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Lesson 16 Volume 40

Complications of Percutaneous Nephrolithotomy*

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to recognize the risk factors, signs and symptoms of complications of percutaneous nephrolithotomy and describe their basic management.

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INTRODUCTION

Percutaneous nephrolithotomy was first described in 1976 for extracting renal calculi percutaneously under radiological control. It gained popularity in the 1980s with improved processes of percutaneous renal access and tract dilation. Over time, PCNL has become the gold standard treatment for management of stones >2 cm or in a staghorn formation. It is also indicated for stones <2 cm when stone factors (density, composition), patient factors (body mass index) and location (lower pole) make successful treatment via other modalities more difficult.[1] While PCNL is the most invasive endoscopic stone procedure, it has the highest stone-free rate, requiring fewer auxiliary procedures than ureteroscopy and extracorporeal shock wave lithotripsy for stones >2 cm.[2] **While morbidity is low and mortality even lower, due to greater invasiveness, there is concern for potentially more severe complications than with ureteroscopy or shock wave lithotripsy.** In this Update, we aim to provide a comprehensive summary of complications of PCNL access, intraoperative and postoperative concerns, and a brief discussion regarding management.

PREOPERATIVE PLANNING

A preoperative computerized tomogram should be obtained to assess the renal anatomy, spatial relationship of the kidney relative to the stone as well as the surrounding structures to direct percutaneous access location. Contrast medium is not necessary unless difficult or variant anatomy is a concern. Key observations include retrorenal colon, hepato-/splenomegaly and potential access sites relative to the pleura, ribs and renal cysts.

Further considerations are given regarding patient health and body habitus. Many PCNLs are performed prone. Physical examination findings including spinal curvature, cervical spine issues and positional abilities (severe contracture, inability to rotate shoulders) should be considered.

PCNL is contraindicated in those who are systemically anticoagulated.[3] Patients should be assessed for the ability to stop or bridge anticoagulation perioperatively, which may require involvement of cardiology and/or primary care. **Several groups have demonstrated successful continuation of aspirin 81 mg throughout the perioperative period.**[4]

COMPLICATIONS OF PCNL

Complications of PCNL fall into 4 main categories: preoperative positioning, renal access, intraoperative and postoperative. The rate of major complications is 1.1% to 7%.[5]

Complications of positioning. Given the potential for long operative times, correct positioning is imperative. When moving the patient, especially from supine to prone, bracing the head in a neutral and non extended position helps minimize head and neck injuries, including pressure necrosis, visual loss and vertebral artery dissection. This is especially important in patients with cervical spine pathology (Down syndrome, rheumatoid arthritis). Properly padding pressure points and avoiding stretch on limbs reduces risk of peripheral nerve injury. **When prone, this includes bending the elbow >90 degrees while keeping the axillary angle <90 degrees to minimize risk of brachial plexus injury.** Ankles should be elevated to reduce pressure over the dorsal foot.[6]

Complications due to access. Image-guided renal access is obtained by either the urologist or interventional radiologist and can be done using fluoroscopy and/or ultrasonography. Fluoroscopy-guided access has traditionally involved 2 techniques: the “bull’s eye” or the “triangulation” technique. The bull’s eye technique allows the surgeon to monitor mediolateral and cephalocaudal planes in real time but necessitates a specific skin entry point dictated by the bull’s eye position. The triangulation technique allows an oblique angle from a skin site of one’s choosing and thus may be angulated parallel to the infundibular axis, decreasing the need for excessive torque on the renal parenchyma. There is no clear advantage of one technique.[7] The disadvantages of fluoroscopy-guided access include inability to visualize the surrounding anatomy in real time, radiation exposure and potential need for contrast medium.

Ultrasound-guided access has several purported advantages over fluoroscopy.[8] It provides real-time 3-dimensional imaging of the kidney and the adjacent structures. While retrograde catheters can be placed to distend the collecting system, retrograde access is not necessary. This is advantageous in patients with anatomical variations such as bowel diversions, where retrograde access can be challenging. Thus, it has the potential for shorter access time. Ultrasound does not subject patients to ionizing radiation or contrast material but may be suboptimal in obese patients. Additional considerations for ultrasound guidance include the learning curve for those not accustomed to ultrasound imaging and targeting.

Ureteroscopy-assisted access can be implemented with either fluoroscopy or ultrasound to allow direct observation of the access needle entering the collecting system to precisely direct the entrance site.

Proper access needle choice is important for preventing complications, notably hemorrhage. Either an 18-or 21-gauge needle can be used. An 18-gauge needle is often more traumatic, with an increased risk for hemorrhage. A 21-gauge needle may not adequately maintain its trajectory, increasing the number of attempts and damage to surrounding structures. **Criteria for an atraumatic puncture includes posterolateral access through renal parenchyma entering the papilla, reducing risk to larger inter-lobar vessels.** The posterior calyces are usually located with the long axis directed laterally toward Brodel’s line. In the prone position, identification of the posterior calyces can be facilitated using an air nephrostogram under fluoroscopy. Thus, the puncture will traverse a relatively avascular area, avoiding puncture or laceration of the segmental arteries that course parallel to the infundibulum.

