Advances in Percutaneous Nephrolithotomy.

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***Abstract**: Percutaneous Nephrolitomy(PCNL) is the procedure of choice for large renal stones. Since its introduction in 1976, many aspects of operative technique and the endoscopic equipments have had constant evolution, increasing the success rate of the procedure. Balloon-tract dilation is preferred. An endoscopic-guided approach to puncture appears to be highly accurate and easily accomplished. Mini-percutaneous PCNL still needs equipments necessary for better results. Tubeless PCNL is increasing in popularity and different tract sealants have been used. Although the evolution of the technique in the last 20 years, urologists must continue to improve their skills and develop new technologies to offer to the patients more and more a safe and effective option to treat large renal stones.*

INTRODUCTION

A percutaneous approach to the kidney was first described in 1955 by Goodwin and colleagues[1]. This approach, with the insertion of a nephrostomy tube, was used to provide drainage for an obstructed renal unit. This example led to the recognition that the same access could also be used as a working channel, resulting in the percutaneous removal of a kidney stone, as first reported by Fernstro¨m and Johansson[2] in 1976. Shortly thereafter, dilation of the percutaneous tract became routine, and soon practitioners performed rigid and flexible nephroscopy and intrarenal manipulation and fragmentation of calculi. Thus began the era of percutaneous renal surgery, as familiar to all urologists.

Over the past 30 years, percutaneous nephrostolithotomy (PCNL) has largely replaced open renal surgery for the management of large uppertract calculi.

Multiple factors are involved in the decision whether to treat renal calculi with extracorporeal shock wave lithotripsy (SWL), ureteroscopy, or PCNL. The factors are the size, number, and composition of the stones, as defined by Hounsfield units (HU); the location of the stones; and the presence or absence of hydronephrosis, calyceal diverticulum, ureteropelvic junction obstruction with calculus, and renal anomalies (eg, horseshoe or pelvic kidney).

STONE SIZE

Stone-free rates after extracorporeal SWL decrease markedly based on stone size. Lingeman and colleagues[3] in 1987 showed that for stones less than or equal to10 mm, the stone-free rate is 77% and this decreases to a mere 29% for stones greater than 30 mm. As a corollary to the latter, the auxiliary procedure rate increases from 12% to 46%. Clearly, the larger the stone, the more efficient percutaneous removal becomes. In the early 1990s, sandwich therapy became an attractive option for these large calculi that were typically treated percutaneously followed by lithotripsy and a second percutaneous procedure to clear any significant residual fragments following lithotripsy[4,5]. However, a more recent study by Denstedt and colleagues[6] showed that primary PCNL resulted in better stone-free rates than sandwich therapy (84% versus 63%) with shorter hospital stay (6 days versus 12.2 days) and decreased need for blood transfusion (1.6% versus 14%) when compared with the sandwich approach advocated by Streem and colleagues[5]. Accordingly, many centers have abandoned the sandwich approach in favor of primary percutaneous treatment because primary percutaneous treatment seems to promise higher stone-free rates and fewer complications.

Regarding complete staghorn calculi, a meta-analysis by the Guidelines Committee of the American Urologic Association has led to the recommendation that these complex cases be approached percutaneously to achieve an average stone-free rate of 65%, compared with 62%, 36%, and 42% for open surgery, sandwich therapy, and lithotripsy alone, respectively [7].

STONE COMPOSITION

CT is now routinely used to diagnose renal lithiasis and to plan treatment. The CT stone density has been found to correlate with clearance rates following lithotripsy. In general, stones less than 500 HU can be expected to have clearance rates of 80% to 100%. This decreases to 70% to 72% for stones measuring 500 to 1000 HU, 26% for stones greater than 1000 HU, and 0% for stones measuring greater than 1200 HU[8]. Armed with this knowledge, a prudent practitioner should use stone size and CT stone density as a guide in recommending to patients either primary ureteroscopic or percutaneous treatment in favor of SWL.

COLLECTING-SYSTEM ANATOMY

Determining the best treatment for the lowerpole stone continues to be an especially difficult challenge. Many calyceal and renal pelvic parameters correlate with the ability of lithotripsy to clear lower-pole calculi and thus may be used as a guide to select the best treatment modality. These include calyceal pelvic height, infundibular length, infundibular width, and lower-pole infudibulopelvic angle, and may be used to determine whether PCNL is the ideal approach or whether ureteroscopy or SWL are suitable first-line management alternatives. Typically, intravenous pyelogram (IVP) determines these parameters[9]. However, with the use of noncontrast axial CT, these parameters are less often determined, but three-dimensional reconstruction may allow these calculations to be made even more precisely. To date, no articles have compared IVP-based findings with CT-based findings with regard to these various parameters.

Poulakis and colleagues[10], using an artificial neural network based on results in 701 patients, determined that an infundibular width of 5 mm or more, an infundibulopelvic angle of greater than 45%, a normal body mass index, and normal urine transport (absence of hydronephrosis) were the only factors that predicted stone clearance following extracorporeal lithotripsy. This group did not find that stone size or chemical composition of the stone were significant factors affecting the stone-free rate; Hounsfield units were not considered in this analysis. An equal number of groups have confirmed or refuted these findings [9-14]. In those studies showing

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that calyceal anatomy did not affect clearance rates, low patient numbers and multiple different lithotriptors, along with concomitant inversion therapy, may have contributed to the lack of correlation[13-14]. Therefore, for lower-pole stones with unfavorable calyceal anatomy, and measured Hounsfield units greater than 500, the authors believe the best approach is either ureteroscopic (stones up to 10–15 mm) or percutaneous (stone >15 mm).

