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Review

Percutaneous nephrolithotomy (PCNL) a critical review

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HIGHLIGHTS

- Percutaneous nephrolithotomy (PCNL) is the preferred treatment of choice for renal calculi.
- The usual indications for PCNL are stones larger than 20 mm, staghorn, partial staghorn calculi.
- The reduction in tract size in PCNl has reduced the complications without affecting stone clearance rate.

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ABSTRACT

Introduction: Percutaneous nephrolithotomy (PCNL) is the preferred treatment of choice for renal calculi. PCNL has evolved remarkably since the eighties when it was first described.
Approach: Approach might be by either supine or prone and the access is made with the help of either fluoroscopy or ultrasound. Recently endoscopy guided puncture has also been described.
Miniaturization: Traditionally the tract size for PCNL used to be 30Fr. Even though the stone clearance rate was good there were complications such as bleeding With the advent of excellent optics and advances in stone fragmentation the tract size has reduced to a great extent which has reduced the complications without compromising the stone clearance.
Complications: The complications related to access might be injury to pleura, and other visceral organs. The other complications are bleeding, infection and incomplete stone clearance.
Conclusion: PCNL has emerged as most efficient procedure among these approaches to stone removal, though not devoid of complications and requirement for skills. The drive for minimal invasive approach should not compromise stone clearance, latter being the core principle of endourology. In skilled hands PCNL is the answer to stone questions we as urologist face day to day. though which form of PCNL is to be chosen depends on surgeons skill level and discretion.

1. Introduction

Percutaneous nephrolithotomy (PCNL) is the preferred treatment of choice for renal calculi. PCNL has evolved remarkably since the eighties when it was first described.

The indications have changed over the years with the introduction of others techniques such as extracorporeal shockwave lithotripsy (ESWL) and flexible ureteroscopy. In the early years, large stones were treated with PCNL and smaller ones left for ESWL. The concepts have changed in context to miniaturization of instruments and advancements in energy and optics where even smaller stones are treated with PCNL with minimal morbidity and better stone clearance rates.

2. Indications of PCNL

The usual indications for PCNL are stones larger than 20 mm, staghorn, partial staghorn calculi. The contraindications for PCNL include pregnancy, bleeding disorders, uncontrolled urinary tract infections [1].

PCNL is the treatment of choice for large stone. PCNL attains stone free rates of upto 95%. AUA guidelines recommend PCNL as a treatment of choice for staghorn calculi. Larger stones in the lower pole are best managed by PCNL as the first treatment option [2]. Data from metaanalysis suggests that larger lower polar stones have lower clearance rates and higher retreatment rates [3]. PCNL is considered to be a gold standard in management of calyceal diverticular stones. In comparison to ESWL, PCNL has higher stone free rates with similar recurrence rates and complication rates [4]. The stone free rates for PCNL range in between 85 and 93%, the

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added advantage of PCNL include it provides excellent access for obliteration of the diverticular sac [5].

2.1. Pre operative evaluation

The preoperative evaluation involves a close study and analysis of imaging which includes a CT IVU. This helps in deciding the primary calyx of puncture through which the majority of the stone bulk is to be cleared, stones situated in separate calyces and which are unlikely to be cleared through the primary tract are also identified. The secondary tracts are usually created in these calyces. Recently staghorn morphometry is used in prediction of number of tracts and stages in which a stone can be cleared [6].This can be done by means of a software which uses the CT scan images to analyse the data.(3D-DOCTOR™; Able Software Corp., USA).

2.2. The approach

The choice of puncture either fluoroscopic or ultrasound guided is dictated by the calyceal anatomy and the surgeon expertise in a particular technique. Regardless of the choice of access ureteric catheter is placed in all cases.

The reasons for placement of ureteric catheter are as follows:-

1) The ureteric catheter helps in instillation of contrast or saline which in turn helps to opacify and or distends the pelvicalyceal system helping in percutaneous access.
2) If the endourologist decides to defer on placement of a double J stent a ureteric catheter will serve the purpose.
3) The ureteric catheter acts as a medial most reference point during dilatation of the PCNL tract. The dilators should not ideally overshoot this reference point.
4) The ureteric catheter in this place helps in inadvertent migration of broken fragments into the ureter.