After access has been confirmed, the tract is dilated. This is accomplished with sequential dilators using reusable metal or

ABBREVIATIONS: CT=computerized tomography, PCN=percutaneous nephrostomy tube, PCNL=percutaneous nephrolithotomy disposable dilators, or one-step balloon dilation. While balloon dilators are more expensive and less effective in densely scarred kidneys, it has been suggested that single dilation may reduce repeated shear injuries.[9] Only the skin/soft tissue up to the minor calyx should be dilated. Dilation extending more medially may risk renal pelvis perforation (fig. 1, *A* and *B*). Additionally, the renal pelvis or ureteropelvic junction can be torn, increasing the risk of hemorrhage.[10] This may be suggested by medial contrast extravasation.

After dilation, the working sheath is placed and should remain in the collecting system. Excessive torque should be avoided to limit parenchymal hemorrhage.

During supracostal access, intercostal nerve injuries have been described. This risk is minimized by medial access and avoiding sheath placement immediately below the rib to avoid the neurovascular bundle.[11]

Intraoperative visceral injuries. Any structure in the vicinity of the kidney has the potential to be injured during PCNL, including the pleura, colon, duodenum, spleen, liver, biliary tree and renal collecting system.

Renal Collecting System: Perforation of the collecting system may occur during initial access, dilation or stone manipulation/fragmentation. It has been reported in up to 7% of cases.[12] Rarely, the ureter is completely avulsed, requiring open exploration.

Risk Factors: Perforation most often occurs during the initial access/dilation due to dilating too medially, inappropriate guidewire selection (should use a floppy tip) or during nephroscopy. Balloon dilators have a radiopaque indicator visible on fluoroscopy to guide advancement. The main risk factor for ureteral avulsion is basketing of impacted stones.[12] Additionally, ultrasonic lithotripsy within the ureteropelvic junction or proximal ureter risks thermal injury resulting in stricture or perforation, and thus should be avoided.

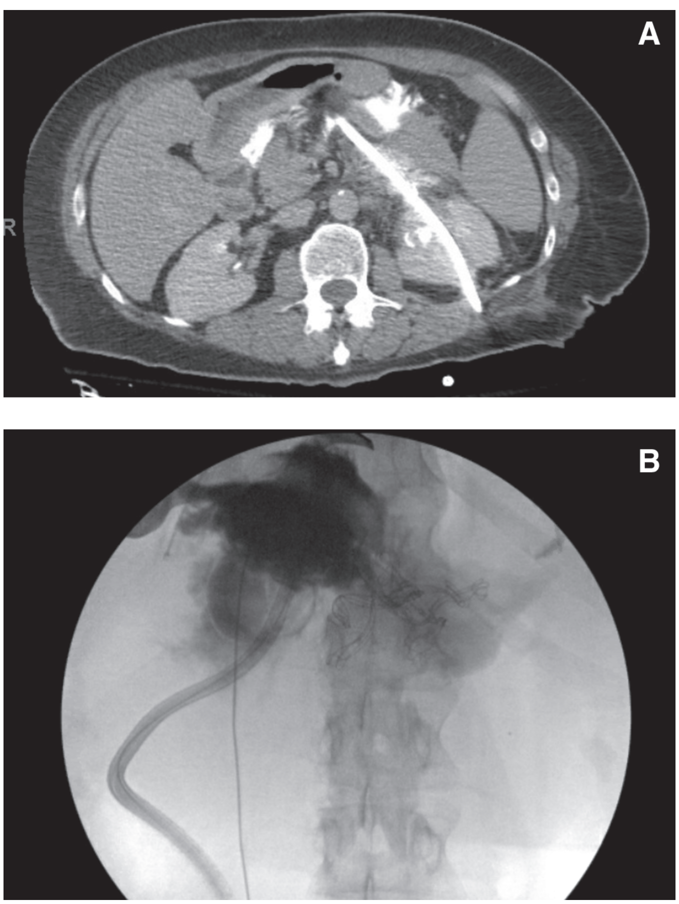

Figure 1. Renal pelvis perforation. (A) CT urogram, delayed phase. (B) renal pelvis perforation—nephrostogram.

Signs/Symptoms: **Perforation should be suspected if there are signs including visualization of perirenal/renal sinus fat or extrarenal structures and inability to maintain distention of the collecting system. More severe signs include a distended abdomen and/or increasing ventilation requirements.[13]** If not recognized intraoperatively, absorption of extrarenal irrigation can manifest as abdominal distention/fluid overload, ileus, unexplained fever or electrolyte abnormalities.[14]

Management: Endoscopically guided renal access provides direct visualization during entry and reduces the risk of dilating too medially.[15] **If a large perforation is noted intraoperatively, the procedure should be aborted and adequate drainage achieved with either a percutaneous nephrostomy tube or ureteral stent.** Smaller disruptions do not necessarily require premature procedural abruption; continuation with careful monitoring and limited irrigation can be considered.[14] Most collecting system injuries heal within 72 hours. Continuation of a PCN for up to a week, and a nephrostogram should be considered for more significant injuries.

