Percutaneous nephrolithotomy made easier: a practical guide, tips and tricks

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Percutaneous nephrolithotomy (PCNL) plays an integral role in managing large renal stones. Establishing percutaneous renal access is the most crucial step in the procedure and requires a thorough understanding of renal, retroperitoneal and thoracic anatomy to minimize the risk of complications. Moreover, access to fluoroscopy and the proper equipment are critical to ensuring complete stone removal. In this review we describe the technique of PCNL used in a high-volume endourology centre, where the urologist is involved in all aspects of the procedure.

KEYWORDS

percutaneous nephrolithotomy, percutaneous renal access, stone disease

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the preferred treatment for large (>2 cm) renal or staghorn renal stones [1]. The planning and successful execution of the initial access into the kidney is crucial to the outcome of PCNL. In many institutions, the kidney is accessed by an interventional radiologist in the radiology department, requiring PCNL to be a staged procedure. The urologist's ability to access the kidney in the operating room, permitting PCNL to be carried out in one stage, is advantageous for several reasons. The inefficiency of having the patient attend in the operating room for retrograde ureteric catheter insertion, then having to be transferred to the radiology suite to place the tract, and then returning to the operating room for stone removal, is eliminated. The urologist's selection of the optimum tract based on the intrarenal anatomy and the ability to make secondary tracts as required [2], permit more effective stone removal. Watterson *et al.* [3] also found access-related complications were fewer and stone-free rates improved when the urologist made the percutaneous access.

Currently many urology trainees have limited opportunities and experience in gaining percutaneous renal access. The use of ultrasonography to gain access requires expertise and equipment that many urologists do not have readily available at present. In North America, the exposure of residents and fellows is variable, although at most high-volume stone centres, urologists obtain their own access. At St Joseph's Hospital in London, Ontario, Canada there have been ≈ 1600 cases of percutaneous stone surgery over a 15-year period, with excellent outcomes [4]. In London, percutaneous access is obtained by the endourologist with no reliance on the interventional radiologists.

SURGICAL ANATOMY

The kidneys lie in the retroperitoneum, although a significant portion of each is actually supracostal; the lower pole is nearly always subcostal. The longitudinal axis of each kidney is oblique and dorsally inclined, making the upper pole calyces more medial and posterior than the inferior pole [5]. The posterior calyces of the kidney are at a 30° oblique angle to the vertical plane when the patient is prone. The upper or lower pole calyces are offset by 10° in the cranial or caudal plane, respectively.

Percutaneous access into the collecting system is safest when using a direct puncture through the overlying renal parenchyma into the fornix of the intended calyx, to avoid major blood vessels [6]. Direct entry into an infundibulum risks injury to one of the interlobar vessels or segmental branches of the renal artery, resulting in significant haemorrhage [6]. Inadvertent puncture of an anterior calyx results in more parenchyma being traversed, increasing the risk of bleeding, and makes it more difficult to access the renal pelvis or other portions of the collecting system.

In many instances the upper-pole puncture is the most appropriate calyx to work in, especially for complete staghorn calculi or when direct access to the PUJ is desired [7,8]. However, supracostal access risks the potential of traversing the pleural space. The medial half of the 12th rib and medial three-quarters of the 11th rib provide attachment to the pleura, while each lung base is located two interspaces higher on full expiration [9]. Munver *et al.* [8], in their series, reported an overall complication rate for supracostal tracts of 16.3%, compared with 4.5% for subcostal access. Further analysis revealed that there were more complications in supra-11th rib punctures (34.6%) than supra-12th rib accesses (9.7%) [8]. In an attempt to minimize the complications for supracostal punctures, we try to avoid supra-11th rib punctures and stay in the lateral half of the rib to remain extrapleural. For all supracostal tracts it is important to ensure that the access sheath remains within the kidney during the procedure. We also leave a ureteric JJ stent at the end of the procedure, to ensure drainage, for all supracostal tracts.

PREPARATION BEFORE PCNL

Proper radiological imaging is essential; historically, IVU was the preferred imaging method of most endourologists before PCNL. With the widespread availability of multiphase CT scanners, allowing imaging during delayed phases of contrast excretion and the capacity for coronal reconstruction, CT is now commonly used in the evaluation

FIG. 1. *Non-contrast CT before PCNL, showing a retrorenal colon.*

before PCNL [10]. The main advantage of CT over IVU is the ability to assess the spatial relationship of the kidney relative to the stone, and the kidney in relation to adjacent viscera, for tract planning. The preoperative detection of hepatosplenomegaly or the presence of a retrorenal colon allows serious complications related to tract placement to be avoided [11] (Fig. 1).

