Percutaneous Nephrolithotomy

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Background

Percutaneous extraction of renal stone - properly termed percutaneous nephrolithotomy (PCNL) - had been invented over three decades ago. Fernstrom and Johansson (1976) first reported the formation of a percutaneous track for the specific purpose of subsequently removing an intrarenal stone. This technique was rapidly taken up by other centres, with Alken et al (1981) and Wickham et al (1981) further demonstrating the effectiveness and safety of the procedure in disintegrating and clearing not just small stones in renal pelvis. It has since evolved and been refined with the development of purposely designed instruments, endoscopes and accessories, and has remained a standard treatment for different varieties of renal stones since the eighties.

PCNL can be in short for nephro-lithotomy or nephro-lithotripsy: ‘lithotomy’ meaning removal of stone, and ‘lithotripsy’ meaning shearing or fragmentation of stone. Different urologists may have their own preferences and variations of the basic operative technique. The standard method should be one that has been most researched and tested, that can be safely applied under all circumstances, that consistently produces optimal and reproducible results, and of paramount importance, that can be taught and learnt easily.

Clinical Applications

PCNL can practically be applied to most, if not all, renal stones. It is the preferred treatment for obstructive stones that have long been impacted or stones that are deemed too big (>1.5 cm) to be optimal for extracorporeal shock wave lithotripsy (ESWL), because percutaneous removal has less infective and obstructive complications and more effective stone clearance. In a prospective randomised trial of ESWL versus PCNL for lower pole nephrolithiasis, Albala et al suggested that lower pole calyceal stones larger than 1 cm are better treated by primary percutaneous removal, as this offers the best chance of rendering patient stone-free after one single procedure. PCNL can also be applied to stones in calyceal diverticulum (Fig 1), horseshoe kidney, transplanted kidney (Fig 2a-f), and in children, though these are challenging situations where substantial technical difficulty would be expected.
Staghorn calculi are complex, infective, and often large renal stones filling both centrally the renal pelvis and peripherally the calyces. Initial experiences with ESWL or PCNL monotherapy were poor. They are now best treated by a combined endourological approach - PCNL followed by adjuvant ESWL - in order to reduce the rates of infection, sepsis, haemorrhage requiring transfusion, pleural complications associated with multiple percutaneous tracks, and residual stone fragments, with the ultimate aim of preserving renal function in the long term. The AUA Nephrolithiasis Guidelines Panel has in fact suggested that the primary treatment modality for most patients with staghorn calculi should be percutaneous stone removal followed by shock wave lithotripsy and/or repeat percutaneous procedures as warranted. The Panel emphasised that the first part of combination therapy should be percutaneous debulking, to remove largest stone burden possible starting from the part centrally located in renal pelvis. This is followed by adjuvant shock wave lithotripsy to the hopefully small residual peripheral burden in the calyces (Fig 3), and a ‘second look’ percutaneous procedure via the mature track to hasten clearance of post shock wave stone fragments, generally referred to as ‘sandwich therapy’.

PCNL is contraindicated if patient has uncorrectable coagulopathy. Antiplatelet medications like aspirin should be discontinued 7 days before operation.

Surgical Technique

The main limitation of PCNL is often technical, as difficulties can be encountered in getting at the stone especially in a kidney with severely distorted and undilated pelvi-calyceal system. Pre-operative urographic assessment with computed tomography is therefore helpful in planning the operation. Any urinary tract infection needs prior treatment with appropriate antibiotic, and a temporary percutaneous nephrostomy can be inserted to drain an obstructed and infected pelvi-calyceal system beforehand.

The standard operative technique of PCNL consists of three main steps:

1. percutaneous puncture of pelvi-calyceal system,
2. development of track,
3. fragmentation and/or removal of stone.

Anaesthesia and Positioning

The PCNL operation should preferably be performed under general anaesthesia, as patients need to lie in an uncomfortable position for a relatively long duration, often up to three hours. However, if the operation is done as a staged procedure, percutaneous puncture without track dilatation or removal of simple small-burden renal stones could be done under sedo-analgesia.

Percutaneous puncture could be the most difficult step, especially when the pelvi-calyceal system is not dilated and/or the anatomy is distorted. Careful positioning of patient facilitates correct puncture of the collecting system, while at the same time protects the anaesthesised patient from inadvertent injury. The positions generally preferred for puncture are:

1. prone oblique with affected side tilted 30 degrees up, so that the posterior lower pole calyx is directed posteriorly on the vertical sagittal plane (Fig 4);
2. completely prone, with puncture performed from posterolaterally.

Percutaneous Puncture

Percutaneous puncture of the pelvi-calyceal system is done with precision under the guidance of one of the following imaging techniques:

1. 1. Radiographic contrast medium, coloured blue with methylene blue, can be injected via a pre-inserted retrograde ureteral catheter to outline the pelvi-calyceal system. This provides an additional advantage of slight distension of the collecting system that may facilitate percutaneous puncture, and can be repeated as often as is necessary without any dose limitation.
2. Hydronephrotic collecting system can be punctured easily under realtime ultrasonographic guidance (Fig 5).
Initial exploratory puncture is performed with a 21G or 22G skinny needle from below the 12th rib, targeting a posterior calyx preferably of the lower pole, aligning the direction of access with the axis of the targeted calyx and its infundibulum, aiming to traverse the minimum thickness of cortical parenchyma possible, and entering the calyx through the papilla. The depth of the advancing needle point and its relationship to the target calyx can be confirmed using C-arm fluoroscopic imaging. Rotation of the C-arm enables biplanar imaging and guidance, or the C-arm can simply be kept in the vertical plane and one judges the relative position of the needle point to the target calyx by applying the principles of parallax. Successful puncture or entry into the target calyx can be ascertained when a stream of blue-coloured fluid flows out from the needle upon withdrawal of the stylet.

