Nephrostolithotomy

Darryl A. Zuckerman, M.D.,¹ and Alena Desai, M.D.²

ABSTRACT

Percutaneous nephrostolithotomy (PCNL) is the treatment of choice for large (>2 cm) renal calculi and staghorn calculi. Percutaneous access into the kidney is often achieved by interventional radiologists, either prior to stone surgery or in conjunction with the urology team. Several basic techniques should be considered in gaining access to the kidney to avoid both intraoperative and postoperative complications. In this article, the authors discuss indications for PCNL, techniques for renal access, complications of PCNL, and management of these complications. They also briefly discuss management of postoperative drainage tube(s).

KEYWORDS: Nephrostomy, nephrostolithotomy, lithotomy, calculi, staghorn

Objectives: Upon completion of the article, the reader should be able to list the indications for percutaneous nephrostolithotomy, techniques for renal access, the complications of percutaneous nephrostolithotomy, and management of these complications as well as postoperative drainage tube(s).

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Access to the kidney via a percutaneous approach, performed for decompression was first described in 1955. These procedures were done under local anesthesia and without the use of radiographic guidance.¹ In 1976, the first percutaneous stone retrieval under fluoroscopic guidance was performed. Progressive dilation was performed over several days to weeks' time.² Since that time, many technological advances have been made to refine percutaneous renal surgery for a wide array of clinical uses.³ PCNL can now be performed with minimal morbidity and shortened hospital stays. Only the rare case of nephrolithiasis requires an open surgical procedure.

INDICATIONS FOR PCNL

Percutaneous nephrostolithotomy is recommended for renal stones larger than 2 cm and staghorn calculi; the

latter tend to fill large portions of the collecting system including the renal pelvis and may branch into several or all of the renal calices.⁴ Calculi larger than 2 to 3 cm are difficult to completely treat with shock wave lithotripsy (SWL), and often require multiple sessions. For most large stones, especially nonstruvite or nonapatite, the success rates of SWL are less than 50%; therefore, these are best treated by PCNL. Kidney stones located in lower pole (dependent) calyces present a challenge for removal via SWL, when stone size approaches 1 cm, in part because the small residual stone fragments may be retained in these dependent calyces acting as a nidus for further stone formation. Hence, it is recommended that stones larger than 1 cm located in lower pole calyces also be removed via percutaneous extraction.^{5,6} PCNL should also be considered in pregnant patients with symptomatic nephrolithiasis, when it is critical to

¹Department of Radiology; ²Division of Urology, Department of Surgery, Washington University School of Medicine, St. Louis, Missouri.

Address for correspondence and reprint requests: Darryl A. Zuckerman, M.D., Department of Radiology, Washington University School of Medicine, 660 S. Euclid Avenue, St. Louis, MO 63110 (e-mail: zuckerman@mir.wustl.edu).

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remove all calculus material, and when SWI has failed previously.

Contraindications include uncorrected bleeding diathesis and presence of hydatid cysts. Relative contraindications are urinary tract infection, medical comorbidity precluding adequate anesthesia, and body habitus.⁶ Ultimately, the decision to proceed with PCNL is based on numerous factors including stone composition and size, number and location of calculi, availability of skilled interventional radiologists and urologists, and the patient's size.

TECHNIQUE FOR PERCUTANEOUS RENAL ACCESS

Access to the renal collecting system can be performed under fluoroscopic or ultrasound guidance. If performed in conjunction with the urologist at the time of stone surgery, a retrograde ureteral catheter is first placed endoscopically and the collecting system may be delineated by retrograde pyelography. An "air pyelogram" can be performed to determine the location of a posterior calyx (air fills the posterior calyces in the prone position). The desired calyx of interest is identified and punctured with an 18-gauge needle and the return of urine (and air) confirms correct positioning of the needle. A guidewire, typically a 0.035-inch Bentson guidewire is inserted through the needle into the kidney and passed into the ureter and bladder. Often a Kumpe catheter is useful for negotiating the guidewire around the stone, which may be closely adherent to the urothelium. For severe stone impaction, an angled torqueable hydrophilic wire with the use of a torque device may be necessary. If used, this should be exchanged for a more reliable safety wire such as the Bentson or 0.035-inch Amplatz super-stiff wire. Once a safety wire has been placed through the nephrostomy tract, down the ureter and into the bladder, a second guidewire, the "working wire" may be placed with the use of an 8/10-French (Fr) coaxial dilating system or a dual lumen catheter. The safest approach to ensure continual access is to obtain "through-and-through" access, wherein, in conjunction with the urology team, a guidewire is placed through the percutaneous nephrostomy tract, down the ureter, out of the urethra, and secured externally on both ends. The nephrostomy tract may then be serially dilated with rigid renal dilators or by balloon dilation working over the stiff wire. Balloon dilation has been shown to be associated with less blood loss and potentially less renal damage compared with sequential mechanical dilation.⁷⁻⁹ At our institution we use a Nephromax dilating balloon (Boston Scientific, Natick, MA) over an Amplatz guidewire. The distal tip of the balloon is placed just within the calyx of interest and the tract is typically dilated to a diameter of 30 Fr to accommodate a working renal access sheath, which is placed over the balloon. Once optimal access

has been achieved, the case is turned over to the urologist to perform stone removal.