If a collecting system injury occurs, there is a small chance of extrarenal stone fragment migration. As long as the stone is not infected and does not end up in close enough proximity to the collecting system to induce inflammation and stricture formation, it does not need to be retrieved.[16]

Lung and Pleura: Pleural injuries occur at a rate of 0.3% to 15%.[17] These include hydropneumothorax (urinothorax/nephropleural fistula, hydrothorax and pneumothorax) and hemothorax.

Risk Factors: **Supracostal access is the greatest risk factor, especially during maximal inspiration and on the right side.[17] At this phase of ventilation, the reported risk of pleural transgression is 86% with access above the 11th rib and 29% above the 12th rib.[18]** Communication with anesthesia to hold ventilation may assist in targeting during the preferred phase, particularly during fluoroscopic access. When using ultrasound, the pleural reflection can be directly visualized and ideally avoided.

Signs/Symptoms: In the majority of cases, a pleural injury may not be evident intraoperatively, as the dilated tract provides tamponade and fluid may not accumulate in the chest. Initial assessment may be performed with chest x-ray, which will detect clinically significant hydrothoraces. Intraoperatively, suspicion for pleural violation includes fluid tracking along the lateral borders of the chest cavity on fluoroscopy with/without compression of the ipsilateral lung and/or increasing ventilation requirements (fig. 2). Intraoperative ultrasound may also be used. A sliding pleura on ultrasound signifies no pneumothorax. Persistent accumulation of fluid within the pleura may suggest a nephropleural fistula.

Management: It is important to obtain supracostal access at maximal expiration. **Small, asymptomatic pneumothoraces and hydrothoraces may be observed. Large or symptomatic (pulmonary compromise, unstable vitals) hydropneumothoraces identified intraoperatively should be drained at that time.** If there is clinical concern, a fluoroscopic image should be taken intraoperatively. If identified intraoperatively, a chest tube should be placed either by the urology team or thoracic surgery, depending on institutional practice. If identified

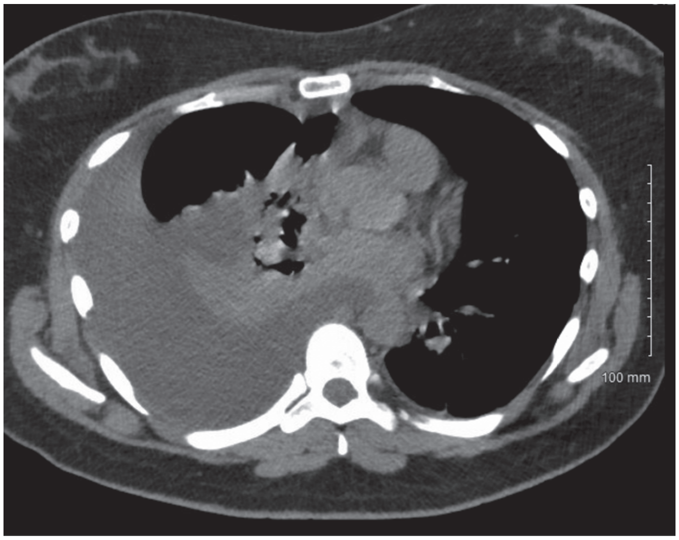

Figure 2. Postoperative pleural effusion.

postoperatively and symptomatic, a consult to interventional radiology is placed for drainage. To facilitate timely closure of the pleural transgression, a nephrostomy tube may be omitted at the site that caused the injury and a lower pole nephrostomy tube is recommended to ensure maximal drainage. If the hydropneumothorax is symptomatic or causes pulmonary compromise, a chest tube should be placed. **If the stone is bacterially colonized or struvite, earlier placement of a chest tube is advised for a hydrothorax regardless of size given the risk of empyema development.[19]** Nephropleural fistulas are treated with continued chest tube and ureteral stent placement.[20] We routinely order postoperative cross-sectional imaging on the morning following the procedure to assess for injuries and guide tube management.

Colon: Colonic injury during PCNL is rare, occurring during access in <0.1% to 1% of reported cases.[5] **Apposition of the colon to the kidney is greatest on the anterolateral left side at the lower pole.**

Risk Factors: There is increased risk of perforation with retrorenal colons (reported in 0.6% of the general population), and injuries are more commonly seen on the left side.[21] Additional risk factors include an overly lateral access puncture, dilated colon, prior colonic surgery or disease, low body mass index and horseshoe kidneys.[22]

Signs/Symptoms: **Colonic perforation is often not appreciated until postoperatively.** It is often detected on routine postoperative imaging assessing for stone burden (fig. 3, *A*). Symptoms may include unexplained fever or leukocytosis, peritonitis, rectal bleeding, fecaluria and pneumouria.[5]

