Percutaneous Nephrolithotomy for Complex Pediatric Renal Calculus Disease

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ABSTRACT

Background and Purpose: Pediatric renal calculus disease has been a management dilemma in view of the concern about the effects of the various treatment modalities on the growing kidney, the significant recurrence rate, and the long-term outcome. We report our experience with percutaneous nephrolithotomy (PCNL) monotherapy in staghorn or complex pediatric renal calculi.

Patients and Methods: We retrospectively analyzed the case records of 116 patients younger than 15 years who underwent PCNL. The stones included 56 complex calculi. We defined complex calculi as either staghorn (complete or partial) or those with a large bulk and involving more than one calyx, the upper ureter, or both.

Results: Complete clearance was achieved in 50 patients (89.8%). Of these, 22 (39%) required a single tract, while 34 (61%) required multiple tracts. With subsequent SWL, the clearance rate increased to 96%. The average hemoglobin drop was 1.9 g/dL. Assessing the factors affecting the hemoglobin drop, the number of tracts and the size of tracts were found to be significant ($P < 0.01$). The average change in the serum creatinine concentration between the preoperative and postoperative measurements was +0.03 mg/dL and was not different in patients with a single tract and those with multiple tracts (+0.02 and +0.04 mg/dL, respectively; $P = NS$). Intravenous urography done in 36 renal units postoperatively revealed good function in all. A DMSA renal scan in six children showed no scar.

Conclusions: Monotherapy with PCNL is safe and effective in the management of staghorn and complex renal calculi in single hospital stay. Ultrasound-guided peripheral caliceal puncture and limiting the tract dilatation to 22F are important factors in reducing the blood loss. Multiple tracts increase the hemoglobin drop but are not associated with an increased risk of complications (bleeding, postoperative infection, and prolonged urinary leak). Also, there is no deterioration in renal function after either single- or multiple-tract PCNL.

INTRODUCTION

PEDETRIC RENAL CALCULUS DISEASE has always been a management dilemma in view of the concern about the effects of the various treatment modalities on the growing kidney, the significant recurrence rate, and the long-term outcome.1,2 Extracorporeal shockwave lithotripsy remains the primary treatment for small calculi. Percutaneous nephrolithotomy (PCNL) has an established role as part of a multimodal approach for treating large, especially complex, pediatric renal calculi.3-6 Herein, we report our experience with PCNL monotherapy in staghorn or complex pediatric renal calculi, with the aim of assessing the efficacy and safety of multiple-tract PCNL monotherapy and identifying technical modifications that will reduce the morbidity.

PATIENTS AND METHODS

Patients

We retrospectively analyzed the case records of 116 patients (128 renal units) younger than 15 years who underwent PCNL at this institute from January 1991 to December 2002. The most
common indications for PCNL were complex calculi, infection, renal insufficiency, and gross hydronephrosis (Fig. 1).

We defined complex calculi as either staghorn (complete or partial) or bulky stones involving more than one calix, the upper ureter, or both. There were 56 complex calculi, of which 13 were complete staghorns, 19 partial staghorns, and 24 complex caliceal calculi. Demographic data of these 56 children are described in Table 1.

The basic work-up included a urine culture, serum creatinine estimation, ultrasound examination of the abdomen, and plain (KUB) radiograph with intravenous urography. Patients with clinical or bacteriologic evidence of infection and renal insufficiency with hydronephrosis had drainage with a nephrostomy tube prior to PCNL. Staging the procedure in such children helps avoid bacteremia and stabilizes renal function. Subsequent tract dilatation and calculus manipulation is deferred to a subsequent stage.

**Surgical procedure**

Initial percutaneous access to the pelvicaliceal system is obtained through an ultrasound-guided peripheral caliceal puncture. A safety guidewire is always placed down the ureter. The degree of dilation and the size of sheath introduced is probably the most critical step in avoiding blood loss during PCNL in children. This assessment is made on the basis of the width of the infundibulum of the calix of entry, which in turn depends on the age of the child and the degree of hydronephrosis. In children less than 6 years of age and those with nondilated collecting systems, a 20F or 22F Amplatz sheath is placed. In older children and those with significant hydronephrosis, a 24F Amplatz sheath is placed. In all cases, we use a 14F Wolf nephroscope. Smaller calculi are removed intact, while larger calculi are systematically fragmented with pneumatic energy through a 0.8-mm probe and then removed.4

For branched calculi where the need for multiple tracts is obvious right at the outset on the basis of the pelvicaliceal anatomy, all punctures thought to be necessary are made at the beginning of the procedure prior to tract dilatation according to the configuration of the calculus and the pelvicaliceal system. The rationale for this approach is that it is easier to puncture the collecting system at the beginning of the procedure when it is full and relatively undisturbed. Once tract dilatation, nephroscopy, and lithotripsy are commenced, the system deflates; and there is extravasation of fluid and contrast medium, making subsequent punctures more difficult. The primary tract is dilated first, and the subsequent tracts are dilated later only if required. In case the procedure has to be staged, nephrostomy

