Percutaneous Management of Staghorn Renal Calculi

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- Abstract -

During a four year period, ending May 1987, 154 cases of symptomatic staghorn calculi have been treated by percutaneous nephrolithotomy. Of these patients, 86% were discharged completely stone free with the remainder having fragments less than 5 mm in greatest diameter. More than one operative procedure during the same hospitalization was required in 24% of patients and multiple percutaneous tracts were established in excess of 73% of them. Significant complications occurred in 16% of patients and there was one death. Most complications can be generally be minimized by careful approach and manageable by interventional radiological means.

The management of patients with staghorn calculi requires a comprehensive understanding of the renal anatomy, selection of appropriate percutaneous nephrostomy tract sites, and radiologic-urologic expertise needed to remove the large stone mass. The advent of extracorporeal shock wave lithotripsy will not abolish the need for nephrolithotomy, particularly complex stones such as staghorn calculi.
Introduction

Staghorn renal calculi have plagued mankind due to the extensive branching as well as their frequent recurrence rate. In 1968, Smith and Boyce reported on the anatrophic nephrolithotomy as a new technique for the removal of staghorn calculi. The idea to reduce renal parenchymal damage and patient morbidity has stimulated numerous therapeutic modalities to accomplish this point.

To date, numerous advances have been made in the field of renal surgery, including the removal of complex staghorn calculi. These techniques compares favorably to the original open surgical procedure with the main advantage being the shorter postoperative convalescence.

With the proliferation of extracorporeal shock wave lithotripsy (ESWL) units throughout the world, staghorn calculi are being approached solely with ESWL, in combination after a prior debulking of stone burden percutaneously, or as the initial method of stone disintegration to be followed by percutaneous nephrolithotomy (PCNL). When the first ESWL machine were being installed, it was frequently stated that they would make percutaneous stone removal obsolete. Indeed, ESWL has been used to attack stones of some complexity partially replacing PCNL. Even after the installation of ESWL at our institution, PCNL plays a major (primary) role in the management of complex stone diseases. The indications for the use of ESWL in the removal of staghorn calculi are currently under evaluation and will require further definition.

The purpose of this paper is to present our experience with PCNL in staghorn calculi and to review the role of PCNL in the era of ESWL.

Materials and Methods

Patients

During a four year period from July 1983 to May 1987, 154 kidneys from 150 patients afflicted with staghorn calculi underwent percutaneous ultrasonic lithotripsy (PUL) at our institution. Four patients had bilateral disease and two had staghorn calculin in ectopic pelvic kidneys. Of these two pelvic kidneys, one was a horseshoe kidney while the other was an allograft renal transplant draining into an ileal conduit urinary diversion.

Forty three patients (28%) had previous open stone procedures including pyelolithotomies and anatrophic nephrolithotomies. There were 95 female and 55 male patients ranging in age from 16 to 96 years, with a mean age of 65 years old. All patients in whom a percutaneous nephrostomy was attempted for removal of staghorn calculi are included in this study.

Although our initial percutaneous experience was limited to high risk patients, as was Clayman et al., all subsequent patients presenting with staghorn calculi at our institution underwent this procedure regardless of operative risk.

Preoperative Evaluation

Routine preoperative laboratory evaluation prior to the establishment of the initial percutaneous nephrostomy tract included a CBC, PT and PTT, serum creatinine, chest radiograph and EKG. Where indicated by history, a bleeding time was added to the standard slate of coagulation profiles. A clean-catch or catheterized urine specimen was obtained for culture and sensitivity.

Routine, intravenous antibiotic therapy was implemented on admission with a broad-spectrum antibiotic, generally a cephalosporin. This was continued into the postoperative period until the patient was afebrile with appropriate changes by results of the sensitivity tests.

The configuration and location of the dendritic extenstions of the staghorn calculi, as well as the collecting system anatomy were evaluated from a recent intravenous urogram. A careful planning of
the placement of the percutaneous nephrostomy tract is then begun on the basis of excretory urography and a plain abdominal radiograph which was obtained just before the creation of the percutaneous nephrostomy tract(s). A coordinated effort between the radiologist and urologist is essential for the systematic removal of these extensive processes.