Management: **If the patient is stable and without peritonitis, a ureteral stent and Foley should be placed, the nephrostomy tube retracted into the colon under fluoroscopy, and the patient started on broad spectrum antibiotics and bowel rest.[22]** General surgical consultation is required if the patient develops peritonitis or signs of sepsis to determine the need for exploratory surgery. A nephrostogram should be performed in 1 to 2 weeks to ensure resolution of the nephrocolonic fistula (fig. 3, *B*).[23] Open surgical exploration with/without colostomy is recommended if the perforation is transperitoneal, the patient has peritoneal signs or is septic or non operative management fails.[21]

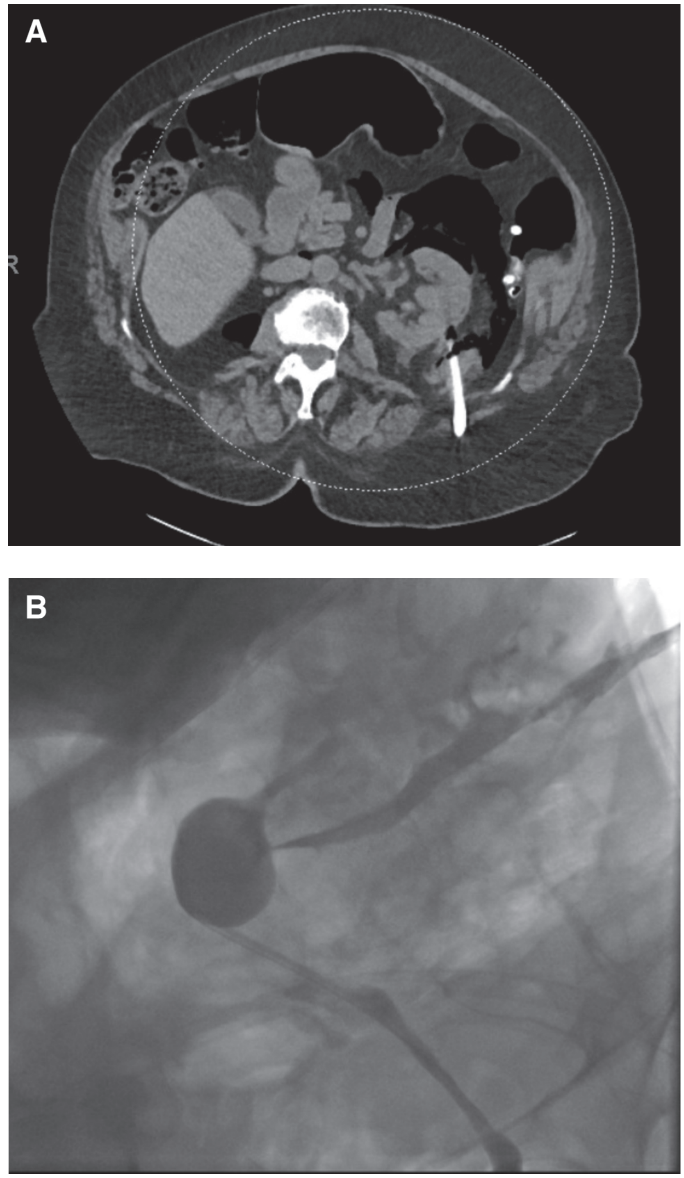

Figure 3. Colonic perforation. (A) CT—colonic perforation by percutaneous nephrostomy tube. (B) nephrostogram demonstrates colorenal fistula.

Spleen: Upper pole access is often preferable in PCNL and at times requires a supracostal approach. In addition to risk of pleural injury, splenic injury risk also increases (fig. 4).[5,18,24]

Risk Factors: The highest risk for injury is upper pole renal access above the 10th rib.[24] Additional risk factors include retrorenal spleen and splenomegaly.

Signs/Symptoms: Acute blood loss anemia can be noted with/without hemodynamic instability or an elevated white count. Injury can be seen on postoperative imaging. Although this is not routinely done at all institutions, we would recommend this in PCNLs with supracostal access.[25,26]

Management: **In hemodynamically stable patients, management of splenic injuries is often non operative.[27]** If injury is noted, the PCN should be left in place to allow for tract maturation for 4 to 14 days.[5] These have been successfully removed at the bedside, with the majority not requiring further intervention. However, if there is concern for hemorrhagic shock,