An alternative approach that has been described involves the use of retrograde ureterorenoscopy to identify a posterior upper pole calyx. Using a combination of fluoroscopic and endoscopic guidance, an 18-gauge needle is passed until it is visualized ureteroscopically. The safety guidewire is then passed through the needle and down the ureter. The nephrostomy tract is then dilated as described above.¹⁰

COMPLICATIONS AND MANAGEMENT

Hemorrhage

Renal hemorrhage is the most worrisome complication of PCNL and can occur at any point from needle insertion to several weeks postoperatively. Bleeding complications during percutaneous access can be minimized by puncturing through the fornix of a posterior calyx along the direction of the infundibulum to avoid injury to adjacent blood vessels.³ The posterior calyx that provides the most direct access to the stone should be chosen.¹¹ The tract should be dilated to the periphery of the calyx under fluoroscopic guidance as proceeding too far medially may result in renal pelvis or hilar vessel injury. The risk of hemorrhagic complications requiring blood transfusions has found to be associated with multiple punctures, renal pelvis perforation, surgical inexperience, preoperative anemia, and overall blood loss.¹² Additional risk factors that have been found to be associated with significant blood loss include diabetes, multiple tracts, prolonged operative time, and intraoperative complications.¹³ The use of mechanical tract dilation with the use of metal dilators or Amplatz dilators versus balloon dilation has also been found to be associated with increased renal hemorrhage.^{13,14}

Intraoperatively, bleeding can occur from the nephrostomy tract and can be due to excessive angulation and torque on the kidney.¹⁵ This further highlights the importance of optimal renal access, as a direct approach to the stone precludes the need for excessive angulation. Flexible nephroscopy can be a useful adjunct to reach certain calyces not accessible with the rigid nephroscope.¹⁶ When excessive bleeding is encountered, it may be due to insufficient length of the renal access sheath within the collecting system. The sheath may be gently advanced over the nephroscope or after repeat dilation of the nephrostomy tract and this may suffice to tamponade the bleeding. Bleeding may also be due to overaggressive advancement of the sheath into the parenchyma; if this occurs, repositioning the sheath should resolve the issue.¹⁷ In all cases, if persistent bleeding impairs visualization, the case should be terminated to avoid inadvertent collecting system or renal trauma. A large-bore nephrostomy tube may be placed over a

guidewire and the balloon inflated in the renal parenchyma to tamponade the bleeding.¹⁸ Alternatively, a Kaye tamponade balloon catheter (Cook Medical Inc., Bloomington, IN), which is a 36-Fr occlusive balloon with a 14-Fr lumen, may be used. The Kaye tamponade catheter is placed over a 5-Fr ureteral stent and serves not only to tamponade the nephrostomy tract, but also to drain the renal pelvis while maintaining access to the ureter.^{19,20} After healing of the nephrostomy tract, definitive treatment of the stone(s) can be performed provided the hematuria has cleared, usually after 24 to 48 hours. In the case of clinically significant bleeding, renal angiography and superselective embolization can be performed. Late complications due to vascular system injury in the form of pseudoaneurysms or arteriovenous fistulas should also be treated with transcatheter embolization. The usual presentation is sudden gross hematuria with or without flank pain that can occur from 1 to 3 weeks postoperatively.²¹

Occasionally, significant bleeding occurs without gross hematuria. A perinephric hematoma should be suspected in cases of decreasing hematocrit levels despite clear urine output. Computed tomography (CT) will confirm the diagnosis, and after the patient has been stabilized, angiography for possible embolization should be considered. It may be useful to place a percutaneous drainage catheter into the hematoma after liquefaction.²²

Infection

Preoperative urine cultures should be obtained and urinary tract infection (UTI) treated appropriately for at least one week prior to definitive stone management. Renal pelvis and stone cultures compared with bladder urine cultures have been found to be more accurate predictors of urosepsis and may not correspond to a specimen obtained from the bladder. If available, a renal pelvis or stone culture should be used to guide antibiotic choice.²³ In the case of infection stones, the urine culture may remain positive until the offending stone is cleared and culture-specific antibiotics should be continued for at least one week postoperatively.²² Patients with negative preoperative urine cultures should be placed on empiric antibiotic therapy perioperatively as this has been found to reduce the risk of infection-related complications.²⁴

Visceral Organ Injury

Injury to adjacent visceral organs is an uncommon, but known risk of percutaneous renal surgery. To study the risks of injury to the lung, spleen, and liver, Hopper and Yakes determined the potential needle paths for a posterior intercostal approach during inspiration, expiration, and with patients in the supine or prone position.