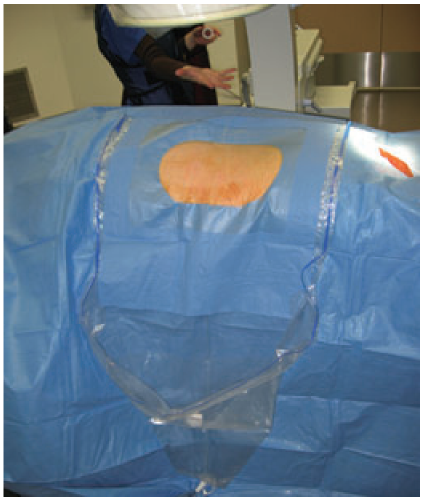
Any UTI should be treated with culture-specific oral antibiotics before PCNL. There is evidence that a 1-week pretreatment with an oral quinolone reduces infective complications in all patients before PCNL, regardless of urine culture results [12]. The patients' coagulation profile including the International Normalized Ratio, partial thromboplastin time and platelet status, should be assessed. Any medications potentially affecting coagulation, including aspirin and NSAIDs are discontinued at the appropriate times before surgery.

An anaesthetic assessment is necessary before PCNL if there is any concern about the medical fitness for PCNL, considering that the operation is done with the patient prone. This is particularly important in obese individuals, who once placed prone might develop high intra-abdominal pressures, resulting in cardio-respiratory compromise. In the morbidly obese, this concern might preclude PCNL under general anaesthesia. We have shown that PCNL can be safe and effective using i.v. sedation and local anaesthesia, obviating the need for intubation and mechanical ventilation in such challenging patients [13].

DURING PCNL

All patients receive broad-spectrum parenteral antibiotic coverage when called to

FIG. 2. *The operative arrangement.*



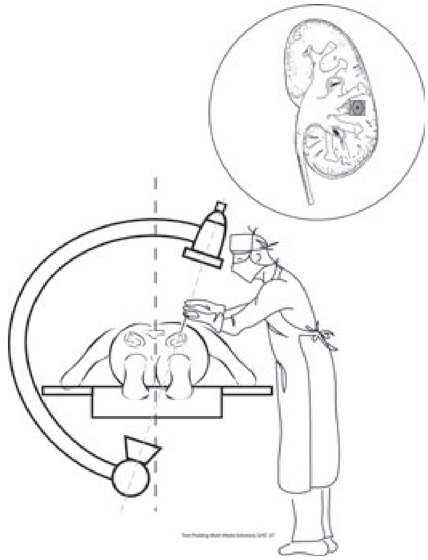
the operating room. After inducing general anaesthesia, the patient is placed prone, with careful attention to the face and extremity pressure points. Padding is used to support the chest, to assist ventilation. After antiseptic cleansing of both the patient's flank and genitalia, an adhesive disposable drape, with its own fluid collection pouch, is applied over the flank to capture the irrigation fluid (Fig. 2).

Flexible cystoscopy is used to facilitate placing a 0.9 mm (0.035 inch) Bentson guidewire over which a 5 F open-ended ureteric catheter is advanced into the renal pelvis under fluoroscopic guidance. Care is taken to avoid introducing air into the bladder during cystoscopy, as identifying the ureteric orifices then becomes more difficult.

The benefits of prone flexible cystoscopy include avoiding a second patient transfer, reducing the likelihood of accidental ureteric catheter dislodgement, and less risk to the airway. Contraindications to prone cystoscopy include those patients who are morbidly obese or with known urethral strictures. In these situations, cystoscopy and placing the ureteric catheter can be done with the patient supine or in the dorsal lithotomy position. Once the ureteric catheter is placed, it is then attached to 60 mL Luer-lock syringe containing 30% nonionic contrast medium. A 16 F indwelling Foley catheter is positioned in the bladder.

