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Percutaneous Nephrolithotomy of Caliceal Diverticular Calculi: A Single Center Experience

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Abstract

Background and Purpose: Caliceal diverticula are rare renal anomalies present in approximately 0.6% of the population. They are associated with calculi in 50% of cases. Therapeutic options include several minimally invasive techniques. We report a retrospective review of outcomes and complications from our series of patients who were treated with a percutaneous approach.

Patients and Methods: A database of outcomes related to percutaneous nephrolithotomy (PCNL) has been maintained at our institution since 1992. Data on all patients with caliceal diverticular stones who underwent PCNL during a 17-year period from 1992 to 2009 were reviewed retrospectively. Our preferred approach to PCNL in these patients is to puncture directly into the diverticulum and to try to advance a guidewire through the infundibular neck. In cases where the caliceal neck could not be intubated, we performed a transdiverticular approach with creation of a neoinfundibulum as a salvage procedure. We evaluated the two techniques with regard to stone-free rates and early postoperative complications.

Results: Seventy-six procedures were performed. The mean age was 43 years (range 17–72 y). The mean stone area was 583 mm^2. The surgical approach was direct puncture in 47, transdiverticular in 20, retrograde in 8, and unknown in 1 patient. Eight patients underwent lining fulguration. The average duration of surgery was 75 minutes (23–169 min) with an average hospital stay of 4.7 days. There were a total of 23 complications, of which 11 necessitated additional intervention. The overall stone-free rates were 77% and 89% for direct puncture and transdiverticular approaches, respectively.

Conclusions: The percutaneous management of caliceal diverticular calculi is highly effective and can be accomplished with low morbidity.

Introduction

Caliceal diverticula (CD) were first described by Rayer[1] in 1841 as congenital renal abnormalities and occur in up to 0.6% of the population.[2] CD are believed to originate during the fifth or sixth gestational week, when developmental anomalies of the renal vessels interfere with the degeneration of the fourth order collecting ducts.[3] By definition, these peripherally located cavities are lined with transitional stratified epithelium and have no secretory function.[3] They usually communicate to a caliceal group by a neck of variable width. Urine usually enters the cavity by retrograde passive filling.

In more than two-thirds of patients, CD are asymptomatic.[4] In up to 50% of patients, calculi may form leading to pain, hematuria, or urosepsis, warranting treatment. Multiple treatment options have been described for the management of such calculi. Historically, open surgery with partial nephrectomy, diverticulectomy, or deroofing were used for treatment.[2,5] After the introduction and widespread dissemination of minimally invasive treatment options in the form of ureteroscopy (URS), extracorporeal shockwave lithotripsy (SWL), laparoscopy, and percutaneous nephrolithotomy (PCNL), the open surgical approach now has a lesser role. PCNL has become widely considered to be the treatment of first choice for most patients.[6] Because of the low prevalence of this anomaly, there are a small number of published series that consider outcomes in patients who have been treated with minimally invasive modalities.

PCNL has been the preferred approach at our center. Realizing that establishing secure intrarenal access is the most important step in managing CDs percutaneously, we developed a technique in which guidewire advancement into the collecting system can be facilitated in those cases when cannulation of the diverticular neck cannot be achieved.[7] This technique of transdiverticular access with creation of a neoinfundibulum has proven to be helpful in situations where

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the CD are small, precluding adequate curling of a guidewire to allow tract dilation.

We describe our experience over a 17-year period with PCNL management of calculi within caliceal diverticula. Outcomes for standard PCNL (SPCNL) were also compared with the transdiverticular puncture approach with neoinfundibulotomy (TDPN). The intent of the comparison, however, was not to demonstrate superiority of one technique over the other, but rather to reaffirm that cases in which the standard approach is not feasible can be salvaged by our modified technique.

Patients and Methods

Patients

Between 1992 and 2009, 76 CD stones were managed with PCNL by one of two surgeons (JDD and HR). Perioperative data, including patient demographics, comorbidities, characteristics of the affected renal unit and calculi, as well as intraoperative and postoperative data were prospectively collected. The primary outcome assessed was stone-free rate (SFR) at hospital discharge determined by either plain abdominal radiography of kidneys, ureters, and bladder and renal ultrasonography or by noncontrast CT. Secondary outcomes included complications that were classified according to the Clavien system,[8] operative duration, length of hospital stay, and need for second-look nephroscopy. Statistical analysis was performed with the Student *t* test (parametric data) and Fisher exact test (nonparametric data) using the Graph Pad Prism 4 statistical package (Graph-Pad Software Inc., San Diego, CA). Significance was assessed at $P < 0.05$.

