Percutaneous nephrolithotomy for pediatric urolithiasis

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ABSTRACT

Pediatric urolithiasis is a management dilemma as a number of treatment options are available such as shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), and retrograde intrarenal surgery (RIRS). PCNL offers good clearance rates in a single hospital stay. The concerns with PCNL include the use of large instrument in pediatric kidneys, parenchymal damage and the associated effects on renal function, radiation exposure with fluoroscopy, and the risk of major complications including sepsis and bleeding. Evolution of pediatric PCNL technique such as miniaturization of instruments, limitation of tract size and advanced intracorporeal lithotripters have resulted in this technique being widely utilized for achieving stone-free status in appropriate patients. Many of the patients in our country come from remote areas thereby requiring special considerations during treatment. This also necessitates complete clearance in a single shorter hospital stay. PCNL appears to be the optimal option available in this scenario. The literature suggests that even complex and staghorn calculi can be tackled with this approach. The choice of the method to gain access is a matter of experience and personal preference. Ultrasound offers the advantage of visualization of spleen, liver and avoids injury. Miniaturization of instruments, particularly smaller nephroscopes and the potential to use lasers will decrease the morbidity and improve the clearance rates further. In this article, we analyze the management of pediatric urolithiasis with PCNL. We discuss our technique and analyze the results, complications and technique mentioned in the contemporary literature.

Key words: Pediatric, percutaneous nephrolithotomy, urolithiasis

INTRODUCTION

Management of pediatric urolithiasis necessitates a balance between stone clearance and morbidity related to the procedure.[1] Pediatric urolithiasis comprises 4.3% of all the cases.[2] The algorithm in these patients for diagnosis, treatment and follow-up considerably differs from the adult counterpart. The incidence of urolithiasis has a wide sociocultural as well as geographical variation. The disease is known to be prevalent in the underdeveloped countries. The incidence of urolithiasis in general is known to be high in the “stone belt” region of Saurashtra and Kutch in Gujarat state of India. Apart from undernourishment, probably the high salinity and warm temperature are the probable contributing factors for the prevalence. A few authors have also noted a higher incidence of upper tract stones[3] in south Asia. Technological advancement and miniaturization of operative instrument have significantly altered the management in these situations. Pediatric urolithiasis is known to be associated with urinary infection, anatomic and metabolic abnormalities, all contributing to increased recurrence rate. Management of urolithiasis in children necessitates complete clearance, eradication of urinary infection and appropriate correction of any underlying metabolic or anatomical abnormalities. The options for management include shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS) and laparoscopic and/or robotic approach. Since the initial report by Woodside et al.,[4] PCNL has come to be accepted as a well-established, minimally invasive procedure in children as well as adults. When we analyze the trends of SWL, PCNL and ureteroscopy done for pediatric urolithiasis over the years, PCNL has gradually become the mainstay replacing SWL. Recurrence is a major problem, as follow-up is not assured due to poor socioeconomic status. PCNL monotherapy for managing urolithiasis is thus associated with lower
re-treatment rates requiring less auxiliary procedures. It achieves the purpose of offering the patient complete stone clearance with minimal morbidity in a single hospital stay. However, PCNL is a potentially morbid and a life-threatening procedure if complicated. This is relevant in children where the body reserves are marginal and fragile. Therefore, the learning curve has to be taken into consideration before starting pediatric PCNL. In this review we describe our technique and analyze the management of pediatric urolithiasis with PCNL.

**SURGICAL ANATOMY RELEVANT TO PERCUTANEOUS RENAL PROCEDURES**

The knowledge of the intrarenal collecting system and the intrarenal vasculature is of paramount importance in making the percutaneous procedure safe and effective. The main renal artery divides into anterior and posterior segmental artery. The anterior branch supplies the anterior surface and the poles. The posterior segmental artery supplies the posterior surface. This artery is commonly injured during any endourologic procedure. The Brodel’s line is the avascular plane between these two vascular territories. The needle tract in PCNL should traverse along Brodel’s line posterolaterally. Unlike the arteries, the intrarenal veins do not have a segmental structure; there is free circulation throughout the renal venous system. A medial upper polar puncture may result in injury to the posterior segmental artery. Sampaio’s pioneering work in delineation of the variations in the calyceal anatomy using the endocasts is useful in determining the exact calyx of puncture depending on the relation of the stone to the calyx. Theoretically, if the needle traverses through the cup of the calyx through a shortest distance the chance of vascular injury dramatically decreases.