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**TABLE 1. DEMOGRAPHIC DATA**

<table>
<thead>
<tr>
<th>Total renal units</th>
<th>56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>9.1 ± 4.7 (6 months–15 years)</td>
</tr>
<tr>
<td>M/F</td>
<td>46/10</td>
</tr>
<tr>
<td>L/R</td>
<td>25/31</td>
</tr>
<tr>
<td>Stone bulk (mm³)</td>
<td>337.6 ± 181.8 (110–989)</td>
</tr>
<tr>
<td>Type of stone</td>
<td></td>
</tr>
<tr>
<td>Complete staghorn</td>
<td>13</td>
</tr>
<tr>
<td>Partial staghorn</td>
<td>19</td>
</tr>
<tr>
<td>Multiple complex</td>
<td>24</td>
</tr>
<tr>
<td>Preop. renal insufficiency (%)</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Preoperative infection (%)</td>
<td>14 (25)</td>
</tr>
<tr>
<td>Preoperative PCN (%)</td>
<td>13 (23.2)</td>
</tr>
</tbody>
</table>
tubes are placed in the unused tracts, so that at the subsequent stage, the remainder of the procedure can be performed through mature tracts. The indications for staging are infection, bleeding obscuring vision, and nephroscopy time exceeding 90 minutes.

At the end of the procedure, a 12F to 14F nephrostomy tube is placed. A double-J stent is inserted in patients with a solitary kidney, impaired renal function, bilateral procedures, suspected pelvicureteral junction obstruction, or associated impacted ureteral calculi. In all other cases, an open-ended ureteral catheter is placed for 48 hours. A check radiograph is taken after 48 hours. Relook nephroscopy is carried out if radiography reveals any residue. Once the nephrostomy drainage is clear and the kidney is stone free, the nephrostomy tube is removed. The patient is discharged after urine leakage from the nephrostomy tract ceases.

Hemoglobin estimation is done preoperatively and 48 hours postoperatively. The need for blood transfusion is decided on the basis of evidence of perioperative bleeding, the hemoglobin drop, and anemia. Assessing the factors affecting the hemoglobin drop, the number of tracts, the size of the tracts, patient age, preoperative presence of urinary infection, and staged procedure in the form of a previously placed 14F nephrostomy tube with subsequent tract dilatation deferred to 48 hours were evaluated using Student’s paired t-test. A comparison of morbidity (hemoglobin drop, infection, prolonged urinary leak, and change in serum creatinine concentration) was done between single- and multiple-tract procedures.

### RESULTS

Of the 56 complex calculi, complete clearance was achieved in 50 patients (89.8%) by PCNL. Of these, 22 (39%) required a single tract, while 34 (61%) required multiple tracts. Also, 31 procedures (55%) were completed in a single stage, while 25 (45%) required multiple stages. Tract and stage-wise distribution of these 56 cases is shown in Figures 2 and 3, respectively. The operative results and morbidity are tabulated and compared with our overall series in Table 2.

The average hemoglobin drop in the 56 patients was 1.9 ± 1.01 g/dL (range 0.3–5.3 g/dL). Assessing the factors affecting the hemoglobin drop, the number of tracts and the size of tracts were found to be significant ($P < 0.01$) (Tables 3–5). Age, preoperative presence of urinary infection, and staged procedure in the form of previously placed 14F nephrostomy tubes with subsequent tract dilatation deferred to 48 hours did not seem to affect the hemoglobin drop.

Eight of the patients with complex calculi required blood transfusions. Of these, four had significant intraoperative bleeding, while the remaining four had existing anemia coupled with the hemoglobin drop. The transfusion rate secondary to intraoperative bleeding differed with respect to the number of tracts (Table 6). The experience curve also had a significant impact on the episodes of intraoperative bleeding, as the bleeding-related transfusion rate dropped from 12% in the first 25 cases to 3.3% in the last 30 cases.

Three patients had persistent urinary leakage from the nephrostomy site after removal of the nephrostomy tube and required double-J stenting, following which, the leak subsided.