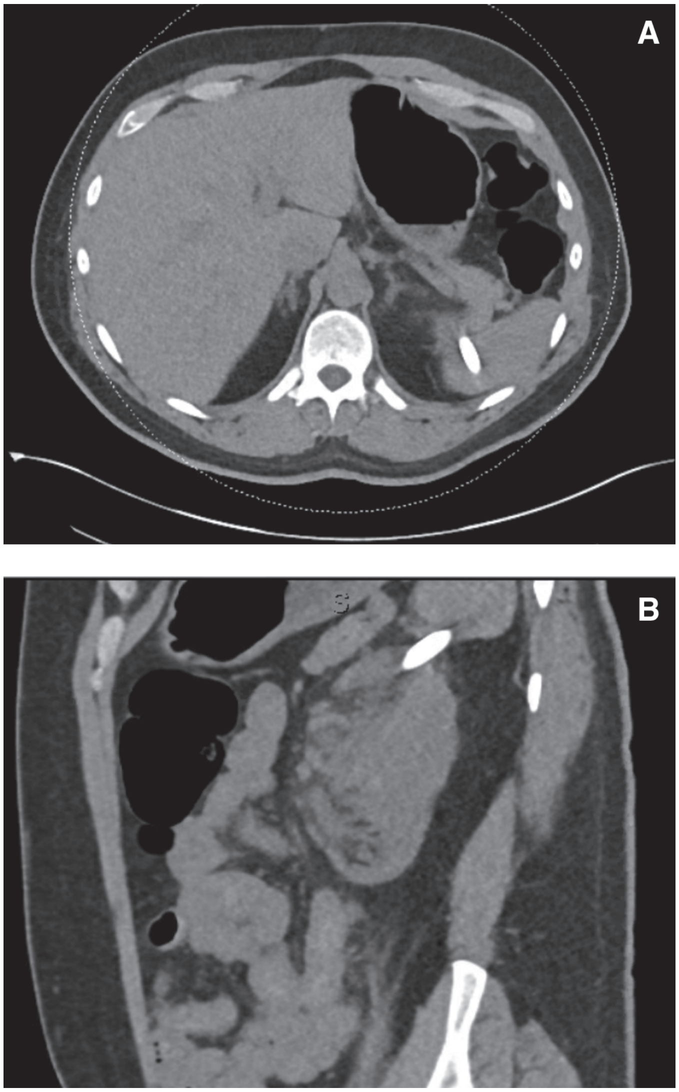

Figure 4. Splenic perforation by percutaneous nephrostomy tube. (A) axial image. (B) sagittal image.

general surgical consultation is warranted and may prompt either embolization or exploration.

Liver: Hepatic injury is rare and often not appreciated unless postoperative imaging is obtained.

Risk Factors: Right-sided, supracostal access above the 11th rib and hepatomegaly are risk factors for hepatic injury.[5]

Signs/Symptoms: Most patients are asymptomatic, and injury is usually noted incidentally on postoperative CT.

Management: Similar to splenic injuries, if the patient is hemodynamically stable, prolonged PCN placement of 4 to 14 days is recommended to promote healing.[5] If a PCN is not left, the patient should be closely monitored. If the patient is unstable, surgical exploration is warranted.

Small Bowel and Biliary System: Small bowel and gallbladder injuries are very rare given the intraperitoneal location. If injured, the most common location is the second and third portions of the duodenum given their proximity to the right renal lower pole.[21]

Risk Factors: Lower pole access into the right renal pelvis, especially in thin patients, is the highest risk factor for small bowel injury.[21] Medial right renal access increases the risk for gallbladder injury.

Signs/Symptoms: During access, aspiration of amber or bilious fluid is concerning. Postoperatively, one may see a change in the character of the PCN output. More concerning is peritonitis.

Management: **Both injuries are usually managed by exploratory laparotomy and cholecystectomy if the gallbladder is injured due to a high mortality rate.** General surgical consultation should be obtained. For small bowel injuries, newer studies have suggested the possibility of minimally invasive approaches utilizing drains, endoscopic repair, total parenteral nutrition and bowel rest.[5,28,29]

Complications of Intraoperative Hemorrhage: One of the most common complications related to PCNL is hemorrhage due to accessing and dilating a tract in a highly vascular organ. The average hemoglobin drop is 1.67.[30] While this is expected, bleeding is not typically considered a complication until transfusion and/or further intervention is required. Transfusion rates are reported between 1% to 11%, and angioembolization rates are ~1%.[30-33]

Preoperative planning with a non contrast CT will help elucidate perirenal anatomy. A hemogram can establish baseline cytopenias,[1] and full anticoagulation should be held or bridged. Ultimately, if risks cannot be sufficiently mitigated, a staged ureteroscopic approach may be best.

Risk Factors: Increased hemorrhage risk occurs when there are multiple access tracts, supracostal access, staghorn formation, larger stone size, diabetes, solitary kidney, thicker parenchyma and increased operative time.[7,30,33,34] Presence of preoperative anemia is more likely to lead to symptomatic blood loss and transfusion.[2]

Signs/Symptoms: Bleeding may occur during any portion of the procedure. With the initial puncture, one may damage a superficial or intercostal blood vessel, especially with supracostal access. **Staying in the lower half of the intercostal space and erring medially may help mitigate this risk.** With kidney access, the ideal puncture is directly onto a posterior calyx along its axis in the relatively avascular Brodel's plane. Some surgeons have advocated use of endoscopic guidance to ensure a papillary puncture as opposed to infundibular, which can increase bleeding. Prior to dilating the tract, urine should be aspirated to ensure adequate placement. **The tract should then only be dilated to the periphery of the collecting system to avoid pelvic wall tears.** Some have suggested an association of decreased bleeding with smaller sheath size, which led to the popularity of mini-PCNL, particularly for smaller stone volumes.[30]

Once the tract is established, excessive torquing of the nephroscope should be avoided as it can lead to laceration of blood vessels alongside the calyx/infundibulum. The use of flexible scopes or additional access is recommended. If the access sheath is not properly secured and is involuntarily retracted, there may be additional bleeding from loss of parenchymal tamponade. If the procedure is tubeless, the surgeon should keep access through the tract with a safety wire when removing the access sheath.

