Percutaneous Nephrolithotomy for Treatment of Nephrolithiasis

Muhammad Mansour Elhefnawy, Abdellatif Mohamed Abdellatif Zayed, Maged Mohammed Ali, Mahmoud Mohamed Malek

Urology Department, Faculty of Medicine - Zagazig University, Egypt

Article History: Received 10th June, Accepted 5th July, published online 10th July 2023

Abstract

Background: Nephrolithiasis is the term employed for kidney stones, also known as renal calculi, and they are crystal concretions formed typically in the kidney. Calculi typically form in the kidneys and ideally leave the body via the urethra without pain. Larger stones are painful and may need surgical intervention. Percutaneous nephrolithotomy (PNL) is the procedure of choice for large renal stones. Since its introduction in 1976, many aspects of the operative technique and the endoscopic equipments have had constant evolution, increasing the success rates of the procedure. We performed a literature search using Entrez Pubmed from January 2000 to July 2007 concerning PNL and many aspects related to all steps of the procedure. We could verify that PNL in supine position has been proved as an acceptable option, but more worldwide experience is necessary. Urologists must be trained to gain their own renal tract access. Minipercutaneous PNL still needs equipments improvements for better results. Tubeless PNL is increasing in popularity and different tract sealants have been studied. Medical prevention is proved to be effective against stone recurrence and should be always used after PNL.

Keywords: Percutaneous Nephrolithotomy, Nephrolithiasis

DOI: 10.53555/ecb/2023.12.Si12.316

Nephrolithiasis is the most common chronic kidney condition, after hypertension, and also an ancient one: treatments for patients with stones have been described since the earliest medical texts. Stones are a preventable cause of morbidity, accounting for over 5 billion dollars in economic costs in the United States each year, both for hospitalization and procedures to remove symptomatic stones, as well as time lost from work1.

Stones are more common in men than in women, and stone types differ somewhat between the sexes in children, reported frequency of stone types differs modestly from those in adults, but the sexes are affected about equally2. Periodic studies of the United States population, called the National Health and Nutrition Examination Surveys, show that the prevalence of stones has been increasing over the past 30 years in both sexes3. The most recent survey found that by the seventh decade almost 12% of white men and 6% of white women reported having had a kidney stone; the prevalence in African Americans is less than half that in Caucasians, but has also been increasing. These surveys only include adults, so that prevalence rates in children are not as clear; however in the earliest cohort, ages 20–29, prevalence was 1.3% in males and 2% in females, giving an upper bound to prevalence prior to age 20.

The reasons for the increasing prevalence are not clear, but one factor may be increased rates of obesity, as risk of stones increases along with body mass index and waist circumference, especially in women4. Both inherited and environmental factors play a role in stone formation. The role of inheritance is clearest in monogenic diseases such as cystinuria, Dent's disease and primary hyperoxaluria5, but there is a clear familial tendency in idiopathic stone formation as well6, although the genes involved are currently unknown. Environmental factors, especially diet6;7 play an important role in expression of the tendency to stone formation.

Calcium oxalate (CaOx) is the predominant component of most stones either as the monohydrate (whewellite) or dihydrate (weddelite), often admixed with some calcium phosphate (CaP) which may form the initial nidus of the stone. Stones composed predominantly of CaP (as apatite or brushite) are less common, and are seen more frequently in women. Rarely, insoluble drugs, such as indinavir, triamterene or ephedrine, may form stones8.

Recurrence is the rule after a first stone, in the absence of preventive treatment. Probability of recurrence for idiopathic calcium stones after the initial event is 40–50% at 5 years and 50–60% by 10 years. The recurrence rate for stones associated with systemic diseases such as cystinuria or primary hyperparathyroidism is often higher.

Stone disease is associated with an increased risk of hypertension, especially in women; the mechanism is not known9. Some forms of nephrolithiasis, especially those associated with systemic disease, are associated with loss of renal function as well10.

ACUTE PRESENTATION AND MANAGEMENT

The initial presentation of nephrolithiasis is often with renal colic - severe pain caused by stone passage - triggered by movement of a stone from the renal pelvis into the ureter, which leads to ureteral spasm and possibly obstruction. Pain starts in the flank area, and progresses downward and anteriorly into the genital region as the stone moves down the ureter. The pain is not usually aggravated or alleviated by change of position, and may be accompanied by nausea and vomiting. Hematuria is always present, but may be microscopic. If the stone is lodged at the uretero-vesical junction, it can cause a sensation of urinary frequency and urgency. All symptoms are relieved quite abruptly when the stone moves out of the ureter into the bladder, and passes. The differential diagnosis for flank pain and hematuria is not long: papillary necrosis with passage of a sloughed papilla, renal emboli, renal tumor, sometimes urinary tract infection. Symptoms in children can be similar, but may consist only of hematuria, generalized abdominal pain or urinary tract infection.

The initial evaluation of patients with suspected acute stone passage optimally includes non-contrast helical CT with 5 mm slices or less, which can accurately visualize the size and location of stones in the urinary tract. A KUB can often visualize calcium-containing stones in the kidney or ureter, including struvite stones, but uric acid or other purine stones may be radiolucent, and cystine stones often visualize poorly as well. Stones less than 5 mm in diameter will usually pass spontaneously, although it may require several weeks of conservative management, while about 50% of stones larger than 5 mm require urologic intervention for removal, and those above 10 mm are very unlikely to pass unaided11. Initial management of stones less than 5 mm in patients without anatomic abnormalities of the urinary tract is watchful waiting, to allow time for stone passage. Pain can be controlled with use of NSAIDS or narcotic agents12. Presence of any signs of urinary tract infection, inability to take oral fluids, or obstruction of a single functioning kidney requires hospitalization and active management. Some studies suggest that use of an α-(1)-adrenoreceptor antagonist such as tamsulosin may hasten the time to stone passage in appropriately selected patients13. Patients should be instructed to strain their urine to recover passed stones for analysis.