They found that with expiration, the risk of injury to the spleen or liver from an 11th to 12th posterior intercostal approach was minimal; however, the risk of pleural injury was found to be 29% on the right and 14% on the left. For punctures above the 10th rib, the risk of pleural injury was found to be excessively high, 86% on the right and 93% on the left, regardless of the degree of respiration. This approach would be expected to puncture the liver in 14% of patients and the spleen in 33% of patients. It was concluded that posterior intercostal approaches have a small risk of splenic or hepatic injury when performed during full expiration and that the risk of morbidity is related primarily to pleural injury.²⁵ The risk of visceral organ injury for approaches above the 10th rib is excessively high and should not be performed.

The site of puncture for percutaneous renal access should lie between the posterior axillary line and the spine to protect visceral organs from injury. Generally, the puncture site in thin patients should be more medial and superior.²⁶ A more laterally placed incision increases the chance of injury to the colon, liver, and spleen.^{27,28} In patients with anatomic abnormalities such as those with spinal dysraphism or known retrorenal colon, the use of CT-guided percutaneous access has been described to achieve high success rates for these complicated cases.²⁹ In all cases, preoperative cross-sectional imaging can help to determine whether organomegaly or intervening viscera exist to plan optimal percutaneous access.

Pleural Injury

Indications for upper pole access during PCNL include large staghorn calculi, large upper calyceal stones, concomitant ureteropelvic junction pathology, and large proximal ureteral calculi.^{30,31} Upper pole access provides the most direct access to most of the collecting system and upper ureter. This access can be achieved both via supracostal and infracostal approaches, depending on the anatomic location of the kidney. Undoubtedly, the supracostal approach is associated with a higher rate of thoracic complications; this risk must be weighed against the benefit of achieving a stone-free status on an individual case basis.³² Picus et al in a study of 50 patients found that a superior, posterior intercostal approach resulted in pleural transgression in 12% of patients, 8% presenting with a pleural effusion and 4% with a pneumothorax.³³ Despite the risk of pleural injury with supracostal access, this approach is advocated to achieve maximal stone clearance in a single procedure.³⁴ Complications include pneumothorax, hydrothorax, and hemothorax due to intercostal vessel injury. If the patient is asymptomatic and has small-volume pneumothorax or hydrothorax, this can safely be observed with serial examination and chest x-rays. Symptomatic effusions or hydrothorax can be managed with thoracentesis or chest tube drainage until output is minimal. Rarely,

thoracoscopy or thoracotomy may be required in cases of loculated effusions or empyema.^{17,22} When recognized intraoperatively, a thoracostomy tube can be placed under fluoroscopic guidance. Routine postoperative chest x-ray should be performed for all punctures above the 12th rib and for upper pole punctures. Persistent drainage after chest tube placement should raise suspicion for a nephropleural fistula. Placement of a ureteral stent usually resolves this issue.³⁵

Colon Injury

Colon injury is rare and occurs in 0.3 to 1% of cases.¹⁷ Risk factors for colon injury includes renal anomalies such as horseshoe kidney, retrorenal colon, and colonic distension. A more lateral puncture increases the risk of colonic injury. If recognized intraoperatively, the nephrostomy tube should be pulled back into the colon and left as a colonic tube to create a controlled fistula. The kidney should additionally be drained with a nephrostomy tube through a separate puncture or with a double-J ureteral stent. The patient should be placed on broad-spectrum antibiotics. The colonic tube may be removed when a drain study demonstrates no communication with the collecting system.³⁶ Preventive measures include obtaining cross-sectional imaging prior to surgery to evaluate any intervening structures in the potential puncture path. Early diagnosis and treatment are key to management of this injury. Intraoperatively, visualization of fecal material during nephroscopy, watery bowel movement, or bowel opacification with nephrostogram are signs of colon injury. Postoperatively, blood in the stool, fecal material in the nephrostomy tube, pneumaturia, ileus, leukocytosis, fever, nausea, vomiting, sepsis, or peritonitis should alert one to the possibility of this diagnosis. If an extraperitoneal injury is suspected, conservative management may be chosen, provided the patient is stable. Both urinary and intestinal tracts must be separated and drained, the collecting system with either a double-J ureteral stent or nephrostomy tube. In cases of sepsis or peritonitis, open surgical repair must be undertaken.