Of the six patients with residual calculi, three underwent

### TABLE 3. FACTORS AFFECTING DECLINE IN HEMOglobin POSTOPERATIVELY

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hb decline (g/dL)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of tracts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>1.28</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Multiple</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>Size of single tract (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤22</td>
<td>1.1 ± 0.45</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>&gt;22</td>
<td>1.61 ± 0.42</td>
<td></td>
</tr>
<tr>
<td>Age (years) (single tract)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>1.15</td>
<td>0.25</td>
</tr>
<tr>
<td>10–15</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>Prior nephrostomy tube</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.19</td>
<td>0.41</td>
</tr>
<tr>
<td>No</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.39</td>
<td>0.29</td>
</tr>
<tr>
<td>No</td>
<td>1.23</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 4. EFFECT OF SIZE OF TRACTS ON BLEEDING

<table>
<thead>
<tr>
<th>Hb drop (g/dL)</th>
<th>≤22 F</th>
<th>24–28 F</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single tract</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1 ± 0.45</td>
<td>1.61 ± 0.43</td>
<td>0.01</td>
</tr>
<tr>
<td>(N = 15)</td>
<td>(N = 7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple tracts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.84 ± 0.65</td>
<td>2.72 ± 1.11</td>
<td>0.01</td>
</tr>
<tr>
<td>(N = 13)</td>
<td>(N = 13)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SWL. Extracorporeal lithotripsy was chosen in preference to relook nephroscopy in three patients because of residual stone in an awkward calix, which would have added further morbidity because of the need for a difficult new tract. All three were completely cleared of calculus. Residual fragment in one patient had passed spontaneously at 3-month follow-up, and two patients were lost to follow-up. Thus, complete clearance was confirmed in 54 of the 56 patients (96.4%).

Two patients presented with renal insufficiency. One patient stabilized to normal renal function postoperatively, while another patient with unilateral staghorn stone and contralateral nephrocalcinosis and a serum creatinine concentration of 2 mg/dL had end-stage renal disease at 28 months’ follow-up.

Postoperative functional assessment was done in all of the remaining 53 renal units that presented with normal biochemical values. Serum creatinine remained normal in all these patients, with the average change between the preoperative and postoperative measurements being +0.03 ± 0.24 mg/dL (range 0.3 to 0.4 mg/dL). Comparing the change in the creatinine values amongst patients with a single tract and those with multiple tracts revealed no significant difference (+0.02 and +0.04 mg/dL, respectively; P = NS).

Eight patients with bilateral disease (16 renal units) underwent bilateral PCNL. The average tract requirement per patient was three. At a mean follow-up of 16.5 months, the average change in serum creatinine was 0.0 ± 0.17 mg/dL.

Intravenous urography was done in 36 renal units postoperatively and revealed good function in all the units. A DMSA renal scan in six children (eight renal units) revealed no scar in any of them. Limited access to radionuclide scans and the economic status of patients limited functional assessment with DMSA scanning, which would be a more specific functional assessment.

Three patients had associated pelviureteral junction obstruction. Two underwent endopyelotomy subsequently, whereas one was initially managed with double-J stenting and later required an open pyeloplasty. Recurrent urinary tract infection was documented in four patients. Metabolic evaluation revealed hypocitraturia as the commonest abnormality (71%) followed by hypercalciumia in 38%. Stone analysis revealed stones of calcium oxalate in 65%, calcium phosphate in 20%, struvite in 10%, and uric acid in 5%.

The mean follow-up was 20.9 ± 14.5 months (range 1–60 months). At least 24 months of follow-up is available for 24 units, and 5 (20%) of these showed recurrence of calculi. We feel that the climatic conditions (extreme tropical heat and humidity) leading to dehydration, along with recurrent urinary infections and metabolic abnormalities, contributes to the high recurrence rate. Of these patients, two required PCNL, and two were treated with SWL, while one was kept on conservative management.

### DISCUSSION

Problems in the management of pediatric urolithiasis relate to the high incidence of metabolic and infective etiologies with increased chances of recurrence, the small size of the kidneys, and the apprehension regarding the long-term effects of various newer treatment modalities on the developing kidneys. Recurrent stone disease in children favors the use of minimally invasive treatment. Shockwave lithotripsy is the treatment of choice for most of the small calculi. Percutaneous lithotripsy has been carried out in cases where SWL is contraindicated or has failed. Combination therapy including PCNL followed by SWL has been the mainstay for complex stone disease, including staghorn calculi in adults and children. We undertook PCNL monotherapy for pediatric complex stone disease because of increased risk of recurrence because of partial clearance associated with SWL. Multiple anesthesia requirements for multiple-sessicn SWL, poor cost-effectiveness of multiple staged combinations (SWL + PCNL), and poor patient compliance. We achieved a clearance rate of 89.8%. However, we believe that PCNL monotherapy in this group requires technical modifications, especially if its use has to be extended for managing complex calculi.