Management: Most patients who bleed postoperatively can be managed non operatively. First, manual pressure against the rib can tamponade superficial bleeding. Electrocautery is used for visible bleeders. Once bleeding has resolved, the safety wire may be removed. If bleeding continues, a 22Fr Councill catheter may be placed and temporarily clamped. If bleeding persists, the surgeon should inflate a 30Fr tamponade balloon for 20 to 30 minutes followed by a large bore (>18Fr) PCN over the wire. If bleeding persists, the PCN should be clamped for 2 to 3 hours. Transitioning the patient from prone to supine may help.[35] **Ultimately, if bleeding is refractory to the conservative measures noted, the next step is angiography with selective embolization, which has success rates up to 92%.[33]** There are case reports of bleeding requiring partial or total nephrectomy for refractory bleeding.[32]

Metabolic and Physiological Complications: **The AUA Guideline recommends use of normal saline for irrigation as it is isotonic and less likely to lead to electrolyte derangements, hemolysis or heart failure with high volume absorption.[1]** Too much extravasation or absorption could lead to unexpected hypoxemia or hypertension. This risk can be minimized by utilizing the lowest irrigation pressure possible to allow adequate visualization. If an obvious perforation occurs, the procedure should be stopped and drainage optimized with a PCN and/or ureteral stent. Hypothermia may occur intraoperatively. This is avoided by controlling ambient temperature, utilizing warmed irrigation fluid and blankets, keeping the patient dry and minimizing exposed body surface.[16]

A rare complication is air embolism. It has been associated with air pyelography and pyelovenous backflow, although it may also occur with regular irrigation or contrast injection. **An air embolus may present with a sudden drop in end tidal CO_2 with associated hypoxemia and hypotension. It is managed by terminating the procedure, rapidly transitioning to 100% oxygen and repositioning the patient with head down and right side up.** If a patent foramen ovale is present, air embolism may result in stroke. The overall risk of this complication is very low but may be further minimized by utilizing less air during injection of the pyelogram or using other gases such as CO_2.[36]

While there may be a small, transient increase in creatinine, over 80% of patients will have stable or improved renal function.[16] Obtaining multiple accesses to a single kidney does appear to have a small but statistically significant effect on renal function compared to single access. This may have greater significance in patients with baseline altered renal function or those who ultimately require multiple procedures.[37]

Postoperative complications. Infectious: These are relatively common in PCNL and can lead to significant morbidity and even mortality. The rate of postoperative fever ranges from 1.2% to 32%, with urosepsis occurring closer to 0.3% to 4.7%.[16,31,38,39]

It is important to adequately treat urinary tract infections prior to PCNL. There is no consensus on the length of treatment prior to intervention, but it usually involves at least 1 week of targeted therapy.[40] If obstruction is concomitantly suspected, the patient should have drainage optimized with ureteral stenting or PCN placement with concurrent antimicrobial administration. Antibiotic selection should be informed by preoperative urine culture and local antibiogram, with consideration of antifungals in those at elevated risk for funguria. **A preoperative urine culture revealing no growth does not necessarily predict a negative renal pelvic urine culture.[40]** In the absence of suspected infection, a single dose of preoperative antibiotics has been recommended.[41]

Sepsis may occur from infected urine, bacterial colonized stones, or infection introduced upon access. Factors associated with postoperative sepsis include longer surgical duration, increased irrigation fluid volume, staghorn calculus, known struvite stones, diabetes, paraplegia, indwelling tubes and multiple access sites.[39,42-44]

To identify potential relevant pathological bacteria, surgeons should consider obtaining a culture from the renal pelvis upon entry. Additionally, a crushed stone culture can be sent, especially if there is suspicion of infected stone, history of recurrent urinary tract infections or if the patient is a higher sepsis risk. **Positive stone culture has proven to correlate more closely with postoperative sepsis compared to voided cultures.[16,45]** Similarly, organisms found in crushed stone cultures are often different than those found on stone surfaces or in voided cultures.[45,46] Culture results may take a few days to finalize, and thus these are precautionary to guide antibiotic selection should sepsis develop or to provide culture directed prophylaxis prior to a second-stage procedure.