Surgical technique

Preoperative CT was performed in all cases to ensure that the diverticulum was posterior and amenable to direct percutaneous access. Each patient was admitted on the day of surgery and administered intravenous broad-spectrum antibiotics. All patients underwent general anesthesia and then were positioned prone on the operating table. A flexible cystoscope was used to visualize the ipsilateral ureteral orifice and pass a guidewire into the renal pelvis under fluoroscopic guidance. A 5F open-ended ureteral catheter was advanced over the guidewire and subsequently used for radiopaque contrast injection to delineate the anatomy of the intrarenal collecting system.

Our preference is to attempt to gain percutaneous access with advancement of the guidewire through the lumen of the diverticular neck whenever possible. This technique is next described.

SPCNL

Renal access was achieved using either an 18-gauge needle for puncture directly into the diverticulum followed by the introduction of a 0.035-inch hydrophilic guidewire or using a Neff set (Cook Medical, Bloomington, IN), which contains a 22-gauge needle and 0.018F Cope-Mandril wire. Once the diverticulum was entered, attempts to cannulate the neck were made. This maneuver was aided by the use of a steerable, angled catheter (Kumpe catheter, Cook Medical, Bloomington, IN). If the neck could not be identified preventing guidewire advancement into the renal pelvis or the diverticulum was not large enough to allow curling of the entire floppy part of the wire, the transdiverticular neoinfundibulotomy technique was used.

Once the catheter was advanced to the distal ureter, the guidewire was exchanged for an extra-stiff guidewire. The tract was created using either serial Amplatz dilators (1992–1995) or a balloon device (post-1995). This allowed the insertion of a 30F working sheath. Both rigid 26F and flexible 14.5F nephroscopes were used in conjunction with several lithotripsy modalities (ultrasonic, pneumatic, electrohydraulic, or holmium:yttrium-aluminium-garnet laser). Once stone fragmentation was complete, any remaining fragments were removed using a combination of grasping forceps and/or baskets. The diverticular infundibulum was inspected and if found to be stenotic, dilated using serial Amplatz dilators or a ureteral balloon dilating catheter (Cook Medical, Bloomington, IN). A 16F or 18F Councill nephrostomy catheter was placed over the guidewire and through the diverticular infundibula to lie within the renal pelvis.

TDPN

For those cases in which guidewire advancement through the neck of the diverticulum was unsuccessful, TDPN was attempted and is described herein.

This approach has been described previously by our group.[7] Using fluoroscopic guidance, a combination of anterior-posterior and oblique projections are used to direct the Neff set puncture needle through the wall of the diverticulum, out its back wall, and into the renal collecting system (Fig. 1). At the completion of stone fragmentation and extraction, the neck of the diverticulum was dilated with a ureteral balloon device. The nephroscope was then advanced to the renal pelvis to ensure complete stone removal. A 16F or 18F Councill catheter

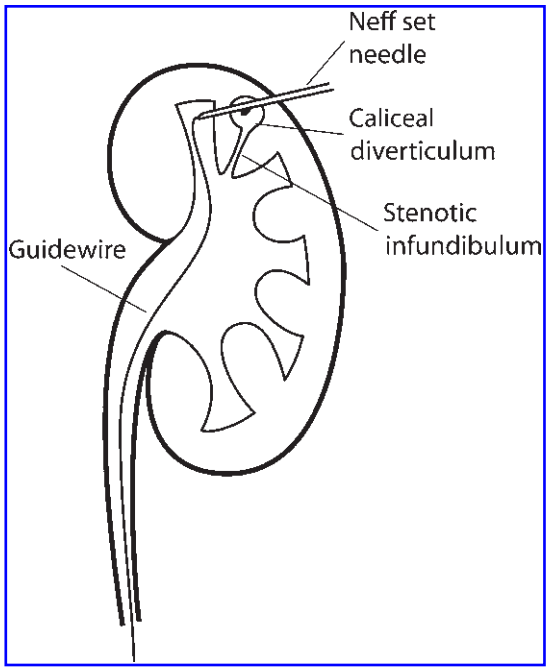

FIG. 1. Neff set needle advanced through wall of caliceal diverticulum into renal collecting system with antegrade passage of guidewire.

was placed over the guidewire and through the neoinfundibulum to lie within the renal pelvis.