A carefully chosen site (calix) for renal access that enables maximum stone clearance is critical. The site is chosen after careful study of stone configuration on anteroposterior and oblique radiographs and ultrasound scanning. The criteria for an ideal calix include:

1. A posterior calix is preferred to an anterior calix.
2. A dilated calix is preferred.
3. The infundibulum should be wide and long, as narrow and

### Table 5. Effect of Multiple Tracts on Bleeding

<table>
<thead>
<tr>
<th></th>
<th>Single</th>
<th>Multiple</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>22</td>
<td>34</td>
<td>–</td>
</tr>
<tr>
<td>Ave. Hb drop (g/dL)</td>
<td>1.28</td>
<td>2.32</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Infection (%)</td>
<td>1 (4.5)</td>
<td>2 (5.8)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean change in serum creatinine (mg/dL)</td>
<td>+0.02</td>
<td>+0.04</td>
<td>NS</td>
</tr>
<tr>
<td>Prolonged leak from tract</td>
<td>1 (4.5)</td>
<td>1 (2.9)</td>
<td>NS</td>
</tr>
</tbody>
</table>

### Table 6. Blood Transfusion Because of Intraoperative Bleeding According to Number of Tracts

<table>
<thead>
<tr>
<th>No. tracts</th>
<th>No. renal units</th>
<th>Ave. stone size (mm²)</th>
<th>No. (%) requiring transfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>303</td>
<td>1 (4.5)</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>335</td>
<td>2 (7.8)</td>
</tr>
<tr>
<td>&gt;2</td>
<td>8</td>
<td>439</td>
<td>1 (12.5)</td>
</tr>
</tbody>
</table>
short infundibula tend to be associated with tears while dila-
tating the tract.

4. The calix offers access to the maximum amount of the stone
burden and the pelvis in a relatively straight line, with entry
into other calices being possible with minimal angulation.

Calices with calculi and those that cannot be approached from
the primary tract without significant angulation are also punctu-
ted at the beginning of the procedure. Excessive angulation to
gain entry into a second calix may cause infundibular tearing
and bleeding, increasing the morbidity more than would an
additional tract. Ultrasonic guidance permits a peripheral puncture,
which traverses minimum cortical tissue, avoids injury to
any major intrarenal vessel, and establishes the shortest straight
tract between the skin and the calix. This approach is safe as it
also avoids visceral injury and minimizes radiation exposure.

The degree of dilatation and the size of the sheath introduced
are probably the most critical considerations in reducing blood loss
during PCNL in children. Woodside and colleagues\(^8\) reported the first pediatric percutaneous nephrolithotomy series.
In seven patients with a mean age of 14 years (range 5–18),
adult instruments were used with no significant complications.
Jackman and associates\(^8\) used an 11F access sheath and stressed the
value of avoiding tract dilatation to an adult size of 24F to
28F, particularly in preschool children. They argued that a
smaller tract leads to less tissue displacement and less nephron
injury. We compared our data with regard to the extent of tract
dilatation and found a significant increase in the average he-
moglobin drop when tract dilatation was increased to 24F and
beyond compared with dilatation to no more than 22F. In no
patient did we dilate beyond 26F.

In most of the literature, PCNL is used chiefly as a part of
combination therapy when managing complex and branched
calculi. We employed multiple tracts in 34 of the 56 units with
complex stone disease (two tracts in 26 patients and three tracts
in 8 patients). Multiple tracts are required to clear calculi from
multiple calices with awkward pelvicaliceal anatomy. Although
there was a significant increase in blood loss in this group, the
incidence of complications (postoperative infection and pro-
longed urinary leakage from the nephrostomy site) was not
found to be different in the group with single tracts compared
with the group having multiple tracts (see Table 5). Limiting the
extent of tract dilatation (≤24F) can also reduce the blood loss.
No patient demonstrated significant deterioration of renal function on follow-up creatinine assessments and intravenous urograms or radionuclide scans. Mor et al\(^3\) performed radioisotope scans in 10 children before and after PCNL and showed unchanged differential function and no evidence of sig-
nificant scarring. Our study, along with the existing literature,
demonstrates the safety of PCNL monotherapy with the use of
multiple tracts in treating multiple and staghorn calculi in this
age group.\(^3,10\)

CONCLUSIONS

Complex pediatric renal calculi are a challenge to manage
and require proper strategic planning to achieve clearance and
reduce the morbidity. As shown here, PCNL monotherapy is
safe and effective in the management of staghorn and complex
renal calculi in a single hospital stay. Ultrasound-guided per-
ipheral caliceal puncture and limiting the size of tract to 22F
are important factors in reducing the blood loss. Planned mul-
tiple punctures with subsequent tract dilatation as required help-
ful. Multiple tracts increase the hemoglobin drop but are not
associated with a higher risk of complications (bleeding lead-
ing to termination of the procedure, postoperative infection, and
prolonged urinary leak). Also, there is no deterioration in renal
function after either single- or multiple-tract PCNL. At the same
time, the clearance rate achieved was 89.8% with PCNL
monotherapy and 96% with subsequent SWL.

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