Large stones in the renal pelvis may present with hematuria, infection or loss of renal function rather than colic. Stones with a branched configuration filling two or more calyces are called staghorn calculi. Struvite stones often present in this fashion, as may cystine stones.

Urologic management

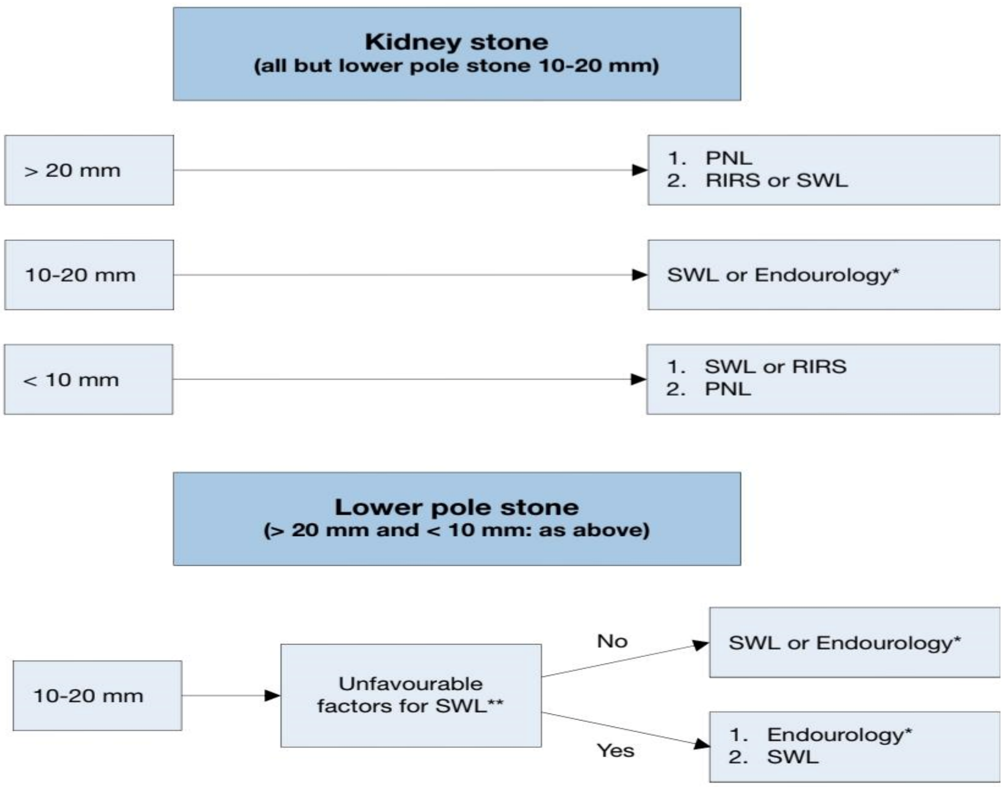
There are several options available for surgical treatment of the 10–20% of symptomatic stones that fail to pass spontaneously14. The appropriate modality for a given case depends on the size, location and type of stone; the presence of anatomical abnormalities or infection also may influence the choice. Extra-corporeal shock wave lithotripsy (ESWL), which uses sound waves to fragment stones into small pieces that can be easily passed, is effective for most stones less than 2 cm in size, although cystine stones and phosphate stones may be resistant to fragmentation. Larger stones, particularly those composed of cystine or struvite, can be approached via percutaneous access through a small flank incision, allowing direct visualization and intracorporeal lithotripsy for stone disruption, and removal of fragments. Ureteroscopy is becoming increasingly useful for stones in the ureter and renal pelvis, and may be used with laser lithotripsy as well.

Selection of treatment of renal calculi is dependent on several factors (**15**).

1. **Stone factors:** Total burden, location and composition.
2. **Urinary tract factors:** Renal function, renal anomalies, calyceal anatomy, pelvic and ureteropelvic junction anatomy, ureteral course and caliber, status of contralateral kidney, ureter, and lower urinary tract.
3. **Patient factors :** obesity, Spine deformity, coagulation disorder, cardiac and chest comorbidity.

Treatment algorithm for renal stones according to EAU guidelines on nephrolithiasis 2023

History:



PCNL

Rupel and Brown, (1941) performed the first nephroscopy when a rigid cystoscope was passed into the kidney following open surgery.

Willard Goodwin, (1955) while trying to perform a renal arteriogram, placed a needle into the collecting system of a hydronephrotic kidney and performed the first antegradenephrostogram. He left a tube to drain the kidney, thereby placing the first nephrostomy tube.

Fernström and Johansson, (1976) were the first to describe a technique for extracting renal calculi through a percutaneous nephrostomy under radiological control.

Arthur Smith, (1978) would describe the first antegrade stent placement when he introduced a Gibbons stent through a percutaneous nephrostomy in a patient with a reimplanted ureter. Dr. Smith would coin the term "endourology" to describe closed, controlled manipulation of the genitourinary tract. His collaboration with Kurt Amplatz, an interventional radiologist and medical inventor, would lead to numerous innovations that would further advance PCNL.

Standardization of the technique of percutaneous stone manipulation was occurred in the early 1980s by **Alken and Michael Marberger** in Germany, by **Wickham and Ronald A. Miller** in England and by **Joseph**

W. Segura and Ralph V. Clayman in the United States, the process of renal access and tract dilation was improved upon and the use of a rigid cystoscope was replaced by offset nephroscopes with a large straight working channel. Radiographic innovations, including improvements in fluoroscopy would further aid in renal access.