For both the SPCNL and TDPN technique, our standard practice was to leave the nephrostomy tube in place for 3 days postoperatively, followed by a trial of clamping for 6 hours and removal in the absence of pain or fever.

Results

Seventy-six procedures were included for analysis. For the purposes of presentation, patients were divided into two groups according to the technique used (TDPN or SPCNL). Demographic data from group A (TDPN) and group B (SPCNL) were not significantly different (Table 1).

The CD were located in the upper calix in 14 (66.6%), midcalix in 5 (25.8%), and lower calix in 2 (9.5%) in group A. In group B, 31 (56%) were in the upper calix, 11 in the midcalix (20%) and 11 in the lower calix. In two patients, the CD location was not noted. Stone surface area is detailed in Table 2.

The mean surgical time was 77 minutes (25–135 min) *vs* 75 minutes (35–169 min) in group A and B, respectively, $P = 0.96$.

In 21 cases, the SPCNL approach was unsuccessful, leading to an attempt to perform the TDPN technique. The TDPN technique was successful in 12 cases. In 9 cases however, neither technique was possible. In two of these patients, salvage treatment was performed with retrograde ureteroscopic access in one and a second attempt at direct puncture and successful cannulation of the neck in another under the same anesthetic. The remaining seven cases necessitated retrograde ureteroscopy at a later date.

In group A, six patients underwent second-look nephroscopy, with residual fragments noted in one. In group B, second-look nephroscopy was performed in 11 patients, with 6 of these patients found to have residual fragments.

There was no statistically significant difference with regard to surgical complications. There were 23 complications, with 7 in group A and 16 in group B. The length of hospital stay was not significantly different between the two groups (5 *vs* 4.6 days, $P = 0.31$).

At the time of discharge, 19 (90%) of those who underwent TDPN *vs* 38 (69%) of SPCNL patients were stone free. Despite a trend in favor of TDPN, this difference did not reach statistical significance ($P = 0.07$). The overall SFR was 78%. Furthermore, if the criterion for stone-free status is set at no stones larger than 5 mm, a SFR of 95% and 85% was achieved in the two groups, respectively.

Table 1. Demographics

	Group A - TDPN (n = 21)	*Group B - SPCNL (n = 55)*
Age, mean (range)	43.4 (17–69)	42.5 (24–72)
Sex (female/male)	14/7	35/20
Side (R/L)	11/10	25/30
BMI, mean (range)	25.5 (17–33)	27.5 (17–41)
ASA, mean (range)	1.6 (1–3)	1.8 (1–3)
Renal anomalies	3	3

TDPN = transdiverticular puncture and neoinfundibulotomy; SPCNL = standard percutaneous nephrolithotomy; BMI = body mass index; ASA = American Society of Anesthesiologists.

Table 2. Stone Characteristics

	Group A - TDPN	*Group B - SPCNL*	P *value*
Stone location			
UC	66.7%	56.3%	0.44
MC	28%	20%	0.75
LC	9.5%	20%	0.49
Multiple	14%	10%	1.0
Unknown	0	3.6%	
Stone surface area			
$\leq 500\,mm^2$	18	42	
501 to $1000\,mm^2$	1	11	0.16
Unknown	2	2	
Stone-free rate (%)	90	69	0.07

UC = upper calyx; MC = midcalix; LC = lower calyx.

Discussion

The pathogenesis of calculi within CD remains controversial and appears to be multifactorial. The most common hypotheses include urinary stasis and metabolic derangements. The first theory is supported by the work of Finlayson and associates.[9] In support of the metabolic theory is the finding that metabolic anomalies are commonly recognized in the CD population.[10] In support of both theories is the study by Matlaga and colleagues,[11] which compared the parameters of urine collected directly from the CD with urine collected from the ipsilateral and contralateral urinary tracts and random voided 24-hour urines from calcium oxalate stone formers. This study demonstrated that the metabolic parameters were similar, especially with regard to the degree of hypercalciuria, although the aspirated urine from the CD showed a lower supersaturation of calcium oxalate, suggesting urine stasis may play a role. Needless to say, the exact mechanisms of stone development in diverticula are unknown.

Because stone-bearing diverticula often become symptomatic and have considerable potential to cause morbidity, active management is indicated in many patients. Open surgical treatment has been largely replaced by a number of less invasive surgical and nonsurgical modalities. Not all treatment choices appear to have equal success.