An important variable in viewing the anatomy prior to PCNL is determining the relation of the rib to the calyx. If the stone-bearing calyx is above the 12th rib it requires probably a supracostal puncture. These stones have increased incidence of thoracic complications. Secondly, the degree of hydronephrosis has a bearing on the difficulty of access. Dilated calyces are technically less challenging to puncture. It is important to decide if the stone-bearing calyx is the anterior or posterior calyx. The preferred one is the posterior calyx because major vascular structures surrounding the renal pelvis are avoided and the transparenchymal route stabilizes the nephrostomy tube. Puncture of anterior calyces may be required for a stone in the calyceal diverticulum but is used only if access from posterior calyces is not possible. Further, access from an anterior calyx to the renal pelvis is technically demanding because it requires directing the wire backward.

**Operative technique**

*Preoperative considerations*

General anesthesia is preferred. Special care is taken to clear the urine of any infection prior to intervention. Literature suggests that this patient population is susceptible to hypothermia and hence measures such as temperature monitoring; warm irrigation fluids and brief operating room time should be followed. At our center we have been using warmers for the purpose.

*Operative considerations*

Positioning is crucial in the pediatric population. Particular care should be executed for positioning the patient in prone position. The body is supported below the chest and the lower abdomen with towel rolls acting as bolsters, unlike adults where stiffer bolsters are used. This results in viscera like spleen and/or liver to fall down thereby avoiding injury. The surgeon and anesthetist should personally supervise this step in order to prevent untoward events such as dislodgment of endotracheal tube or neuropraxias. Certain conditions such as spinal anomalies make the positioning of the patient challenging where assessing the degree of mobility of the trunk and extremities is crucial. Special attention should be given to padding pressure points in patients with meningomyelocele.

**Figure 1:** CT with 3D reconstruction volume rendering. Shows stone configuration in PA, Oblique and AP view.
Planning access

Historically, the anatomy was assessed preoperatively with an intravenous urography (IVU). However, nowadays, we prefer a contrast-enhanced computed tomography (CT) scan to assess the pelvicalyceal anatomy. This provides a functional as well as anatomical evaluation. The anatomical considerations include planning the number and location of puncture [Figure 1]. A retrograde dynamic contrast study is done initially to measure the infundibular width, length and angle of entry into the pelvis. Infundibular width also decides the size of the Amplatz sheath to be used.

Ultrasound-guided puncture

Ultrasound guidance is used for gaining initial access. The advantages of this are a shortest straight tract to the desired calyx and avoidance of visceral injury. The ultrasound probe is usually 3.5 MHz /5 MHz. The scan starts at the posterior axillary line and proceeds anteriorly. The first calyx to be seen is the posterior calyx. The visualization of the needle during the puncture throughout the needle path is the ‘key’ to the success of ultrasound-guided puncture. Once the site of puncture is decided a “jiggling” movement of the needle shows the tip of the needle along the needle path. The proper access is confirmed with return of clear fluid and performing a contrast study.

 Fluoroscopy-guided puncture

In pediatric patients, the technique remains the same as adults, however, the operating surgeon should take into consideration the short distance between the skin and the kidney. The depth the needle needs to traverse before it reaches the desired calyx should be kept in mind. The C-arm is placed in vertical position, and the concerned calyx identified. The ideal tract should be the shortest straight tract to the calyx. Examination with the C-arm at 90 degrees delineates the vertical plane. The C-arm is then rotated approximately 30 degrees toward the surgeon. This provides a direct end-on view of the posterior calyces. The 18-gauge needle is advanced with the C-arm in 30 degrees. The appropriate direction for needle advancement is determined by obtaining a “bull’s-eye sign” on the fluoroscopic screen, this can be observed only when the needle hub is superimposed on the needle shaft. In our opinion the drawback of fluoroscopy-guided puncture in pediatric patients is additional risk of radiation, in addition, the adjacent organ is not visualized and hence the chance of visceral injury increases.

Tract dilatation

The access is confirmed by return of clear fluid from the needle. A 0.035 guide wire is passed into the system preferably down into the ureter; if not, into a distant calyx. We prefer to initially dilate the tract with a fascial dilator (6 or 8 Fr.) followed by metal or co-axial telescopic dilators. The tract size is kept to minimum. Kukreja et al., compared Amplatz serial dilatation, telescopic dilators and balloon dilators. The Amplatz system was associated with the least blood loss in comparison to telescopic dilators. However, the telescopic dilators have the advantage, particularly in children, of gradual controlled dilatation. In all cases, one of the slender nephroscopes ranging from 12 Fr to 20 Fr is used for fragmentation. It accommodates a 0.8 mm pneumatic probe that has an inbuilt suction. The holmium laser helps in fragmenting the stones into small fragments and in restricting the tract size as it can pass through the smallest working channel of a nephroscope. Recently, we have been doing pediatric “minipercs” through a miniature nephroscope system developed by Karl Storz. This consists of a 12 Fr nephroscope having a 6.7 Fr channel for use with instruments up to 5 Fr. The set has a one-step dilator with a central channel, for operating sheaths of 15/21 Fr for continuous irrigation and suction [Figure 2].