**Technique of Percutaneous Ultrasonic Lithotripsy**

Our methods for visualization of the collecting system, techniques of percutaneous nephrostomy access, tract dilatation, and stone removal, have been described previously. All patients were admitted to the hospital two days prior to their planned operative procedure. On the first hospitalization day, a cystoscopy and retrograde ureteral catheter was inserted under local anesthesia after preliminary testing and intravenous antibiotics were administered. This catheter was utilized to opacify and hydrodilate the affected collecting system in order to facilitate percutaneous nephrostomy insertion. Other advantages of placing the retrograde ureteral catheter preoperatively is the prevention of antegrade migration of stone fragments down the ureter during ultrasonic lithotripsy and facilitation of establishing a controlled guide wire tract by grasping the end of the open ended ureteral catheter with the two pronged grasping forceps and then inserting a torque guidewire down the ureteropelvic junction and into the bladder.

On the second hospitalization day, the patient is premedicated with parenteral analgesics and is transferred to the radiology suite where percutaneous nephrostomy tract(s) are established under local infiltration of 1% lidocaine using intravenous analgesics. On the following day, definitive stone removal is undertaken. Since November 1985, all patients have been admitted to the hospital one day prior to surgery and retrograde ureteral catheterization performed on the day of admission. All percutaneous nephrostomy tracts along with stone removal were subsequently done in the operating room at the same session.

On the day of procedure, the patients are brought into the operating room and are induced under general anesthesia via the endotracheal route. The patient is then turned onto the operating room table in the prone position and the portable C-arm fluoroscopic unit is utilized. For those patients having nephrostomy tracts established in the operating room with the C-arm fluoroscopy, retrograde pyelogram is performed to visualize the renal collecting system in order to select nephrostomy tract sites.

It is essential, whenever possible, to select a posterior middle or lower pole calyx for nephrostomy tract puncture to enter the collecting system. For staghorn calculi branching into upper and lower pole calices, initial puncture into the lower pole calyx may provide adequate exposure to the entire stone. If the stone extends into the middle and lower pole calices, then two nephrostomy tracts will often be needed into each system. Occasionally, access to an upper caliceal stone can only be obtained by direct supracostal puncture. In these cases, diligent search for accompanying intrusion into the pleural space must be sought. Appropriate measures should be instituted in the operation room to treat this problem.

In the case of ectopic pelvic kidneys, special techniques must be utilized to aid in the establishment of the nephrostomy tract. For extensive staghorn calculi, as many as three nephrostomy tracts may be created to gain access to the various extensions.

After the initial guidewire is introduced down the ureter, a second torque guidewire is inserted. This will become the “working” wire and the initial one will be set aside as the “safety” guidewire. In the case of a bulky staghorn calculus that fills the entire collecting system, percutaneous punc-
ture directly on the stone situated in the calyx is done and the ultrasonic lithotrite burrows a path through the stone to allow the guidewire to pass into the collecting system.

The nephrostomy tract is then dilated with the Amplatz renal dilators (Cook Urological, Spencer, IN) up to a 34F. outer sheath diameter. The accompanying 30F. dilator is removed and the to rigid 26F. Storz nephroscope (Karl Storz, Culver City, CA) is inserted. The outer sheath remains in place throughout the procedure as a conduit to the collecting system to facilitate the passage of percutaneous instruments, to tamponade bleeders created during tract dilatation, and to maintain a low intrapelvic pressure during intrarenal irrigation. Normal saline irrigant is our fluid of choice because of the physiologic compatibility.