If surgeons encounter purulent urine during the procedure, they should obtain a culture of the fluid, place a drainage tube (ureteral stent or PCN) and abort the procedure. Prior to proceeding with definitive stone treatment, appropriate antibiotics along with drainage should be continued until the infection is sufficiently treated.[1]

Intraoperatively, high pressures in the collecting system may lead to pyelovenous backflow and/or perforation, leading to systemic absorption of potentially infected urine and/or endotoxins.[39] One should pressurize the system only up to a point where there is adequate visualization. This may mean utilizing only gravity-assisted pressurization. If there is not sufficient space to drain around the nephroscope through the sheath, it may be worth considering a ureteral access sheath to assist with drainage. Bladder drainage should be maintained through the case via a Foley catheter or ureteral access sheath.

Hemorrhagic: Postoperative bleeding typically occurs in the immediate postoperative period. As previously mentioned, we recommend holding pressure, followed by replacement of PCN, then balloon tamponade and angiography as the last resort. If a patient presents with delayed bleeding (1 to 3 weeks), this is more likely secondary to an arteriovenous fistula or pseudoaneurysm rupture (fig. 5). Patients will often present a few weeks after the procedure with new or worsening gross hematuria and more rarely hypotension. This can initially be managed conservatively (close monitoring with/without irrigation if clots are present, followed by repeat imaging). **However, if there is persistent or recurrent bleeding, hemodynamic instability or decreasing hemoglobin, the next step is to proceed with angiography/embolization by interventional radiology.** If a patient's hemoglobin is decreasing while the urine remains relatively clear, a developing perinephric hematoma should be considered and confirmed by imaging. This can be managed conservatively if limited to the retroperitoneal space. In some cases, hematomas may be associated with infection.

Renal Collecting System: Notable, yet rare, long-term complications of collecting system injuries include infundibular stenosis, ureteral stricture and nephrocutaneous fistulas. Stenosis and stricture have been reported in 1% to 2% of cases.[47] They typically involve the proximal ureter or ureteropelvic junction.[16] Nephrocutaneous fistulas occur in 1.5% to 4.6% of cases.[48]

Risk Factors: There is a higher risk of stenosis development during prolonged operative times, large stone burden requiring multiple procedures and extended postoperative PCN placement leading to a prolonged inflammatory reaction.[47] Risk factors for ureteral stricture include inflation of a ureteral

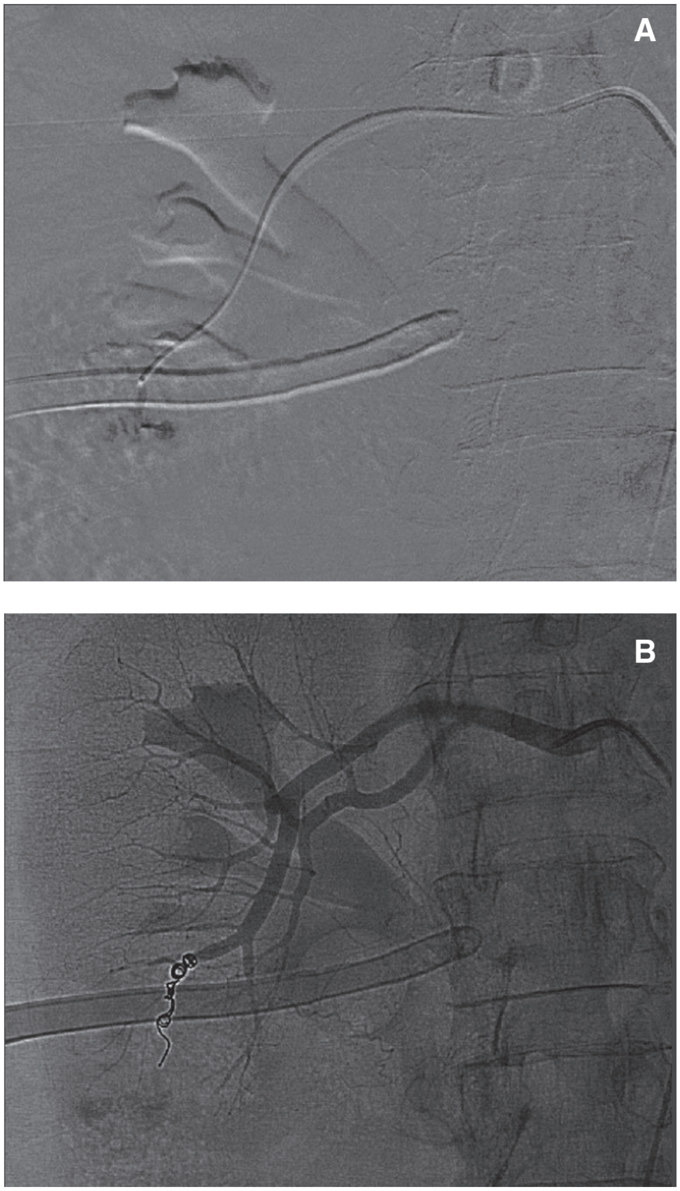

Figure 5. Pseudoaneurysm on angiography. (A) Pseudoaneurysm. (B) After coil embolization.

occlusion balloon in the ureter, ureteral manipulation and basketing impacted stones. There is an increased risk of nephrocutaneous fistula formation when any type of distal obstruction is present, including clot, edema and residual calculi.