A second definitive puncture is then performed with a larger 18G needle. Insertion of this needle into the target calyx enables subsequent introduction of a .038 or .035 working guidewire into the pelvi-calyceal system. It can be achieved under fluoroscopic guidance, by parallel puncture beside the initial skinny needle (Fig 6a-b), or by co-axial puncture making use of a Mitty-Pollack needle. This latter technique is particularly useful to a novice urologist.

Additional puncture may be necessary subsequently, if there remains significant stone fragments not reachable through the primary access using either rigid or flexible endoscope (Fig 9). A supracostal puncture provides upper pole renal access that is needed when there is substantial stone burden in the upper pole calyces, or in horseshoe kidneys.

Development of Track

The second step is to dilate a track from the skin through the renal parenchyma into the collecting system, and to place a working sheath.

Over the guidewire, fascial dilators are inserted to serially dilate the track between the skin and the renal calyx to enable subsequent instrumentation. There are 3 types of fascial dilators:

1. Amplatz teflon dilators,
2. Alken telescopic metal dilators,
3. balloon dilator.

Under fluoroscopic guidance, fascial dilators are inserted along the extra-stiff guidewire until their tips enter well into the collecting system. Serial coaxial dilatation using telescopic metal dilators over a central guide rod is better than sequential dilatation using teflon dilators, as the
former technique is faster and has much less danger of losing the track. The fastest method of track dilatation is to use a balloon dilator, as it does not require serial insertion of multiple dilators of increasing size. Its only drawback is the cost of the balloon dilator.

After dilating the track to the desired size (generally 26 to 30 Fr), an Amplatz sheath made of teflon with a lumen of the same size is slipped over the dilator and manipulated into the collecting system (Fig 10). This Amplatz sheath provides tamponade to stop any bleeding from the freshly developed track, while at the same time serves as a conduit for introducing instruments and a channel for irrigation fluid to flow out easily.

Nephroscopy and Stone Extraction

The third step is to introduce a nephroscope via the Amplatz sheath into the pelvi-calyceal system to locate the stones (Fig 11). The standard 26 Fr rigid rod-lens nephroscope with off-set eyepiece provides excellent optics and allows the use of strong rigid instruments to deal with the stones. Continuous irrigation with warm normal saline is set up to fill the pelvi-calyceal system with fluid, with inflow via the endoscope and outflow simply via the Amplatz sheath. This allows a very rapid flow to clear stone fragments and blood, and thus enables good endoscopic view. It dissipates the heat energy of mechanical lithotripsy and so minimises its potential injury. Last but not least, the importance of an effective irrigation system is to maintain a low pressure in the pelvi-calyceal system that reduces the risks of pyelo-renal reflux and its resultant fluid absorption and sepsis.

Smaller stones can be retrieved with rigid stone forceps directly via the Amplatz sheath. Commonly preferred instruments are tripod graspers or forceps with strong alligator jaws. Larger stones have to be fragmented first using either one of the following energies:

1. ultrasonic lithotripsy,
2. holmium laser lithotripsy,
3. pneumatic lithotripsy.

The modern ultrasonic lithotripter is particularly suitable for staghorn stones. Ultrasonic energy readily pulverises soft staghorn stones, and the resultant tiny fragments and powder are simultaneously sucked away by the hollow rigid metallic probe that delivers the energy. Holmium laser is ideal for cutting harder stones into smaller pieces.

Post-operative Care

At the end of the operation, a percutaneous nephrostomy catheter is inserted along the track and left in place for one to two days. This temporary catheter nephrostomy provides monitoring for haemorrhage and diverts urine in case drainage down the ureter is not functioning well due to temporary obstruction by inflammatory swelling or blood clot.

The patient is only left with a wound of the size of the working sheath, that is, no more than 1 cm. However, the patient may still have some pain albeit moderate, and nausea is not uncommon. It is advisable on the first day post operation to limit oral intake to fluids, give intravenous fluid infusion, prescribe appropriate analgesic as required, and to continue antibiotic therapy. Simple uncomplicated cases can be discharged two or three days post operation.

Possible complications of PCNL include sepsis, haemorrhage requiring transfusion, traumatic arteriovenous fistula or false aneurysm, injury to adjacent bowel, failed access or failure of equipment, and with supracostal punctures, pneumothorax and pleural effusion. Major complications can occur in 1% to 7% of patients undergoing PCNL.

Conclusion

Percutaneous nephrolithotomy has long been proven to be safe and efficacious. It is minimally invasive surgery and is an indispensable tool in the armamentarium of urologists for the treatment of renal stones. Its indications can be extended further to include upper ureteric stones by the use of antegrade ureteroscopy, or to deal with concomitant pelvi-ureteric junction stricture by percutaneous endopyelotomy.

References