Splenic Injury

Splenic injury is uncommon for punctures below the 12th rib; however, the presence of splenomegaly increases this risk.¹⁵ Management of this uncommon injury ranges from expectant management with close observation, bedrest, and serial hematocrit measurement to open exploration and splenectomy.³⁷⁻⁴⁰

In a small series of inadvertent splenic injuries, the greatest degree of blood loss was seen in an injury that went unrecognized until the time of nephrostomy tube removal. In this case, direct pressure was held over the nephrostomy site and the patient was admitted for monitoring. The other two injuries were detected by

postoperative CT and managed with prolonged nephrostomy tube drainage for 12 to 15 days followed by removal and inpatient observation to ensure hemodynamic stability. Importantly, none of these patients required blood transfusion or intervention.³⁸ We have previously described a case of a transplenic percutaneous nephrostomy tube managed with nephrostomy tube removal and Gelfoam pledgets deposited along the nephrostomy tract at the time of removal and antegrade ureteral stent placement.⁴¹ Injuries not amenable to conservative management such as those due to splenic perforation, ruptured hematoma, or excessive bleeding require splenectomy.^{37,40}

Liver Injury

Liver injuries are even less common than splenic injuries and most can be managed conservatively. Indeed, large drains are routinely placed following biliary surgery without incident. Intentional percutaneous transhepatic access has also been described for anatomic aberrancy without complication.⁴²

Small Bowel

Injury to the small bowel is exceedingly rare and may be suspected when bowel contents or mucosa are seen during PCNL. This can be confirmed with a nephrostogram, which will demonstrate contrast within the bowel lumen. In a case report of small bowel injury, conservative management was initially attempted with catheter placement into the small bowel, ureteral stent placement, and a drain within the perinephric space. Ultimately, laparotomy was performed for drainage of a pelvic abscess and resection of the involved loop of small bowel.²⁶ In cases of extraperitoneal perforation, conservative management with broad-spectrum antibiotics and parenteral hyperalimentation along with separation of the gastrointestinal tract from the urinary tract with ureteral stenting and formation of a controlled fistula may be attempted. However, in the case of an intraperitoneal perforation, a large fistula, or failure to improve clinically with the above measures, open surgery should be undertaken.^{15,17,43}

Gallbladder Injury

Gallbladder injury should be suspected with aspiration of bilious fluid during puncture. Postoperative peritonitis should also alert one to this possibility. Exploratory laparotomy, cholecystectomy, and washout of the abdomen are usually necessary.⁴⁴⁻⁴⁷ Medial right-sided percutaneous renal access may increase the risk of gallbladder injury; recognition of this complication should prompt a general surgery consultation in case cholecystectomy is necessary.⁴⁷

Collecting System Injury

Collecting system injury can occur during any portion of the case and should be suspected when fluid discrepancy between inflow and outflow exceeds 500 mL. If the perforation is intraperitoneal, electrolyte abnormalities may occur. Small perforations usually heal within 24 to 48 hours and the procedure does not necessarily need to be terminated prematurely.⁴⁸ In the case of a large collecting system injury such as at the renal pelvis, the case should be terminated. In the postoperative period, flank pain, fever, or abdominal distention and ileus should raise the suspicion for urinary extravasation.¹⁷ Percutaneous drainage of the urinoma and drainage of the collecting system either percutaneously or with the placement of a ureteral stent may be necessary for continued symptoms or evidence of infection.¹⁵

Management of Urinary Drainage Postoperatively

The selection of postoperative drainage tube(s) has come under recent debate and is dependent upon multiple factors including residual stone burden, difficulty of access, significant bleeding, or the possibility of distal obstruction. Generally, smaller caliber nephrostomy tubes trend toward lower pain scores and postoperative analgesic requirements.^{49,50} There have been several studies advocating "tubeless" PCNL (although a temporary internal ureteral stent was utilized in most cases) without untoward outcome; the mean stone burden in these studies, however, was relatively small.^{51,52} (Newer on the horizon is the use of hemostatic agents within the nephrostomy tract to avoid tube placement for hemostatic purposes; however, at the present time this remains experimental.^{53,54}) Typically, a ureteral catheter is left in place following the PCNL along with a large-bore catheter, which is left in the kidney to tamponade the tract, so that the tract to the kidney can heal. Ultimately, management of postoperative urinary drainage tube(s) is based on intraoperative findings, postoperative imaging, and clinical course, along with surgeon judgment and preference. Once a post-PCNL nephrostogram is performed to confirm the absence of any residual stone fragments (including *steinstrasse*), to verify patency of the ureter, and to document that there is no significant injury to the renal collecting system or ureter, the catheters can be removed.

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