Post-PCNL tubes

As in adult patients, drainage tube is a standard after the procedure. Besides causing immediate tamponade of the tract bleeding, a re-look nephroscopy option is available. This is of importance particularly in children because any residual fragments in children are likely to be a nidus of infection and future stone formation. The types of
nephrostomy catheters vary. We prefer to keep a Nelatons catheter as a nephrostomy of 12 Fr or 14 Fr. A double J stent is inserted in solitary kidneys, bilateral procedures, suspected ureteropelvic junction obstruction or when deemed necessary by the operating surgeon. The procedure is staged if the patient is having renal insufficiency, urinary tract infection and or bilateral stone disease. An intra-operative decision to stage the procedure is done if there is significant bleeding and or nephroscopy time exceeds 60 minutes.

**Follow-up protocol**
A kidney ureter bladder KUB skiagram is taken at 48 hours. If needed a re-look procedure is done. This is followed by removal of the tubes. The patient is followed up with an ultrasound and KUB at one month and an IVU at one year. A urine metabolic evaluation and blood chemistry is done once the patient returns to normal activity.

**Literature review**

**Indications**
There were concerns with PCNL in small children, namely the use of large instruments in pediatric kidneys, parenchymal damage and the associated effects on renal function, radiation exposure with fluoroscopy, and the risk of major complications including sepsis and bleeding. PCNL is increasingly being used as monotherapy and in combination with SWL (sandwich therapy) in children and adults,[11] with stone-free rates ranging from 68–100%. Although debatable, indications for PCNL as primary therapy in children include large upper tract stone burden (greater than 1.5 cm, lower pole calculi more than 1 cm, concurrent anatomical abnormality impairing urinary drainage and stone clearance, or known cystine or struvite composition.[2,12] PCNL as a part of sandwich therapy was introduced to reduce the number of tracts and associated morbidity.[13,14] The decision to follow PCNL with SWL is related to operator experience with percutaneous technique and available technology. Technically challenging in nature, surgeon experience with PCNL is paramount. It is our preference to perform a second-look nephroscopy through the original tract to ensure stone-free status during the same hospital admission.

**Age**
There were concerns regarding the applicability of PCNL in young children because of the necessity to use large endourologic equipments.[15] Recent advancements in instrumentation such as smaller nephrosopes (15 to 18 Fr) and more efficient energy sources for intracorporeal lithotripsy including holmium:YAG laser as well as smaller pneumatic lithoclast and ultrasound probes have greatly facilitated percutaneous treatment techniques. As a result, PCNL has now replaced open surgery as the treatment of choice for large stone burdens in children of all ages. As workers gained experience PCNL started being performed in smaller children. PCNL has been performed in children as young as 19 months.[16,17]

**Tract size**
Many authors have reported that 24 Fr to 26 Fr dilation does not cause significant morbidity in children, and it has been shown in animal models that there is no advantage in using a small access based on renal scarring alone.[22] Earlier studies with PCNL in children described the use of adult size instruments. Desai et al., showed that intra-operative hemorrhage during PCNL in children is related to the caliber and number of tracts and suggested the need of technical modifications in children.[23] The efforts to use the smallest and least traumatic instruments have significantly reduced complication rates.[24,25] However, the size of the tract is still the main concern related to blood loss.[26,27] Zeren et al., showed a significant correlation of intra-operative bleeding with operative time, stone burden and sheath size. [28] With availability of smaller endoscopes, miniperc procedure is facilitated percutaneous treatment techniques. As a result, PCNL has now replaced open surgery as the treatment of choice for large stone burdens in children of all ages. As workers gained experience PCNL started being performed in smaller children. PCNL has been performed in children as young as 19 months.[16,17]

**Renal damage**
Historically, there were concerns regarding similar or even more renal damage with PCNL compared to open surgery in children.[18] However, now most studies demonstrate minimal scar formation and insignificant loss of renal function.[19] Mor et al., performed radioisotope scans on 10 children before and after PCNL and showed no change in differential function and no evidence of significant scarring.[20] Dawaba et al., found a significant increase in the glomerular filtration rate GFR following PCNL, in 65 pediatric patients with no renal scarring after long-term follow-up.[21]