For percutaneous intrarenal access, biplanar fluoroscopy with a rotating C-arm is essential. The image intensifier is sterile-draped and the foot pedal is positioned to allow control by

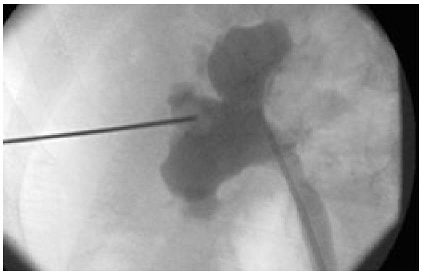
FIG. 3. *The C-arm rotation toward the surgeon to align the needle tip with the desired entry calyx. The inset shows the 'bull's eye' appearance of the needle on the fluoroscopy monitor.*



the surgeon. Retrograde pyelography is performed with the C-arm in the vertical position, to delineate the intrarenal collecting system and to locate the stone(s). Once the target calyx is identified the image intensifier is angled toward the surgeon at 20–30° from the vertical in the axial plane (Fig. 3). A 5–10° tilt is added in the caudal or cranial direction, depending on whether the lower or upper pole is being accessed. With this orientation the desired posterior calyx will appear to be circular. Precise determination of anterior or posterior calyceal position can be difficult, as the calyces might be distributed in a variable arrangement even using oblique or lateral views [14]. The posterior calyx can be correctly identified, as it will appear less dense relative to the anterior calyces after retrograde contrast administration. Injection with 10 mL of air via the retrograde ureteric catheter can also help to identify posterior calyces, as air will preferentially enter these calyces when the patient is prone (Fig. 4).

The tip of a haemostat is then used to mark the position on the skin overlying the selected calyx, while using short bursts of fluoroscopy. This position is chosen during end-expiration, as the kidney is stationary in this position for longer. An 18 G/15 cm long 'diamond' point Angiographic Needle (Cook Inc, Bloomington, IN, USA) is introduced through the skin at this position. The needle is then advanced at the end of full-expiration under fluoroscopic

FIG. 4. A retrograde study with air injection.

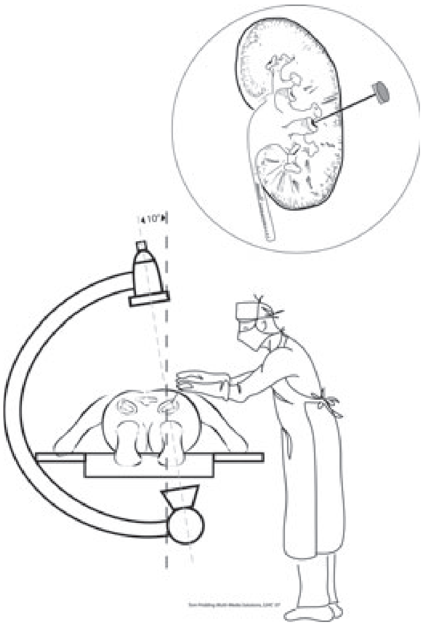


guidance, in the same trajectory as the orientation of the C-arm. This configuration can easily be identified as 'looking at the target end-on down a barrel' with the needle and the overlying hub in the same alignment as the calyx, creating a 'bull's-eye' effect. Entry into the overlying renal parenchyma is confirmed when respiratory-induced movement of the needle in a cranio-caudal direction is noted. As noted previously, the point of entry into the calyx should be into the fornix and not the infundibulum, to avoid haemorrhage.

After confirming that the needle is in the renal parenchyma, the C-arm is rotated away from the surgeon to ≈10° from the vertical plane, to provide depth perspective (Fig. 5). The needle will now be seen in profile. The needle is then advanced into the tip of the calyx. The stylet is removed from the centre of the needle and a urine drip might be noted. Although the technique of contrast-medium injection through the needle is advocated by some, we find this is rarely necessary. Indeed, if the needle is not in the collecting system, contrast medium extravasation might obscure important anatomical detail, making accurate needle redirection impossible.

A 0.9 mm (0.035-inch) hydrophilic-coated angled-tip guidewire is passed through the lumen of the needle and curled within the renal collecting system. A scalpel blade is used to incise the skin for a further 2–3 mm after the needle is removed. An angled tip or 'hockey stick' catheter (5 F, Kumpe Access Angiographic Catheter, Cook, Bloomington, IN, USA; Fig. 6) is then advanced over the guidewire into the collecting system. This is an important step in reducing the chance of losing the safety guidewire. We have found no need to place a second safety wire with this technique. In situations where there is significant perinephric scarring preventing the

FIG. 5. C-arm rotation away from the surgeon to gauge the correct depth perception and to guide the needle tip into the entry calyx. The inset shows the profile appearance of the needle on the fluoroscopy monitor.



advancement of the hockey-stick catheter, the use of a 10 F sheath (8/10 F coaxial dilatation stylet and sheath, Boston Scientific Corp, Natick, MA, USA) positioned within the renal parenchyma can act as a conduit to assist the forward advance of the catheter. The hockey-stick catheter is steerable and allows the guidewire to be directed down the ureter and into the bladder; this wire is then replaced with an Amplatz 0.9-mm (0.038-inch) extra-stiff wire. If the situation is encountered where the wire cannot be directed down the ureter, we attempt to advance as much of the stiff portion of the guidewire as possible into the renal pelvis. However, the first manoeuvre after tract dilatation should be to secure guidewire access. This can be done most easily by retrograde advancement of a 260-cm length 0.9 mm (0.035-inch) Bentson exchange guidewire (Cook) through the ureteric catheter. The wire can then be grasped with the rigid nephroscope graspers and brought out from the working sheath, and secured to the drape to give 'through and through' access.