Signs/Symptoms: Infundibular stenosis is observed on imaging as a dilated calyx in the presence of a non-dilated pelvis. Ureteral strictures often present with pain and associated hydronephrosis. Nephrocutaneous fistula presents as a constant cutaneous leakage of urine.

Management: Infundibular stenosis is often endoscopically incised or balloon dilated. Observation may be considered if the patient is asymptomatic with stable renal function.[47]

Regarding nephrocutaneous fistulas, urinary tract drainage usually ceases within 6 to 12 hours after PCN removal.[49] **If persistent nephrocutaneous leakage occurs, consider imaging to assess for obstruction. Fistulas will often self-resolve after removal of the obstruction or placement of a stent promoting antegrade drainage**.

CONCLUSIONS

Percutaneous nephrolithotomy is the gold standard for stone disease >2 cm. While morbidity and mortality are quite low, due to its greater invasiveness, complications can be more severe than with other endoscopic stone procedures. Careful patient selection and preoperative planning with appropriate imaging are critical to decrease the risk of complications. Should a complication occur, early recognition and management are key to minimizing the severity.

DID YOU KNOW?

- A preoperative CT scan without contrast medium should be obtained to optimize percutaneous access and reduce risk of visceral organ damage.
- Ultrasound-guided access provides 3-dimensional imaging of the kidney and the adjacent structures, reducing risk of damage to surrounding structures during access.
- A preoperative urine culture revealing no growth does not necessarily predict a negative renal pelvic urine culture.
- Small hydropneumothoraces after PCNL can be observed, with indications for intervention including respiratory/hemodynamic compromise or infected stone.
- Colonic perforation is often not appreciated until postoperatively. If the patient is stable and without peritonitis, a ureteral stent and urethral catheter should be placed, the nephrostomy tube should be retracted into the colon under fluoroscopy, and the patient should be started on broad-spectrum antibiotics and bowel rest.

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Study Questions Volume 40 Lesson 16

1. A 40-year-old woman undergoes a PCNL for a large struvite stone discovered during evaluation for persistent *Proteus* urinary tract infections. Initial access is obtained by ultrasound above the 11th rib. The procedure is uncomplicated. At the end of the case, a small but appreciable hydrothorax is noted. The patient shows no signs of hemodynamic or respiratory compromise. The next steps are
   a. extubate, obtain a baseline chest x-ray in the recovery unit and consult thoracic surgery
   b. extubate, observe with serial chest x-rays, place a chest tube if the hemothorax expands or if the patient spikes a fever or develops respiratory compromise
   c. aspirate the hydrothorax intraoperatively and then observe with serial chest x-rays
   d. place a chest tube intraoperatively

2. A 60-year-old man undergoes an uncomplicated PCNL for a 3.5 cm left lower pole renal stone. His CT scan the following morning shows his percutaneous nephrostomy tube traversing the colon. He has a ureteral stent and Foley that were placed intraoperatively. He is hemodynamically stable, afebrile and has a normal abdominal exam. The next step in management is
   a. observation with consultation to general surgery
   b. remove the percutaneous nephrostomy tube
   c. withdraw the percutaneous nephrostomy tube into the colon under fluoroscopy
   d. open surgical exploration with/without colostomy

3. A 70-year-old-man with a history of calcium oxalate stones undergoes PCNL for a 4 cm staghorn stone requiring multiple access sites. During the procedure, a renal collecting system perforation is noted and the case is aborted. The following day, a postoperative CT is obtained and shows a small stone fragment in the retroperitoneum approximately 5 cm from the kidney. The next step in management is
   a. no intervention
   b. percutaneous retrieval via the current nephrostomy tube and perforated calyx
   c. immediate open exploration with general surgery
   d. delayed laparoscopic exploration with consultation to general surgery

4. A 62-year-old woman is undergoing PCNL in the prone position for a 2.9 cm left renal pelvis stone. Prior to obtaining percutaneous access, air is injected through a ureteral catheter to help define the collecting system. Shortly thereafter, the patient becomes hypoxic and hypotensive. The next step is
   a. reposition to the supine position and continue the procedure
   b. obtain renal pelvic urine for culture, place a ureteral stent and abort the procedure
   c. abort the procedure, place patient in left lateral decubitus with head down and instruct the anesthesiologist to administer 100% oxygen
   d. abort procedure, place the patient in steep Trendelenburg position and transfer the patient to a hyperbaric oxygen chamber

5. A 34-year-old diabetic man has a right-sided partial staghorn calculus and is scheduled for a PCNL in the prone position. Preoperative urine culture shows no growth. Upon placement of the retrograde ureteral catheter, there is a hydronephrotic drip of purulent urine. The patient is afebrile and hemodynamically stable The next step is
   a. send the fluid for urine culture and proceed with PCNL
   b. send the fluid for urine culture, broaden the antibiotic coverage and proceed with PCNL
   c. send the fluid for urine culture, place ureteral stent and abort the PCNL
   d. change to ureteroscopy and send stone for culture