2.3. Position for gaining access

2.3.1. Supine or prone PCNL

The conventional PCNL is done in a prone position. This allows direct access to the posterior calyx. In prone position, the bowels do not come in the line of puncture. PCNL can also be done in supine which has the advantages of combined ante grade and retrograde approaches easier switch of regional to general anesthesia and usefulness in patients with cardiac co morbidities. But in supine position, we would not be able to establish multiple channels and the space is limited. In Valdivia position, the operative time is more and it also has a less stone clearance rate. The Barts modification of Valdivia position uses both X ray and USG in combination [7].

Algorithm for management of renal calculus (EAU2016).

Renal stone(all but lower pole 10-20 mm)
>20 mm— 1)PCNL 2)RIRS or ESWL>
10-20 mm— ESWL or endourology
<10 mm — 1)SWL or RIRS 2)PCNL
Lower pole stone (10 -20 mm)
Unfavourable for ESWL ——endourology Favourable for ESWL —— ESWL

2.4. Choice of access

2.4.1. Ultrasound guided access

The obvious advantages of ultrasound guided access are well known, they include, no radiation, minimal chance of visceral injury and proven safety in pregnancy. The downside of using ultrasound as an access modality are need for expertise, need for fluoroscopy in dilatation stage of the procedure.

2.4.1.1. Technique. The sector probe (3 Mhz or 5 Mhz) is generally used for gaining access. The puncture is ether done free hand or using a needle guide. Depending on the make of the ultrasound probe, the puncture guide can be either situated on the side or the centre of the probe. The electronic dotted line in most cases corresponds to the path of the needle. For proper visualization of the needle an echo tip needle is useful. Alternatively the serrated side of the needle should face the probe.

The ultrasound probe should be scanned posterior to anterior. The first calyx to be seen would be the posterior calyx. The probe should thereafter be positioned in such a way that the calyx, infundibulum and the pelvis is seen. Ideally the needle should be seen throughout its course. The prerequisite for this would be a sharp needle or a motionless/steady probe. The site of needle entry should be marked on the skin. The needle is inserted with jiggling motion in the subcutaneous tissue thereafter the needle is advanced through the cup of the calyx into the desired calyx. Ideally the trajectory of the needle should be seen throughout the course. The appropriate puncture is confirmed with egress of clear urine.

3. Fluoroscopic guided puncture

3.1. Fluro guided PCNL

The advantages of fluoroscopic guided puncture are ability to gain access to the kidney through an end on posterior calyx. The obvious disadvantage of this approach is increased risk of radiation to the operator, patient as well as the surgeon. Further, unlike the ultrasound guided access there is no real time visualization of visceral organs such as the kidney or the liver, thus potentially adding to risk of injury to these organs.

Kidney should be approached from below the 12th rib to reduce the risk of pleural complications. The site of entry on the skin is usually just inferior and several centimeters medial to the tip of the 12th rib.

The triangulation technique is the commonest technique used for achieving fluoroscopic guided puncture. The C-arm is placed over the patient in the vertical position. A retrograde pyelogram is obtained, and the skin over the desired calyx is marked. The C-arm is then rotated 30° toward the surgeon for an end-on view of the posterior group of calyces. The skin site over the calyx is marked lateral to the first site. Move in a vertical line inferiorly until a site 1–2 cm below the 12th rib is reached. This third site is marked and serves as the site of needle entry. From this point, the needle is advanced to the junction of the vertical plane and the 30-degree plane. Access is achieved at the junction of all three axes [8].

The exact puncture can assessed by the parallax technique. In this technique the Carm is kept at 90° (A)and an access gained, once this is done the Carm is rotated 30° (B) towards the surgeon. If the position of the needle in (A) and (B) both are the same the access is gained.

4. Endoscopic guided renal access(EGA)

4.1. Technique

The technique involves the use of endoscopic vision using a flexible ureteroscope for identifying the ideal calyx for puncture A flexible ureteroscope is used to confirm the calyx entry. Once the guide wire is passed in the rest of the steps which include dilatation are done either under endoscopic vision or under fluoroscopic guidance. In a study the endoscopic guided access (EGA) [9] was compared with fluoroscopic guided puncture (FGA), EGA was found to be better in terms of fluoroscopy time, and need for secondary procedures.