If difficulty is encountered in placing a guidewire into an undilated collecting system, or if the stone is impacting the calyx, contrast media can be injected through the ureteric

FIG. 6. The hockey-stick catheter.

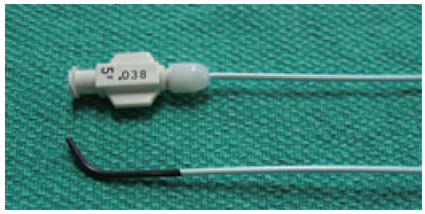


FIG. 7. Correct placement of the balloon dilatation catheter into the entry calyx.

catheter to dilate the collection system, allowing a little more space for the guidewire to pass between the stone and the collecting system walls.

The skin incision is extended to 15 mm long; during this part of the procedure the C-arm of the fluoroscopy unit remains 10° off the vertical, with the C-arm head rotated away from the surgeon, to provide depth perspective. Over the Amplatz 0.9 mm (0.038-inch) extra-stiff guidewire, the tract is then dilated to 30 F, allowing the working sheath to be placed. It is our routine to use a one-step balloon dilatation system for tract dilatation. Under fluoroscopic guidance the radio-opaque marker should be positioned such that only the calyx will be dilated. Dilatation should not involve the infundibulum, to avoid causing significant haemorrhage (Fig. 7).

Although dilatation can also be effectively accomplished using either Amplatz or Alken dilators, balloon dilatation has been shown to be more rapid and associated with less bleeding than other methods [15]. Among patients who have had previous kidney surgery or pyelonephritis causing significant perinephric scarring, balloon inflation pressures might exceed safe levels without dilatation being completed. In these situations, the use of an 18 G coaxial fascial incising needle (Cook; Fig. 8) or the serial

Amplatz or Alken dilators, might be required. When using the fascial incising needle, care must be taken so as not to inadvertently lacerate the nearby subcostal or intercostal neurovascular bundle on the inferior rib margin.

For all supracostal tracts it is important that the working sheath remain within the kidney for the remainder of the procedure, to minimize the chances of hydro- or pneumothorax. Once the working sheath has been placed, the stone can then be removed percutaneously.

NEPHROSCOPY AND STONE REMOVAL

After securing renal access, tract dilatation and placing the working sheath, the rigid nephroscope is inserted under direct vision. Nephroscopy is performed under video-endoscopic monitoring. Irrigation fluid (0.9% normal saline, warmed to room temperature), is used routinely.

Various intracorporeal lithotripters can be used effectively during PCNL, including ultrasonic, pneumatic, electrohydraulic and laser devices. In general, ultrasonic and pneumatic devices are more efficient in dealing with the large stones most often encountered during PCNL. It is our current preference to use an ultrasonic lithotripter, as it can fragment and aspirate fragments simultaneously, potentially reducing operative times. Significant fragments can be retrieved with any of several reusable or disposable stone graspers.

We reserve electrohydraulic methods and the holmium: YAG laser for use with the flexible nephroscope to treat small stones in a calyx that is difficult to reach, thereby reducing the need for additional access tracts. We routinely inspect all areas of the renal collecting system and ureter with the flexible nephroscope, and use ≤3 F flexible Nitinol baskets to remove stone fragments of >3 mm before concluding the procedure.

PLACING A PERCUTANEOUS NEPHROSTOMY

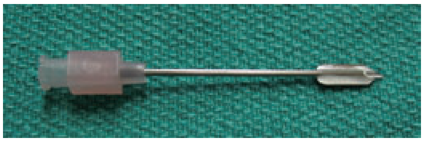
On completing stone removal, a 16–20 F Council catheter is advanced into the renal pelvis over the extra-stiff wire, to serve as a nephrostomy tube. The larger nephrostomy is chosen if there is brisk bleeding from the tract after removing the working sheath. Contrast medium (1–3 mL) is used to inflate the balloon, depending on the volume of the renal pelvis. The Council catheter is sutured to the skin using a heavy nonabsorbable suture for additional security. Occasionally a 5 F open-ended ureteric catheter is placed antegradely and guided down the ureter to provide more secure access. This is especially beneficial in obese patients, where inadvertent removal of the nephrostomy tube is not uncommon, when we are sure that a second-look nephroscopy will be required, or when the patient has a very small renal pelvis precluding inflation of the catheter balloon.

