Review
15. Zilberman DE, Lipkin ME, de la Rosette JJ, et al. Tubeless percutaneous nephrolithotomy—the new standard of care? *J Urol* 2010;184(4):1261-1266
16. Bilen CY, Gunay M, Ozden E, Inci K, Sarikaya S, Tekgul S. Tubeless mini percutaneous nephrolithotomy in infants and preschool children: a preliminary report. *J Urol* 2010;184(6):2498-2502
17. Patel U, Abubacker MZ. Ureteral stent placement without postprocedural nephrostomy tube: experience in 41 patients. *Radiology* 2004;230(2):435-442
18. Aubert D, Rigaud P, Zoupanos G. Double pigtail ureteral stent in pediatric urology. *Eur J Pediatr Surg* 1993;3(5):281-283
19. Wilkinson AG, Azmy A. Balloon dilatation of the pelviureteric junction in children: early experience and pitfalls. *Pediatr Radiol* 1996;26(12):882-886
20. Sweeney C, Geary DF, Hebert D, Robinson L, Langlois V. Outpatient pediatric renal transplant biopsy—is it safe? *Pediatr Transplant* 2006;10(2):159-161 Erratum in: *Pediatr Transplant*. 2006 May;10(3):400
21. Sinha MD, Lewis MA, Bradbury MG, Webb NJ. Percutaneous real-time ultrasound-guided renal biopsy by automated biopsy gun in children: safety and complications. *J Nephrol* 2006;19(1):41-44
22. Nyman RS, Cappelen-Smith J, al Suhaibani H, et al. Yield and complications in percutaneous renal biopsy. A comparison between ultrasound-guided gun-biopsy and manual techniques in native and transplant kidneys. *Acta Radiol* 1997;38(3):431-436
23. Webb NJ, Pereira JK, Chait PG, Geary DF. Renal biopsy in children: comparison of two techniques. *Pediatr Nephrol* 1994;8(4):486-488
24. Nahas WC, Mazzucchi E, Henrique A, et al. Percutaneous needle biopsy of the renal allograft using the automated needle system: evaluation of 87 procedures. *J Urol* 1993;150(2 Pt 1):313-315
25. Feneberg R, Schaefer F, Zieger B, Waldherr R, Mehls O, Schäfer K. Percutaneous renal biopsy in children: a 27-year experience. *Nephron* 1998;79(4):438-446
26. Davis ID, Oehlenschläger W, O'Riordan MA, Avner ED. Pediatric renal biopsy: should this procedure be performed in an outpatient setting? *Pediatr Nephrol* 1998;12(2):96-100
27. Vidhun J, Masciandro J, Varich L, Salvatierra O Jr, Sarwal M. Safety and risk stratification of percutaneous biopsies of adult-sized renal allografts in infant and older pediatric recipients. *Transplantation* 2003;76(3):552-557
28. Sweeney C, Geary DF, Hebert D, Robinson L, Langlois V. Outpatient pediatric renal transplant biopsy—is it safe? *Pediatr Transplant* 2006;10(2):159-161 Erratum in: *Pediatr Transplant* 2006;10(3):400
29. Birk PE, Blydt-Hansen TD, Dart AB, Kaita LM, Proulx C, Taylor G. Low incidence of adverse events in outpatient pediatric renal allograft biopsies. *Pediatr Transplant* 2007; 11(2):196-200