Nephroscopy localizes the stone and under direct vision and fluoroscopic backup, the stone is fragmented and aspirated with the ultrasonic lithotrite. This device, the safest and most versatile form, converts ultrasonic energy produced in the range of 20-27Khz into transverse and longitudinal vibrations that are transmitted to the calculus via contact with the hollow steel probe. This probe is used like a drill with the fragments being sucked into the central core connected to a vacuum pump, to keep in close contact with the probe for maximal transmission of energy and to permit irrigation to clear the operative field and to cool the probe. If large fragments could be removed, a two or three pronged grasping instrument was utilized to extract these stones through the Amplatz sheath. At the termination of the procedure, a combination of nephroscopy and fluoroscopy confirmed a stone free collecting system. If the guidewire was placed down the ureter, a 24F. reentry nephrostomy tube (Van-Tec, Spencer, IN) was inserted and additional tracts drained with a 14 Fr. Malecot nephrostomy (Cook Urological, Spencer, IN) tube. All tubes were secured to the skin with accompanying skin discs and suture ligatures of heavy silk suture material. The nephrostomy tubes were connected to appropriate closed drainage system.

**Follow-Up Studies**

On the second postoperative day, non-contrast nephrotomography was performed to identify any residual stone fragments. Nephrostogram was then performed to determine any collecting system perforations, obstructions, or clot retention. If satisfactory results are obtained, the nephrostomy tubes are clamped that day and removed the following morning provided that the patient does not develop fever, flank pain, or flank leakage around the nephrostomy tube site. The patient is discharged home when the flank is dry.

For those patients identified with residual stone fragment, various options are offered to obtain a stone free kidney. Patients either have residual fragments removed under local anesthesia, begin intrarenal chemolysis\(^{10}\), or are rescheduled for a second stage procedure under general anesthesia. The procedure is considered successful only if the kidney is completely stone free.

All patients have random diet 24 hour urine collection brought back for their first postoperative visit. They are enrolled in our stone clinic to determine the etiology of their stone disease by comprehensive metabolic and nutritional evaluation. Excretory urography was routinely performed at 3-6 months postoperatively and then annually there after.

**Results**

The results of 154 kidneys afflicted with staghorn calculi from 150 patients are as follows; Use of two or more access route was necessary in 110 patients (73%). Seventy six kidneys (49%) required creation of a second nephrostomy tract for access to all parts of the stones and 34 kidneys (22%) required a third tract. Thirty seven patients
(24%) required multistaged nephrolithotripsy for complete stone removal. A total of 110 kidneys (71%) were rendered stone free after one operative procedure (Fig. 1). Seventeen more kidneys were made stone free by chemolysis or panendoscopy. At the time of discharge, 132 of 154 kidneys (86%) were completely stone free (Fig. 1) (Table 1). The procedure was considered successful only if the kidney was stone free at discharge. Results among the first 75 kidneys and the last 79 kidneys remain relatively unchanged, because more difficult cases were accepted during later period.

Of the 22 patients with procedure failure, residual stone fragments were less than 5 mm in diameter. Hospitalization stay averaged 13(range 8-32) days. Yet, the most cost effective saving was that the postoperative convalescence at home only averaged 16 days.

Major complications occurred in 25 (16%) patients (Table 2). The most common complication was bleeding requiring transfusion for hematocrit less than 30%. Only two patients required selective angiography to document the site of active bleeding and then to embolize the segmental vessel. Despite preoperative parenteral antibiotic coverage, approximately 25% of the patients developed positive urine cultures associated with fever greater than 101°F. We believe that these infected stones release bacteria during ultrasonic lithotripsy.

Table 1. Results of Percutaneous Ultrasonic Lithotripsy of Staghorn Calculi in 154 Kidneys

<table>
<thead>
<tr>
<th>No. (%) of procedures (average/ kidney)</th>
<th>201 (1.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average procedure time (min)</td>
<td>165</td>
</tr>
<tr>
<td>No. ( %) stone free after single session</td>
<td>117 (76)</td>
</tr>
<tr>
<td>No. having chemolysis (success/total)</td>
<td>7/8 *</td>
</tr>
<tr>
<td>No. having panendoscopic fragment removal</td>
<td>23</td>
</tr>
<tr>
<td>No. ( %) stone free at discharge</td>
<td>132 (86)</td>
</tr>
<tr>
<td>Average (range) hospital stay (days)</td>
<td>13 (8-32)</td>
</tr>
<tr>
<td>Average post-discharge convalescence (days)</td>
<td>16</td>
</tr>
</tbody>
</table>

1. The patient in whom chemolysis failed was seen early in the series: anatrophic nephrolithotomy was used to remove the stone remnants.