Although we have not routinely left small-diameter percutaneous tubes, there are several published reports of improvements in patient comfort [7]. Proponents of the use of smaller tubes advocate their use after PCNL in cases where there has been minimal bleeding and a small stone burden. Some centres have reported using tubeless PCNLs in selected patients, using haemostatic sealants, with good results [16]. Although this has been reported to be safe, we see no advantage, as these patients also require ureteric stenting and a urethral catheter after PCNL, negating any perceived advantage.

CARE AFTER PCNL

Patients who have had a supracostal puncture have a chest X-ray in the recovery room to assess for hydro- and/or pneumothorax. Our usual routine is to take a nephrostogram or use non-contrast CT at 1 or 2 days after PCNL. If the patient is stone-free, the nephrostomy tube is clamped for 8 h; if the patient is afebrile and pain-free the tube is then removed. For those patients with supracostal tracts, the nephrostomy tube is removed, as one would remove a chest tube, at end expiration, and with immediate application of an occlusive dressing. An upright chest X-ray is then taken. In situations where a stent is left *in situ*, the urethral catheter is removed when the patient's nephrostomy site is dry. If significant stone fragments remain, 'second-look' nephroscopy is performed, usually in a procedure room under local anaesthesia. If the tract is supracostal or additional tracts will be necessary, general anaesthesia is required and the patient is brought back to the operating room.

FIG. 8. The fascial incising needle.



COMPLICATIONS AND MANAGEMENT

The main complications during PCNL include bleeding, collecting system perforation, urinary tract sepsis and adjacent organ injury. In our experience bleeding necessitating blood transfusion is rare, and required in <1% of patients in our series [4]. Bleeding is most often venous, originating from the tract, and can be managed simply by placing a large (20 F) nephrostomy tube. If bleeding persists the next step is to clamp the nephrostomy catheter, allowing a clot to form in the collecting system to provide further tamponade effect. A Kaye tamponade catheter (Cook) can also be used if the above manoeuvres are unsuccessful. In instances where haemodynamic instability occurs and bleeding cannot be managed with these measures, angiography and selective renal artery embolization should be undertaken.

Major perforation of the collecting system usually involves the medial wall of the renal pelvis and is heralded by the appearance of yellow fat. Depending on the size of the perforation, it might be possible to complete the procedure, but with more significant injuries the procedure should be terminated and a large-bore nephrostomy tube and ureteric stent should be inserted.

Occasionally, on gaining entry into the collecting system, purulent material is seen draining from the needle or sheath. In this situation the most prudent manoeuvre is to leave a nephrostomy tube, maintain the patient on antibiotics, and return at a later date to deal with the stone. Fever is not uncommon after PCNL and rarely requires intervention. To avoid the risk of sepsis, all patients are maintained on i.v. antibiotics for 24 h after PCNL, and discharged home with a 7-day course of broad-spectrum oral antimicrobial coverage.

Adjacent organ injuries involving the liver, spleen or bowel are usually occult at the time of surgery. If transcolonic access is discovered and the patient has no signs of peritonitis, management includes retracting the nephrostomy catheter into the colonic lumen, and placing a ureteric JJ stent in the kidney to separate the urinary and fecal streams [17]. Broad-spectrum antibiotics are started and the patient has nothing by mouth initially, and is later put on a low-residue diet for 1 week. Unless complications ensue, the catheter draining the bowel can be removed in 1 week if contrast studies show separation of the urinary and fecal streams. Liver injury rarely requires further treatment, while splenic trauma might need immediate surgery [18,19].

CONCLUSIONS

PCNL plays an integral role in managing complex and large upper tract renal calculi. We think that the operating urologist should be adept at gaining renal access. Using a standardized technique and with the proper equipment, PCNL can achieve excellent stone-free rates and with minimal patient morbidity.

CONFLICT OF INTEREST

John D. Denstedt is a Consultant and Advisor for Boston Scientific and Hassan Razvi is a Consultant and Advisor for Cook Urological.

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Abbreviation: **PCNL**, percutaneous nephrolithotomy.