The development of various lithotripsy devices and the introduction of the holmium laser improved the efficiency of stone fragmentation and clearance. The increased clinical experience and utilization of PCNL would lead to the characterization of stone-free rates and complications for the procedure **(16)**.

Indications of PCNL:

according to the EAU Guidelines for urolithiasis (Skolarik 6s et al. 2023), indications For active removal of renal calculi include obstruction, infections, other symptoms Caused by stones and stone growth

1. stones larger than 15 mm or smaller than 15 mm if Observation is not the option of choice.
2. stones in high-risk patients as well as patient Related factors like patient preference, comorbidities and patient social situation

PCNL is still considered the standard procedure for large renal calculi. It is thé
Gold standard and primary treatment option for renal calculi >20 mm. PCNL is ah
Alternative to RIRS and SWL in calculi between 20 and 10 mm due to its higher stone
Free rates (SFR) although there is a higher risk of bleeding and prolonged hospita

PCNL is recommended by the Guidelines of the European Association of Urology for the following indications **(17).**

- **a.** Large stone burden >2 cm or 1.5 cm for lower calyceal stones.
- **b.** Staghorn stones.
- **c.** Stones those are difficult to disintegrate by ESWL (calcium-oxalate monohydrate, brushite and cystine).
- **d.** Urinary tract obstructions that need simultaneous correction (e.g. PUJO).
- **e.** Malformations with reduced probability of fragment passage after ESWL (e.g. horseshoe and calyceal diverticula).
- **f.** Obesity

***Contraindications to PCNL* (17):**

Absolute:

- **a)** Uncorrected bleeding diathesis**.**

Relative:

- **a)** Urinary tract infection
- **b)** Comorbidity precluding appropriate Anesthesia

Technique :

A. Anesthesia:

The choice of anesthesia for PCNL depends on patient, surgeon preference and skills of anesthesiologist. General anesthesia, spinal anesthesia and epidural anesthesia are all used as anesthetic techniques for PCNL **(18).**

Anesthesiologists should be aware of the possibility of intravascular fluid absorption, blood loss, possibility of hypothermia during the procedure and the organs may be injured during PCNL such as the pleura, with possible pneumothorax and/or hydrothorax **(19)**.

B. Patient position:

1) Prone position

When PCNL was initially described in 1976 the prone position was chosen because it was believed that this would be the safest way to avoid damage to the colon and visceral organs. The technique was standardised over the following years as a two-stage procedure. The first part is with the patient supine, to give anaesthesia and gain retrograde access to the upper urinary tract. Then the patient is repositioned prone for the main part

of the procedure either completely prone or Prone oblique with affected side tilted 30 degrees up, so that the posterior lower pole calyx is directed posteriorly on the vertical sagittal plane **(19)**.
Rolled supports are placed under the thorax and the upper abdomen or on both sides, extending from shoulder to hip, to facilitate ventilation **(20)**
Padding is placed under all pressure points (knees, feet, forehead, eyes, elbows, fingers) and the shoulders, and the elbows are carefully positioned to prevent brachial plexus injury **(20)**

Advantages (20)

- Excellent exposure of lumbar area, this gives the surgeon ample room to place the puncture, provides enough space for manipulation with the instruments.
- Upper-pole puncture is facilitated in the prone position because of the posteromedial location of the upper pole, which is closer to the posterior abdominal wall.
- Depended renal pelvis (better visibility and room for movement).

Disadvantages

- Patient repositioning during the procedure **(21).**
- Respiratory/cardiovascular function compromised and hard to manage cardio-respiratory emergencies **(21).**
- If the procedure is carried out under spinal or epidural anesthesia, conversion to general anesthesia with endotracheal intubation will represent a great challenge to the **(18).**

Increased risk of injuries from pressure **(20)**

- ankylosing spondylitis or other spinal or lower limb deformities, the prone position might not be possible **(22)**.

Theoretical risk of ocular complications **(20).**

Theoretically greater exposure to radiation **(20).**

2) Reverse lithotomy position (23)

Patient is placed prone with the legs abducted at the hips, the thighs and knees fixed in plastic cradles specifically

Advantages

reverse lithotomy Position

- Similar advantages to prone position
- Allow simultaneous retrograde access to the upper urinary tract during PCNL with flexible instruments.

Disadvantages

- Similar disadvantages to prone position

Prone flexed position (20)

3)

A modification of the prone position was described which incorporates a flexed position of the patient during the procedure, after the patient is turned to prone the table is flexed 30–40 degree to open the space between the 12th rib and the posterior iliac crest.

Advantages

Figure (1): prone flexed Position

- Similar advantages to prone position.
- increased working space.
- Allow to change from supra-11th to supra 12thorsupra 12thto infracostal access.

Disadvantages

- Similar disadvantages to prone position

4) Split-leg prone position (24)

Prone position with legs are padded, secured independently and abducted at the hips without being flexed. The genitalia are positioned at the bottom of the operating table, making room for retrograde access.

Advantages

- Similar advantages to prone position
- Allow simultaneous retrograde access to the upper urinary tract during PCNL with flexible instruments.

Disadvantages

- Similar disadvantages to prone position

5) Lateral decubitus and lateral flexed position (25)

The patient is put into the lateral position with the legs slightly bent lying on the unaffected side and exposing the flank through which the access is made, a wedge support can be placed under the patient's torso, both arms are supported in separate adapters and flexed slightly at the elbow.

A modification of the pure lateral position, the lateral flexed position, has the additional advantage of significantly increasing the operating field. The operating table is flexed, which widens the space between the 12th rib and the iliac crest.