4.2. Procedure

Once the patient is placed in prone position the primary calyx of puncture is identified using either ultrasound or fluoroscopy. A guide wire is passed in the ureter following which access is gained in the proposed secondary tracts. Once all the desired access has been gained and the guide wires are in position the primary tract is dilated. It is imperative that the tract should not be dilated at the outset as this would lead to extravasation and subsequent difficulty. The operating time is limited to 90 min because it has been shown in number of studies of the risk of fluid absorption with prolonged surgery. If it is decided that the procedure is to be staged the 14 Fr malecot tubes are inserted in the secondary access tracts These serve the dual purpose of achieving mature tracts and providing a conduit for subsequent intervention. The primary tracts are dilated upto 26 Fr while the secondary tracts are dilated till 20 Fr [10].

4.3. Single tract with use of flexible instrumentation

This technique involves creation of a strategic tract which clears majority of stones. Once the bulk is cleared, stones present in inaccessible calyces are approached with flexible instruments [11] The disadvantage of this approach is additional cost for instrumentation.

5. Newer concepts in percutaneous surgery

5.1. Miniperc

Miniperc is PCNL done with sheath size less than or equal to 20 Fr. Miniperc was originally devised for handling stones in children [12] but it has been widely used in adults because of its ability to minimize blood loss and hasten recovery and with similar clearance rates.

In miniperc the scopes used range from 8 fr to 16 fr. and the tract size varies from 12 fr to 20 fr. Both lithoclast and laser can be use for stone breaking modalities in mini PCNL. Mini PCNL can also be used in situations where the infundibulum is narrow and the smaller size of the scope can be used to navigate through the narrow infundibulum.

Miniperc [13] is ideally suited for treating stones of sizes varying from 1 cm to 2.5 cm stones of slightly larger sizes can also be tackled via miniperc by using modalities such as additional tracts, or Y tracts etc.

In a prospective study conducted by Mishra et al. [13] the authors were able to prove that Miniperc has equal efficacy in clearing stones when compared to standard PCNL whereas it has an advantage of less bleeding and tubeless procedure as well in some cases. They also noted that miniperc has a drawback of lengthy operative time.

5.2. Microperc

Traditionally, PCNL required a 30 Fr nephrostomy sheath for renal access. With the development of smaller sheaths it was found to reduce morbidity without affecting stone clearance rates. Microperc uses 16 G all seeing needle and a 0.9 mm flexible microperc telescope and the stone is fragmented with laser. The ureteric catheter drains the pelvicalyceal system continuously. Intermittent manual suction through the ureteric catheter further reduces the intrarenal pressure.

Microperc is currently used to manage single renal calculus or multiple renal calculi, which can be accessed with a single puncture and cumulative diameter of less than 1.5 cm in diameter. . In a comparative study done by Sabnis et al. [14] it was proved that microperc is similar to RIRS in terms of stone clearance and complications for small renal calculi.

6. New nomenclature

To avoid confusion with regards to various names used in PCNL schilling et al. [15]proposed a uniform nomenclature based on sheath size (Table 1).

7. Complications

The majority of complications post PCNL are minor [16]. Minor complications include fever and nephrostomy leak [17]. Major complications can either be related to access or stone removal.

8. Related to access

8.1. Pleura

The pleura might be injured more during supracostal access than infracostal [18]. We usually use infra costal approach for routine access unless special indications such as requirement of upper pole access.

8.2. Liver and spleen

Injury to the liver during PCNLis rare. The main concern after Transhepatic percutaneous access is injury to major intrahepatic vessels. If there is severe bleeding angioembolization can be done.

Splenic injury is also a rare during PCNL. Intraoperatively one should suspect splenic injury if the patient is hemodynamically unstable and there is no visible bleeding. In case of uncontrollable hemorrhage, splenectomy may be required. This is usually confirmed by intraoperative USG.