2. For our purpose a staghorn calculus was defined as a branching calculus involving the majority of the renal pelvis and at least two major calices.
Table 2. Complications of Percutaneous Ultrasonic Lithotripsy of Staghorn Calculi in 154 Kidneys in 150 Patients.*

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. patients (%)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAJOR:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>1 (0.7)</td>
<td>Myocardial infarction</td>
</tr>
<tr>
<td>Pneumothorax/hemothorax</td>
<td>11 (7.1)</td>
<td>Resolved with chest tube drainage</td>
</tr>
<tr>
<td>Renal pelvic laceration</td>
<td>5 (3.3)</td>
<td>Nephrostomy drainage &amp; stenting (3)</td>
</tr>
<tr>
<td>Septicemia/shock</td>
<td>3 (2.6)</td>
<td>Responded to parenteral antibiotics</td>
</tr>
<tr>
<td>Stricture (UPJ)</td>
<td>2 (1.3)</td>
<td>Tissue reaction to stone?</td>
</tr>
<tr>
<td>Delayed bleeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
<td>1 (0.7)</td>
<td>Controlled by embolization</td>
</tr>
<tr>
<td>A-V fistula</td>
<td>1 (0.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 (15.6)</td>
<td></td>
</tr>
<tr>
<td>MINOR:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemorrhage (transfusion)</td>
<td>86 (56)</td>
<td>Average transfusion=2 units: bleeding delayed 1–4 weeks in 3</td>
</tr>
<tr>
<td>Fever/infection</td>
<td>38 (25)</td>
<td>Proteus infection, most common</td>
</tr>
<tr>
<td>Pneumonia/atelectasis</td>
<td>15 (10)</td>
<td>Transient pleural effusion in 6</td>
</tr>
<tr>
<td>Urinary extravasation</td>
<td>19 (12)</td>
<td>Stopped with nephrostomy drainage, 1 urinoma drained.</td>
</tr>
<tr>
<td>Paralytic ileus</td>
<td>20 (13)</td>
<td>No special measures</td>
</tr>
<tr>
<td>Stone fragments in retroperitoneum</td>
<td>4 (2.6)</td>
<td>No special measures</td>
</tr>
<tr>
<td>Catheter dislodgement</td>
<td>9 (5.8)</td>
<td>Removal (8), reposition (1)</td>
</tr>
<tr>
<td>TUR syndrome</td>
<td>1 (0.7)</td>
<td></td>
</tr>
</tbody>
</table>

* Forty-six patients had >1 complication.

therapy causing such high infection rates. We are now administering antibiotic coverage for proteus infection, as it comprises the most common pathogen cultured from the struvite stone population. Only four patients developed urosepsis.

A ureteropelvic junction obstruction was observed in two patients on follow up IVU. However, it may have been caused by tissue reaction to the stone rather than by the procedure itself.

One mortality has occurred in this group of first 150 patients. This 67 year old obese female with a history of hypertension and diabetes mellitus suffered a myocardial infarction in the recovery room after a successful percutaneous procedure. Post-mortem examination revealed no evidence of renal or perirenal hematoma. Because of the extent of her obesity, this patient was not suitable candidate for ESWL.