**Table 1: Outcomes in various series**

<table>
<thead>
<tr>
<th>Study</th>
<th>Renal units</th>
<th>Mean age</th>
<th>Tract size</th>
<th>Complications</th>
<th>Success rate (after auxiliary procedures)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahmud M et al.[19]</td>
<td>30</td>
<td>3.8 (1.4-5)</td>
<td>&lt;22 Fr</td>
<td>2.3-5 cm (1.3-6 cm)</td>
<td>Overall -6%</td>
</tr>
<tr>
<td>Zeren et al.[29]</td>
<td>67</td>
<td>10-14 years (7.9)</td>
<td>24-30 Fr</td>
<td>25-2075 mm²</td>
<td>Hemorrhage -23.9%</td>
</tr>
<tr>
<td>Manohar et al.[30]</td>
<td>35</td>
<td>11 months to 4.5 years</td>
<td>&lt; 22 Fr</td>
<td>140 mm²</td>
<td>Transfusion rate-5%</td>
</tr>
<tr>
<td>Salah et al.[31]</td>
<td>138</td>
<td>8-14 (8.9)</td>
<td>26 Fr</td>
<td>124-624 mm² (507mm²)</td>
<td>Urine leak -8%</td>
</tr>
<tr>
<td>Nouralizadeh et al.[32]</td>
<td>20</td>
<td>3.1 years</td>
<td>26 Fr</td>
<td>33 (20-46)</td>
<td>Bleeding-0.7% Retropitoneal collection-0.7%</td>
</tr>
</tbody>
</table>

feasible. Helal et al., demonstrated using 15 Fr access sheath in a two-year-old child.[29] Jackman et al., used a 11 Fr access sheath for pediatric PCNL.[30] Though a smaller nephrostomy tract may decrease the morbidity of PCNL, it also necessitates the use of smaller instruments and a more frequent need of stone fragmentation. We believe that placement of the first tract should be planned well and should enable the surgeon to remove most of the stone, so that the residual fragments can be retrieved through smaller tracts. Jackman et al., suggested that a smaller tract leads to less tissue displacement and less nephron injury.[30] They reported a repeat session rate of 43% with an average stone burden of 120 mm², with visualization problems due to bleeding being the leading reason for postponing surgery. Our experience with miniperc in this age group was promising in selected patients. The smaller pneumatic probe and holmium:YAG laser lithotripsy have an important role in miniperc, and are known to be safe in children.[31]

Complications
Zeren et al., reported a 24% incidence of hemorrhage requiring transfusion.[28] Chest complications are known after supracostal percutaneous access. The majority of hydrothoraxes are asymptomatic, and intervention is required in only a small percentage of patients. Certain measures should be taken while performing supracostal punctures. First, the supra 11th rib approach may be better avoided because of the higher incidence of pleural and pulmonary violation. The use of an Amplatz sheath which should be well positioned reduces the risk of symptomatic hydrothorax by allowing free exit of irrigant. Additionally, intra-operative chest fluoroscopy at the end of the procedure is beneficial to identify a fluid collection. Injury to the pelvicaliceal system and sepsis are the other major concerns. Desai et al., recommended staged operation to reduce these complications.[23] Another potential complication of percutaneous nephrolithotomy is hypothermia, especially in this age group.[32] The decrease in body temperature is correlated with the duration of the procedure and preoperative preparation.

Results
Percutaneous nephrolithotomy has been described even in children as small as 11 months, having complex calyceal stones and or staghorn calculi. The key to success in these small patients is staging the procedure if required, miniaturization of instruments and using ultrasound as the method of achieving access. In this study there was a statistically significant increase in the blood loss in patients having multiple tracts. The tract size notably did not have bearing on the blood loss. In the study the authors advocate staging the procedure if the nephroscopy time exceeds 60 min.[33]

In a study from Yemen, Salah and associates used instruments as large as 26 Fr with no significant increase in complications, however, in smaller children they recommend use of a ureteroscope through a smaller tract.[34]

The aim of this procedure is to offer stone clearance without adding any morbidity. The commonest complication reported in the majority of the series is hemorrhage. Zeren notes this complication to be significant in the initial part of the learning curve and tends to decrease as one gains experience.[28] The success rates after adjuvant or auxiliary procedures in various series is given in Table 1. Samad et al., performed Dimercaptosuccinic acid (DMSA) renograms in 60 renal units who underwent PCNL out of 60 renal units. Cortical scars were seen in 10 renal units (17%). In three of these kidneys the site of local defect corresponded to the access site. In the rest there was no association with the access site. There was no correlation between the tract size and the renal damage.[35]

CONCLUSION
PCNL offers good clearance rates with acceptable morbidity. The literature suggests that even complex and staghorn calculi can be tackled with this approach. The choice of the method to gain access, ultrasound or fluoroscopy, is a matter of experience and personal preference. Ultrasound offers the advantage of visualization of the spleen, and liver and avoiding injury. Miniaturization of instruments, particularly smaller nephrosopes and newer energy sources will decrease the morbidity and improve the clearance rates.

REFERENCES
Ganpule, et al.: Pediatric PCNL


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