8.3. Colon

Injury to colon, can occur in 0.2%–1% of PCNL patients [19,20].The factors associated with increased risk are female gender, low BMI, and previous bowel surgery, left side access [21,22]. Symptoms include rectal bleeding, fever, pain, ileus elevated counts, gas or feces from the percutaneous nephrostomy (PCN) tube. Intraoperative diagnosis is usually made after injection of contrast reveals colonic enhancement. Post operative diagnosis can be made by CT or contrast study. The treatment of colonic injury is antibiotics and bowel rest. In case of delayed diagnosis, PCN tube should be removed and a drain kept after consulting a general surgeon.

8.4. Duodenum and jejunum

Duodenal and jejunal injury is extremely rare in PCNL. CT scan

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Table 1
Proposed nomenclature in PCNL.

Term	Acronym	Definition
Patient position (p)	P	Prone position
	S	Supine position
Outer sheath size (c)	XL	≥25 FR
	L	20 to <25 FR
	M	15 to <20 FR
	S	10 to < 15 FR
	XS	5 to <10 FR
	XXS	<5 FR
Irrigation flow(r)	CF	Continuous flow, low pressure
	CO	Closed/open
	PC	Pressure controlled
Urinary Diversion(u)	DT	Drain tube: nephrostomy tube and ureteral stent
	TU	Tube only: nephrostomy tube
	TL	Tubeless: only ureteral stent
	TT	Totally tubeless: no stents in place
	TTa	Removal of ureteric catheter within procedure
	TTb	Removal of ureteric catheter within 24 h
Tract treatment (t)	SL	Sealed: closure of access tarct
	NS	Non Sealed: Non closure of access tarct

helps in diagnosing duodenal injury in the post operative period. The preferred treatment is open surgical approach, whereas, nonoperative management with bowel rest, nasogastric suction, with or without percutaneous duodenal drainage, and renal collecting system drainage has also been described.

9. Related to stone removal

9.1. Infection and urosepsis

Mild fever post PCNL occurs in about one third of the patients, but incidence of sepsis is much lower, in patients treated with appropriate perioperative antibiotics. Post operative sepsis can be prevented by preoperative antibiotics, low-pressure irrigation, use of drainage when required.

9.2. Intravascular fluid overload

Intravascular fluid overload can occur if there is injury to vessels, increased duration of surgery, hypotonic solutions, high-pressure irrigation, patients with cardiac co morbidities such as CCF.

9.3. Extravasation of fluid

Extravasation of fluid during PCNL occurs due to injury to the collecting system. Systemic absorption leads to volume overload and electrolyte abnormalities. If it is identified in the post operative period, then it should be aspirated percutaneously under USG guidance.

9.4. Post percutaneous nephrolithotomy bleeding

Post PCNL bleeding is the most dreaded complication following PCNL. Most of post PCNL bleeds subside with conservative management. The causes of post PCNL bleed are mainly multiple punctures and increased intra-operative time [23]. Superselective angioembolization (SAE) is an efficacious and safe method of controlling post PCNL bleeding. Pseudoaneursym is the commonest finding on SAE responsible for post PCNL bleeding. A recent study suggested that multiple percutaneous accesses, more than 2 bleeding sites identified during renal angiography and using gelatin sponge alone as the embolic material were high risk factors for failure of SAE [24].

10. Conclusion

PCNL has emerged as most efficient procedure among these approaches to stone removal, though not devoid of complications and requirement for skills. As the time has passed, we have been able to reduce tract size, thereby reduced pain with clearance rate still comparable with the standard technique. This was possible with advent of better lasing techniques, options of improved suction and lithoclast. Recently shock pulse technology has marked its presence for stone lysis in PCNL. However procedure is not devoid of complications. Bleeding is the most significant complication while requirement for staged procedure in large bulk disease is still concern. Tubeless PCNL should be performed in selected cases, allowing patient to be free from nephrostomy related morbidity. Stone density, volume and patient characteristics should allow us to decide which form of PCNL we shall employ.

Ethical approval

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Author contribution

Arvind P Ganpule: study design, data collection. Data analysis, writing.
Mohankumar vijayakumar: study design, data collection. Data analysis, writing.
Ankur Malpani: Data analysis, writing.
Mahesh R Desai: study design, data collection. Data analysis, writing.

Conflicts of interest

No.

Guarantor

Arvind P Ganpule, Mohankumar vijayakumar, Mahesh R Desai.

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