Discussion

Management of urologic patients is being gradually but dramatically altered with new advances in technical innovation and refinements of interventional uroradiology. At present, in most institutions, PCNL has replaced the conventional operations, becoming the primary method of treatment in the absence of ESWL. Although ESWL
has become the treatment of choice for small, uninfected stones, there are numerous situations where its use is less than ideal\(^\text{[11]}\). Since approximately 15% of all renal stones are radiolucent, inability to synchronize the ESWL beams on the stone reduces its use. As with the one mortality illustrated, the size of the patient may preclude utilization. Finally, ESWL has been some what disappointing with regard to its use with staghorn calculi. When used without percutaneous methods, only approximately 73% of kidneys are stone free after treatment\(^\text{[12]}\). Often, ureteroscopic procedures are required to reduce the ‘steinstrasse’. In comparison, our study demonstrates an 86% stone free kidney which is corroborated by similar results by other groups\(^\text{[13,14]}\).

The safety of PCNL was elegantly demonstrated by Webb and Fitzpatrick\(^\text{[15]}\). They showed that neither the percutaneous tract large enough to accommodate a nephroscope nor the vibration of the lithotripter had adverse effects on the dog kidney. Specifically, there was no cortical scarring, no effect on large renal blood vessels, no pelvic or ureteric damage, and no changes in the creatinine clearance. It has also been found in a study by us and Marberger et al that there is no permanent loss of renal parenchymal function along the nephrostomy tract\(^\text{[16,17]}\).

Bleeding tends to be the most serious and frequent of the complications of PCNL. Approximately 56% of our staghorn calculi required blood transfusions for hematocrit less than 30%. This is significantly higher than the ESWL group alone. When delayed bleeding occurred, as in our series (2 patients) one must consider various vascular consequences such as pseudoaneurysms or arteriovenous fistula formation. The number of nephrostomy tracts seems not to be coincise with the formation of vascular complications\(^\text{[18]}\). With the exception of arteriovenous malformations, the bleeding that occurs after percutaneous nephrolithotomy can usually be controlled by nephrostomy tract tamponade with the Amplatz sheath or a balloon catheter.

The second most frequent problem encountered relates to the rate of urinary tract infection following ultrasonic lithotripsy. Since the majority of the staghorn calculi are associated with struvite (magnesium ammonium phophate) composition and urea-splitting bacteria such as Proteous, seeding of the urinary tract during lithotripsy is a problem. Exacerbation of the problem may be higher after ESWL but the only data available is by Kahnoski et al, who described 2 of 8 cases treated in conjunction with percutaneous ultrasonic lithotripsy\(^\text{[19]}\).

Certain problems pertain only to percutaneous techniques. In the case of upper pole caliceal stones, the insertion of nephrostomy tracts above the 12th rib is associated with hydrothorax, pneumothorax, and/or hydrothorax. This requires a thoracotomy tube for a few days postoperatively. This has not been the case with ESWL.

Electrolyte abnormalities from hyperabsorption syndromes can be avoided with the implementation of saline irrigation as compared to glycine\(^\text{[20]}\).

Although PCNL may require several sessions and be a frustrating experience for a less experienced team of radiologists and urologists, it is a more efficient means of removing staghorn calculi than is anatrophic nephrolithotomy\(^\text{[21]}\). The procedure is faster, required less blood transfusions, was better tolerated by patients, and had a faster postoperative convalesce nc. Patients are usually able to return to normal activities within 7 days after hospital discharge. Since many patients will be stricken with recurrent stone formation, the minimizing of the scar eases future percutaneous intervention.

The disadvantages of the higher retained stone fragment rate following PCNL can be managed effectively by meticulous ultrasonic lithotripsy, calyx by calyx, and proper tract planning. Adjunctive
effort between the radiologist and urologist is essen-
tial for the systemic removal of this disease because of the high morbidity from obstruction, especially in the face of infection. Many urologists are finding success with debulking staghorn calculi by percutaneous methods and cleaning up residual pockets of stones with the ESWL unit\(^\text{24}\). Certainly, more investigation will be needed to evaluate this new modality and its application to the removal of staghorn calculi. Our results prove the efficacy of the percutaneous approach to the ablation of staghorn calculi. Coordinated effort between the radiologist and urologist is essential for the systemic removal of this extensive process\(^\text{25}\).

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