Advantages

- Can be used in patients who could not tolerate being prone
- Familiar to urologists who perform open renal surgery

Disadvantages

- Unusual fluoroscopic view of the kidney, which can also be obscured by the underlying spine
- Patient repositioning is required

6) Modified lateral position (the 'Barts technique) (26)

The patient is placed in the lithotomy position with the ipsilateral hemi-pelvis tilted by 45 degree, supported by a foam wedge. The torso is twisted to the contralateral side, with the shoulders perpendicular to the operating table. The ipsilateral lower limb is slightly flexed in a ventral direction and follows the lateral rotation of the

Advantages

- Allow simultaneous ante- and retrograde access
- Repositioning of the patient is minimal

Disadvantages

- Requires significant patient mobility
- Not suitable for patients with musculoskeletal deformities
- Fluoroscopy is technically limited, as with lateral position.

7) Supine position

Valdivia-Uria et al.,(27) reported a safe percutaneous access to the kidney with the patient supine with a water bag below the ipsilateral flank and with the ipsilateral leg totally extended. As the abdominal wall is punctured more laterally, away from the lumbar muscles, movements of the endoscopic instruments are less restricted.

Figure (2): supine position (22)

Advantages (22);

- According to anatomical CT studies, the risk of colon perforation might even be less than in the prone position, as the bowel can float free in the uncompressed abdomen and is not pressed towards or behind the kidney
- The direction of the tract preserves a low pressure in the renal pelvis, and thereby reduces the risk of fluid absorption and allows even spontaneous clearance/washout of fragments
- Reduced cardio circulatory or ventilatory dysfunction
- Less time needed because patients do not have to be turned after induction of general anesthesia and positioning of the ureteral catheter
- The surgeon can comfortably sit during the operation
- X-ray exposure is reduced because the bodies and limbs of the surgical team remain outside the field of the fluoroscopy

Disadvantages
(20)

- The main drawback of the supine position is that the flank is not fully exposed, which makes access to the posterior-medially lying upper pole more difficult and provides less availability for multiple accesses limiting use in staghorn calculi.
- The absence of abdominal compression leaves the kidney more mobile, which can make puncture and dilatation of the tract more challenging.
- Some calyces are dependant and collect fragments during the disintegration of the stone.
- Low intrarenal pressure leaves the collecting system less expanded and therefore nephroscopy and manipulations can be more difficult.
- Targeting the upper calyx is difficult, this problem is more on the left side**.**

8) The Galdakao-modified Valdivia position

This position was described by Ibarluzea in 2007 The main characteristic is a slight lateralisation of the Valdivia supine position, with the contralateral leg flexed. The patient is placed in an intermediate supinelateral position with a 3-L bag placed to raise the flank. The ipsilateral leg is extended and the contralateral leg is abducted and flexed**. (28)**

Figure (3):Galdakao-modified Valdivia position (28)

Advantages

- Similar advantages to supine position
- Simultaneous retrograde access to the kidney.
- There is more space for manipulating the instruments

Disadvantages

- Similar disadvantages to supine position

9) Flank free modified supine position (29)

The patients were placed in a modified supine position by putting a suitable cushion (3L water bag or less) according to patient body mass under the ipsilateral shoulder, fixing ipsilateral arm over the thorax, and crossing the extended patient ipsilateral leg over the contralateral leg, all pressure points were checked carefully and padded.

Similar to supine position with better wide space available in flank free position for manipulation of stones especially if another tracts needed as in staghorn stone.

C. Puncture:

Complex renal calculi are renal stones occupying the renal pelvis and at least two of the three major calyceal systems. It can be the extension of the pelvic stone (staghorn) or a multiple primary or secondary renal calculi occupying the calyceal group.

The successful removal of stones requires the accurate placement of a percutaneous tract that provides direct access to the stone (optimal kidney access). Inferior calyceal stones are usually approached through the posterior inferior calyx. In complex renal calculi, complete clearance may often not be possible through a single tract in an inferior calyx because of problems in negotiating the acute angles between calyces. However, inferior lower calyceal punctures are being performed more commonly because it has fewer complications **(30)**.

The supracostal upper pole access and multiple accesses provide a good approach and straight access to staghorn calculi, proximal ureteral calculi, and calculi associated with primary ureteropelvic junction obstruction, and calculi associated with retained ureteral stents. The upper pole of the kidney is aligned medially and posterior to the lower pole, making the upper pole a shorter and easier access route. However, staghorn calculi are the most difficult cases, take a longer time to be completely removed **(30)**.

Prone position:

[1] lower pole puncture

A lower pole puncture is made 1cm inferior and 1cm medial to the tip of 12th rib **(31)**

[2] Supra-costal puncture

The point of entry at the skin is the inferior border of 11th rib just lateral to paraspinal muscle. The puncture is made above the lateral half of the 12th rib at the mid-scapular line. The needle will be advanced in the middle of the intercostal space, thus avoiding the intercostal nerve and vessels. Skin and subcutaneous puncture is made during the expiratory phase to avoid injury to the lung or pleura whereas renal parenchymal puncture was done during deep inspiration to provide full downward displacement of the kidney for easy access to upper pole posterior calyx

Supine position:

The skin is punctured in the posterior axillary line 1 cm below the last rib for a lower calyceal puncture and above the last rib for an upper calyceal one **(32).**

D. Guidance for percutaneous puncture:

Fluoroscopic antegrade approach:

The high-quality of current C-arm fluoroscopic equipment and the familiarity among urologists of fluoroscopic imaging has led to its preferred use in percutaneous renal access, particularly in the operating room. Surgeons prefer fluoroscopy for guidance due to the clear visibility of the needle and guide wire. For percutaneous renal surgeries such as PCNL or endopyelotomy, fluoroscopic monitoring is very important for the entire procedure during renal access, guide wire manipulation, tract dilatation, residual stone evaluation, and post-procedural nephrostogram. The renal collecting system opacified with contrast following retrograde ureteral catheter placement, the C-arm is rotated approximately 30º towards the surgeon once the preferred calyx has been selected. With this technique, the axis of the C-arm is in the same central posterior plane as the kidney and therefore provides a direct end-on view of the posterior calyces. The needle is advanced in the plane of the fluoroscope beam with the C-arm in the 30º direction. The appropriate direction of the needle is confirmed by obtaining a ‘bull’s eye sign’ on the fluoroscopic monitor, which is, due to the needle hub, superimposed on the needle shaft, and the plane of the needle is the same as that of the X-ray beam **(33)**.

Another technique for renal access is to use methods of triangulation.The triangulation technique can be used to avoid intercostal needle puncture. The vertical (90-degrees) plane defines the medial extent of needle penetration, and the 30-degree plane provides an end-on view of the posterior calyces. In the triangulation technique, the needle is advanced from a point1 to 2 cm below the 12th rib to the junction of the vertical and 30-degree planes **(34).**

Fluoroscopic retrograde approach

A sharp wire is passed through a ureteral catheter and directed out of the selected calyx, the indication for a retrograde approach has decreased, there are a few advantages of this approach in cases of a non dilated collecting system and obese patients, in whom the thick layer of fat may be an obstacle for an antegrade approach (**35).**

Ultrasonic approach

Real-time diagnostic ultrasonography (US) has been widely accepted as the imaging guidance for a dilated renal collecting system. The overall success rate is 88-99%. The complication rate is 4-8% and depends on the indications. Ultrasound is radiation free, effective, and rapid, and is possible with a portable machine causing minimal complications in experienced hands **(33)**.

CT guided approach:

Computed tomography (CT) guidance is another alterative for management of complex cases. This imaging guidance is essential in patients with specific medical conditions such as morbid obesity, splenomegaly, hepatomegaly, severe skeletal anomalies like scoliosis or kyphosis, or who have had previous major intra-abdominal surgery, and in patients with minimal or no dilatation of renal pelvis. CT-guided puncture may provide a better mapping for a supracostal PCNL approach **(36)**.

F. Dilatation of the tract:

Guidewires:

A hydrophilic wire is preferred for entering the pelvicalyceal system the guidewire should be directed in the ureter to protect the tract from loss during the dilatation. However, passing the wire into the ureter is not always easy, for example in case of stone impaction or, ureteropelvic junction obstruction the wire should be coiled as much as possible in a calyx or in the renal pelvis. With a lower pole puncture, the Cobra angiographic catheter often facilitates directing the hydrophilic wire through the ureteropelvic junction. Once the wire is positioned in the ureter, it is exchanged for a stiffer wire, such as super-stiff wire. This wire is stiff enough to support the dilatation. Some recommend the use of a second safety guidewire, which is inserted adjacent to the working wire. The purpose of using safety guidewire is to maintain access to the nephrostomy tract when the working wire is kinked or displaced **(37)**.

Dilators:

There are four methods of tract dilatation, Amplatz dilation (AD), metal telescopic dilation (MTD), balloon dilation (BD), and one-shot dilation (OSD)

a) Amplatz dilator set:

Due to its flexibility, the Amplatz dilator can follow its way into the ureter, sliding over the guidewire and protecting it to prevent kinking during progressive dilatation. The nephrostomy tract can be dilated in a step-wise fashion with the full set of dilators, but it is also possible to skip some sizes. It is important to make sure that the dilators are advanced over the wire until they enter the collecting lumen, to prevent damaging the integrity of pyelcalyceal system **(38)**.

b) Metal telescopic dilators:

The Alken coaxial dilator is rigid; therefore, it is theoretically excellent for patients with previous surgery and patients associated with perirenal fibrous tissue. In addition, it is a reusable and durable instrument and, as such, is less expensive than other methods. However, the main disadvantage is that it is difficult to control the pressure exerted during the dilatation. Excessive force during dilatation can lead to perforation of the renal pelvis, extravasation and haemorrhage **(38)**.

c) Balloon dilators:

Several studies have shown that balloon dilatation is safer, faster and reduces the X-ray exposure of the patients and surgeons. Dilatation and tract formation using a balloon can be achieved in a single step. Due to the fact that the balloons generate lateral compressive forces rather than angular shearing forces, this technique is less traumatic and causes less haemorrhage. It should be considered as the gold standard among dilators. Although balloons have several advantages and are easy to use, they are more expensive than other systems. Moreover, balloon dilatation is usually not suitable when there is a need to dilate dense scar tissue, such as a perirenal fibrosis after previous surgery. It may also not be suitable in case of completed staghorn calculi, which does not have enough space for balloon application. **(**39**)**.

d) One-shot dilation:

A novel device, the Pathway Access Sheath (PAS) has been developed that allows for balloon tract dilation and percutaneous access sheath placement in one simple step. After threading the PAS over guidewire, the 6F tapered catheter tip facilitates insertion. Internal balloon expands sheath from 18F to 30. This technique is safe and efficacious and results in a shorter insertion time for PCNL and less blood loss (**40**)**.**

Nephroscopes:

Standard rigid nephroscopes are 19.5 to 27 French (F) in diameter and have rod lenses with offset eyepieces or fiberoptic bundles. Flexible nephroscopes with an outer diameter around 15F are also manufactured, a semi-rigid nephroscope that integrates the function of rigid and flexible nephroscopes. It can be deployed with an ultrasonic or pneumatic lithotripsy system in rigid mode and a holmium laser in flexible mode, switching between the two is straight forward. Rigid nephroscopes usually afford a better view because of the superior optics of the rod lens system and bigger caliber irrigation channels. They also permit the passage of larger, stronger, and more powerful instruments to facilitate procedures. Flexible nephroscopes enable access to inaccessible calices without the need for secondary calyceal puncture. There has been increasing interest in the use of a smaller sized rigid nephroscope, introduced through a smaller track (the "mini-perc") from 13F to 20F **(41).**

Irrigation:

Isotonic solutions should be used for irrigation during PCNL to minimize the risk of dilutional hyponatremia, However distilled water proved to be safe also. The height of the irrigant should be at 80 cm or less above the patient to prevent excessive fluid absorption through pyelovenous backflow **(42)**.

Stone fragmentation and extraction:

a) Ultrasonic lithotripsy:

Ultrasound lihotripters employed through rigid endoscopes provide high fragmentation rates (97-100%) and stone free rate (94%). (**43)**.

b) Lithoclast:

Pneumatic lithotripters work on the same principle as collision with a bullet; on impact, energy transmits compressed air pulses within a steel probe to the calculi to be fragmented. This technique offers safe, cheap, and effective clearance of calculi (**43)**.

c) Electrohydraulic lithotripsy (EHL):

The benefits of using EHL is for the very hard stones, However, a significant downside compared to ultrasonic lithotrites is that suctioning cannot be performed simultaneously **(43)**.

d) holmium:YAG laser:

Holmium laser is also effective in very hard stones as EHL and can be used through flexible nephroscope, now reported the use of an innovative suction device together with the Holmium laser make it preferable option over other options **(44).**

Types of drainage:

After completion of PCNL, the use of nephrostomy tubes for kidney drainage is usually recommended. The nephrostomy tube serves several purposes, such as to tamponade bleeding from the nephrostomy tract, to allow maximised drainage of urine and to allow a secondary PCNL when required. It may also allow the nephrostomy tract to mature **(45)**.

1. Types of nephrostomy tube:

Nephrostomy tubes are classified into several categories:

- Catheters without self-retention (red rubber catheter)
- Self-retaining catheters (pigtail, cope-loop,Malecot or balloon Foley catheters)
- Re-entry catheters
- Circle nephrostomy tube **(21)**

Proposed that all PCNL for complex stone disease should be followed by nephrostomy placement for drainage. Small (8.5-10F) cope- loops are sufficient in most of the patients and they provide better patient comfort without any difficulty with urinary drainage, surgical access or post-operative bleeding. The re-entry catheters are utilised in cases of gross residual stone burden and pyonephrosis. The circular loops are most appropriate in cases of difficult renal anatomy necessitating multiple accesses for clearance of the stone burden. **(21)**

2. Size of nephrostomy tube:

Postoperative pain has been related to the nephrostomy size. It was found that a small bore nephrostomy catheter was better tolerated than alarge one. The type of nephrostomy drainage after percutaneous surgery should be tailored to the individual patient. Patients with a large complex calculus, prolonged procedure, multiple renal tracts, bleeding, perforation or preexisting urinary infection should receive conventional large (20 to 24 Fr) nephrostomy tube drainage. In the patient with a low volume calculus burden and an uncomplicated short procedure, the tubeless approach may help decrease postoperative morbidity. In the patient who may be at high risk for stent related symptoms or who may require percutaneous access for subsequent calculus manipulation, a small bore (8 to 12Fr) nephrostomy tube may be a reasonable option **(46)**.

3. Tubeless PCNL:

There were multiple researches on ‘tubeless’ renal surgery. They reported that tubeless surgery may be safe and effective in selected patients. These selected patients should has these criteria, operative time less than two hours, one access only, no perforation of the collecting system, no bleeding and no significant residual stone that necessitates a secondary procedure **(42)**.

Tubeless PCNL technology is associated with shorter hospitalization time, lower incidence of postoperative pain and less analgesia requirement after nephrolithotony. **(47)**.

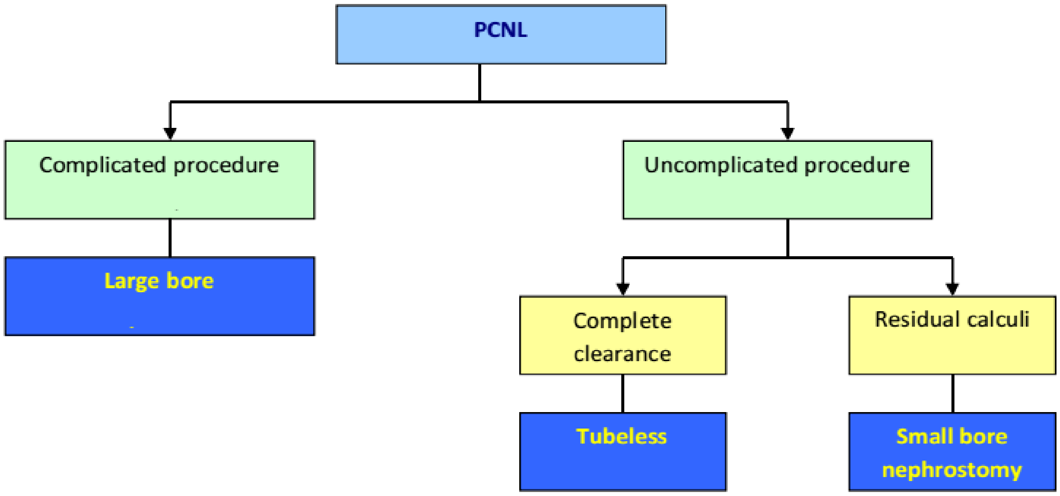


Figure (4): Algorithm for nephrostomy drainage after PCNL (48).