SWL is an attractive minimally invasive option; however, results are inferior to other options. In one series, SWL was associated with a SFR of only 58%[12] and a 16% complication rate. Thirty-one percent of patients needed salvage with either URS or PCNL in another report.[13] In contrast, laparoscopic techniques have been described with excellent SFR, which come at the expense of increased invasiveness. The role of laparoscopy appears to be mainly in the management of stones within anteriorly located or thin-walled CD. The approach can be limited by the presence of perirenal adhesions.[14,15]

Currently, the gold standard for the management of CD is PCNL.[16] Most series report SFRs above 78% percent,[2,17–20] which compare favorably with the overall SFR of 78% demonstrated in our series.

Our series would suggest that PCNL of CD stones can be accomplished with acceptable morbidity. Only 9% of patients experienced a major complication (Clavien IIIA). No

patient needed reintervention under general anesthetic (Clavien IIIb). There were no admissions to intensive care or deaths in our series (Clavien IV/V). These figures compare favorably with previously published series.[20,21] In our cohort, the most common complications encountered were pulmonary (7 cases in group A and 14 in group B). In group A, the pulmonary complications comprised four pleural effusions, one pneumothorax, and one case each of atelectasis and pneumonia. In group B, there were 10 pleural effusions, 4 pneumothoraces, and no cases of atelectasis or pneumonia. These figures are a reflection of the fact that most CD were located in the upper calix necessitating supracostal access, rather than a technical issue with the type of approach. The theoretically increased risk of interlobar artery injury with the TDPN technique was not seen in our cohort of patients. The only patient with a hemorrhagic complication was in the SPCNL group. The remaining complication in group B was postoperative pyrexia that needed antibiotic therapy only. The rate of complications highlights the challenging nature of the procedure.

Even after successful puncture of CD, the urologist often has to deal with several pitfalls, such as limited working space, thin overlying parenchyma, stenotic infundibula, acute angulation between the puncture site and the ostium, and a lack of communication with the main urinary tract. This may hinder access to the renal pelvis or preclude incision or dilation of the diverticular infundibula.

To overcome these problems, our group developed the TDPN approach. The main advantage to this technique is the creation of a neoinfundibulum, which allows access to the main collecting system. Other authors have described alternative techniques, such as a single-stage approach, in which a puncture is made directly into CD, using the calculi as target without the use of retrograde contrast. The guidewire is coiled in the cavity without any attempt to communicate the CD with the urinary system.[22] The main drawback of this technique is that slippage or loss of the guidewire can occur with a resultant loss of access. The single-stage approach has the added disadvantage of precluding second-look nephroscopy, because access to the collecting system is not achieved.

Our data show that both techniques have a high overall SFR that exceeds that seen with SWL or URS.[16] When comparing the results of our TDPN technique against previously reported cohorts, we have demonstrated a very favorable SFR of 90% when compared with 80% described by Auge and coworkers.[18] If a direct comparison is made with the one-step technique, reported SFRs are comparable (94.2%).[20] We propose, however, that the added benefit of having access to the main collecting system and a guidewire in the bladder makes TDPN a superior technique. The SFR seen in association with the TDPN technique was higher than that of the SPCNL, although this did not reach statistical significance and should be interpreted with caution given that the SPCNL group had a higher number of patients with a stone surface area of more than 500 mm^2 (Table 2).

Finally, we must acknowledge the limitations of our study, including the retrospective reporting and absence of long-term follow-up. Randomized controlled trials in this group of patients will continue to be logistically difficult because of the scarcity of such cases. The data were acquired in a systematic, prospective fashion and to our knowledge, this represents one of the largest cohorts reported. This report spans a 17-year period in which technical advances and surgeon experience may have introduced bias; however, at our center the standard technique for PCNL has not significantly varied during this time.

Large studies of patients with CD will probably necessitate long-term and pooled multicenter cohorts. The report of these cases and the creation of a CD study group or registry should be entertained to provide additional data on the outcomes of the surgical treatment of these patients.

Conclusions

The use of PCNL, either in the standard form or with the TDPN salvage approach for the management of CD harboring calculi, offers comparably high SFRs with an acceptable major complication rate of 9%. The use of TDPN is an alternative option that should be considered in cases where the infundibulum cannot be traversed.

Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

CD = caliceal diverticula
CT = computed tomography
PCNL = percutaneous nephrolithotomy
SFR = stone-free rate
SPCNL = standard percutaneous nephrolithotomy
SWL = shockwave lithotripsy
TDPN = transdiverticular puncture and neoinfundibulotomy
URS = ureteroscopy