References

1. Saigal CS, Joyce G, Timilsina AR. Urologic Diseases in America Project. Direct and indirect costs of nephrolithiasis in an employed population:opportunity for disease management? Kidney Int. 2005;68:1808–1814. (A) [PubMed] [Google Scholar]
2. Stapleton FB. Childhood stones. Endocrinol Metab Clin North Am. 2002;31:1001–1015. [PubMed] [Google Scholar]
3. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC. Time trends in reported prevalence of kidney stones in the United States: 1976–1994. Kidney Int. 2003;63(5):1817–1823. [PubMed] [Google Scholar]
4. Taylor EN, Stampfer MJ, Curhan GC. Obesity, weight gain, and the risk of kidney stones. JAMA. 2005;293(4):455–462. [PubMed] [Google Scholar]
5. Coe FL, Evan A, Worcester E. Kidney stone disease. J Clin Invest. 2005;115(10):2598–2608. [PMC free article] [PubMed] [Google Scholar]
6. Goldfarb DS, Fischer ME, Keich Y, Goldberg J. A twin study of genetic and dietary influences on nephrolithiasis: a report from the Vietnam Era Twin (VET) Registry. Kidney Int. 2005;67(3):1053–1061. [PubMed] [Google Scholar]
7. Curhan GC, Willett WC, Rimm EB, Stampfer MJ. A prospective study of dietary calcium and other nutrients and the risk of symptomatic kidney stones. N Engl J Med. 1993;328(12):833–838. (A) [PubMed] [Google Scholar]
8. Daudon M, Jungers P. Drug-induced renal calculi: epidemiology, prevention and management. Drugs. 2004;64:245–275. [PubMed] [Google Scholar]
9. Gillen DL, Coe FL, Worcester EM. Nephrolithiasis and increased blood pressure among females with high body mass index. Am J Kidney Dis. 2005;46(2):263–269. [PubMed] [Google Scholar]
10. Worcester EM, Parks JH, Evan AP, Coe FL. Renal function in patients with nephrolithiasis. J Urol. 2006;176(2):600–603. [PubMed] [Google Scholar]
11. Coll DM, Varanelli MJ, Smith RC. Relationship of spontaneous passage of ureteral calculi to stone size and location as revealed by unenhanced helical CT. AJR Am J Roentgenol. 2002;178:101–103. (B) [PubMed] [Google Scholar]
12. Holdgate A, Pollock T. Systematic review of the relative efficacy of non-steroidal anti-infllammatory drugs and opioids in the treatment of acute renal colic. BMJ. 2004;328:1401. (A) [PMC free article] [PubMed] [Google Scholar]
13. Hollingsworth JM, Rogers MA, Kaufman SR, Bradford TJ, Saint S, Wei JT, et al. Medical therapy to facilitate urinary stone passage: a meta-analysis. Lancet. 2006;368:1171–1179. (A) [PubMed] [Google Scholar]
14. Auge BK, Preminger GM. Surgical management of urolithiasis. Endocrinol Metab Clin N Am. 2002;31:1065–1082. [PubMed] [Google Scholar]
15. Asplin JR, Parks JH, Lingeman J, Kahnoski R, Mardis H, Lacey S, et al. Supersaturation and Stone Composition in a Network of Dispersed Treatment Sites. J Urol. 1998;159:1821–1825. [PubMed] [Google Scholar]

16. Ordon M, Urbach D, Mamdani M, Saskin R, RJ DAH, Pace KT.The surgical management of kidney stone disease: a population based time series analysis. J Urol. 2014;192:1450–6.
17. Assimos D, Krambeck A, Miller NL, et al. Surgical management of stones: American Urological Association/ Endourological Society Guideline, PART II. J Urol 2016; 196: 1161–1169
18. Turk C, Petrik A, Sarica K. EAU Guidelines on interventional treatment for urolithiasis. Eur Urol. 2015.
19. Elbealy E, Rashwan D, Kassim SA, et al.(2008): A comparison of the effects of epidural anesthesia, lumbar paravertebral block and general anesthesia in percutaneous nephrolithotomy. J. Med. Sci.; 8 (2): 170-176.
20. Ganpule AP, Vijayakumar M, Malpani A, et al. Percutaneous nephrolithotomy (PCNL) a critical review. Int J Surg 2016; 36: 660–664
21. Ray AA, Chung DG and Honey RJ (2009): Percutaneous nephrolithotomy in the prone and prone-flexed positions: Anatomic considerations. J Endourol; 23: 1607-1614.
22. Lingeman JE, Matlaga BR and Evan AP (2007): Surgical management of upper urinary tract calculi. In: Campbell- Walsh Urology. Edited by: Wein AJ, Kavoussi LR, Novick AC, et al., 9th edition, Chapter 44, Philadelphia: Saunders Elsevier; 4: 1431-1507.
23. De Sio M, Autorino R, Quarto G, et al.(2008): Modified supine versus prone position in percutaneous nephrolithotomy for renal stones treatable with a single percutaneous access: A prospective randomized trial. Eur Urol; 54: 196-202.
24. Lehman T, Bagley DH. Reverse lithotomy: modified prone position for simultaneous nephroscopic and ureteroscopic procedures in women. Urology. 1988; 32(6):529–531.
25. Grasso M, Nord R, Bagley DH. Prone split leg and flank roll positioning: simultaneous antegrade and retrograde access to the upper urinary tract. J Endourol. 1993
26. Karami, Amir Haji Mohammad Mehdi Arbab, Alireza Rezaei, Mojtaba Mohammad hoseini and Iraj Rezaei Percutaneous Nephrolithotomy with Ultrasonography- Guided Renal Access in the Lateral Decubitus Flank Position Journal of EndourologyVol. 23, No. 1 2009
27. Papatsoris AG, Zaman F, Panah A, Masood J, El-Husseiny T, Buchholz N. Simultaneous anterograde and retrograde endourologic access: “the Barts technique” J Endourol. 2008
28. Valdivia-Uria JG, Valle J, Villarroya S. (1990): Why is percutaneous nephroscopy still performed with patient prone? J Endourol; 4: 269–72.
29. Ibarluzea G, Scoffone CM, Cracco CM Supine Valdivia and modified lithotomy position for simultaneous anterograde and retrograde endourological access. BJU Int. 2007
30. Desoky, Esam & N. Allam, Mohammed & K. Ammar, Mostafa & M. Abdelwahab, Khaled & A. Elsaid, Diab & M. Fawzi, Amr & A. Alayman, Ahmed & Shahin, Ashraf & M. Kamel, Hussein. (2012). Flank free modified supine position: A new modification for supine percutaneous nephrolithotomy. Arab Journal of Urology.10. 143–148.
31. Gupta M, Ost MC, Shah JB, et al. (2007): Percutaneous management of the upper urinary tract. In: Campbell- Walsh Urology. Edited by: Wein AJ, Kavoussi LR, Novick AC, et al., 9th edition, Chapter 46, Philadelphia: Saunders Elsevier; 4: 1526-1563.
32. Kim SC, Kuo RL, Lingeman JE. Percutaneous nephrolithotomy: an update. Curr Opin Urol 2003; 13 : 235–41
33. Shoma AM, Eraky I, El-Kenawy MR, et al. (2002): Percutaneous nephrolithotomy in the supine position: Technical aspects and functional outcome compared with the prone technique. Urology; 60: 388-392.
34. Tepeler A, Armağan A, Akman T, Polat EC, Ersöz C, Topaktaş R, Erdem MR, Onol SY. Impact of percutaneous renal access technique on outcomes of percutaneous nephrolithotomy. J Endourol. 2012;26:828–833.
35. Bernardo NO, Silva ML. Percutaneous nephrolithotomy access under fluoroscopic control. In: Smith AD, Preminger G, Kavoussi L, Badlani G, editors. Smith's Textbook of Endourology. Wiley Blackwell: UK; 2019. pp. 210–20
36. Kawahara T, Ito H, Terao H, Yoshida M, Ogawa T, Uemura H, Ureteroscopy assisted retrograde nephrostomy: A new technique for percutaneous nephrolithotomy (PCNL) BJU Int. 2012;110:588–90
37. Munver R, Delvecchio FC, Newman GE, et al.(2001): Critical analysis of supracostal access for percutaneous renal surgery. J. Urol.; 166: 1242-1246.
38. Raymond Ko, Frédéric Soucy, John D. Denstedt and Hassan Razvi Percutaneous nephrolithotomy made easier: a practical guide, tips and tricks. (BJU 2007)

39. Ozok HU, Sagnak L, Senturk AB, Karakoyunlu N, Topaloglu H, Ersoy H. A comparison of metal telescopic dilators and Amplatz dilators for nephrostomy tract dilation in percutaneous nephrolithotomy. J Endourol. 2012; 26:630–4.
40. Tomé Lopes, Kandasami Sangam, Peter Alken, Benjamin Silva Barroilhet, Christian Saussine, Lei Shi, and Jean de la Rosette, The Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study: Tract Dilation Comparisons in 5537 Patients Journal of EndourologyVol. 25, No. 5 2011
41. Nour HH, Kamal AM, Zayed AS, et al. Single-step renal dilatation in percutaneous nephrolithotomy: A prospective randomised study. Arab J Urol 2014
42. Bo Xiao, Song Chen, Xin Zhang, Wei-Guo Hu, Yu-Bao Liu, Yu- Zhe Tang, and Jian-Xing Li A Novel Semi-rigid Nephroscope Percutaneous Nephrolithotomy: The Best Therapy for Renal Staghorn Calculi Chin Med J 2015
43. Aghamir SM, F. Alizadeh, A. Meysamie, Shadi Assefi Rad, Ladan Edrisi, Sterile water versus isotonic saline solution as irrigation fluid in percutaneous nephrolithotomy. Published 2009 Urology journal
44. Leveillee R. J. and Lobik, L. (2003). Intracorporeal lithotripsy: which modality is best?. Current opinion in urology, 13(3), 249-253.
45. M. Atar, M. N. Bodakci, A. A. Sancaktutar et al., "Comparison of pneumatic and laser lithotripsy in the treatment of pediatric ureteral stones," Journal of Pediatric Urology, vol. 9, pp. 308–312, 2013.
46. Winfield HN, Weyman P and Clayman RV (1986): Percutaneous nephrostolithotomy: Complications of premature nephrostomy tube removal. J. Urol.; 136: 77-79.
47. Maheshwari , M G Andankar, M Bansal et al., Nephrostomy tube after percutaneous nephrolithotomy: large-bore or pigtail catheter? J Endourol. 2000 Nov.
48. Zhong-Jun, Chen, You-Ji, Yan, Jia-Jie, Zhou et al. Comparison of tubeless percutaneous nephrolithotomy and standard percutaneous nephrolithotomy for kidney stones: c meta-analysis of randomized trials Asian Journal of Surgery Volume 43, Issue 1, January 2020, Pages 60-68