HYDRONEPHROSIS

Another key consideration in the evaluation and selection of the treatment ideally suited to a given patient and stone is the presence or absence of hydronephrosis. Winfield and colleagues[15] in 1988 found that in normal undilated systems the stone-free rate following extracorporeal lithotripsy was 70% with an auxiliary procedure rate of 12%. By contrast, in hydronephrotic systems, the stone-free rate was only 53% with an auxiliary procedure rate of 27%. These findings are also supported by the artificial neural network of Poulakis and colleagues[10].

SPECIAL CIRCUMSTANCES

Unique circumstances mandating modifications to the standard approach include stones in pediatric kidneys, the transplanted kidney, stones within calyceal diverticula, horseshoe kidneys, and other malrotated or malpositioned kidneys.

DIVERTICULAR CALCULI

Caliceal diverticula are congenital, nonsecretory, urothelium - lined cavities with in the renal parenchyma that communicate with the caliceal fornix through a diverticular neck. Management of diverticular calculi involves stone removal and treatment of diverticular cavity.This can be achieved with PCNL and diverticulum fulgration with 85.7% of stone free rate and 87.5% of diverticulum obliterated. Fulgration of the diverticular lining is performed with 24-Fr resectoscope with a rollerball electrode. Diverticulum treatment can also be achieved by creating a large communication to the collecting system to promote drainage and prevent urinary stasis. This procedure requires placement of nephrostomy tube for longer period 48-72 hrs.

ENDOSCOPIC ENERGY SOURCE

The most common percutaneous endoscopic lithotripsy energy sources in use today are the holmium yttrium, aluminum, and garnet (holmium: YAG) laser; the ultrasonic lithotriptor; the pneumatic lithotriptor; and a combination ultrasonic– pneumatic device. Electrohydraulic lithotripsy is not commonly employed in present-day practice because the previously mentioned devices are safer and perceived to be more efficient. The holmium:YAG laser is the only commonly used intracorporeal energy device that can be combined with either the flexible nephroscope or flexible ureteroscope. Attempts so far at making flexible ultrasound or pneumatic probes have not been wholly successful because the resulting probes have been much stiffer than the laser fiber and too stiff to be practical. Devices combining ultrasound and pneumatic lithotripsy are most efficient for stone fragmentation. The holmium:YAG laser is generally less efficient than the combined device described above.

ACCESS & PUNCTURE TECHNIQUES

These are addressed elsewhere in this issue.

IS SINGLE TRACT ENOUGH?

Intuitively, fewer the punctures of the renal parenchyma necessary, the better the overall renal functional outcome should be. Pertinent questions remain: Can one achieve an equivalent stone-free rate with a single access and do multiple accesses increase the complication rate?

Kukreja and colleagues[17] in 2004 analyzed the factors affecting blood loss during PCNL. They found that in 301 procedures in 236 patients analyzed prospectively, the factors associated with significant blood loss were diabetes, multipletracts, prolonged operative times, and the occurrence of intraoperative complications. Higher blood loss was associated with telescoping metal dilators versus Amplatz or balloon dilation. Wong and Leveillee[18] in 2002 reported on the use of a single upper-pole access to treat large complex staghorn calculi. They treated 45 complete and 7 partial staghorn calculi and required a mean of 1.6 procedures to render patients stone free with 18 of 35 (51%) upper-pole accesses and 4 of 10 (40%) middle and lower-pole accesses after a single procedure. The estimated mean blood loss was 238 mL and only 1 patient needed a blood transfusion. In keeping with the single-access theme, Davol and colleagues[19] also treated 43 patients all with a single tract (calyx punctured was not specified) and obtained an immediate stone-free rate of 85%. However, this study was retrospective and the mean stone size was 2.1 cm as compared with 6.7 cm in the Wong study. Also, stone free status was determined by KUB in 82% as opposed to the more sensitive thin slice CT scan[19]. In a concerted effort to reduce the number of accesses required, Marguet and Preminger and colleagues[20] recommended the simultaneous use of retrograde flexible ureteroscopy to clear stones in calyces that would be otherwise inaccessible via a single percutaneous access. These stones were either treated with the holmium:YAG laser and fragmented or were repositioned so that they could be extracted percutaneously. Of seven patients reported, all but two were stone free, having asymptomatic residual fragments less than 3 mm. The blood loss in this group was 79 mL versus 345 mL when multiple nephrostomy tracts were used. This combined percutaneous and ureteroscopic approach using an access sheath was described by Landman and colleagues[16] in 2003. They treated nine patients, six with staghorns and three with partial staghorn calculi. The mean operative time was 3.1 hours and the mean estimated blood loss was 290 mL. No major complications occurred, but there were four (44%) minor complications. Seven patients achieved a stone-free status. Meanwhile, some groups perform multiple accesses to clear stones in calyces that would be difficult to enter via a single tract. To this end, Aron and colleagues[21]in 2005 published their experience with 121 renal units undergoing PCNL for a mean stone size of 4800 mm^2. This patient group required a total of 397 tracts, with 121 in the upper calyx, 178 in the middle calyx, and 98 in the lower calyx. The stone-free rate was 85% and increased to 94% with extracorporeal lithotripsy in 8 kidneys with residual fragmentsLiatsikos and Smith and colleagues[22] in 2005 reported the technique of "angular percutaneous renal access" employed at the Long Jewish Hospital, New York. In this technique, the needle is advanced to the desired calyx through the original skin incision. Then the guide wire is advanced into the collecting system. Dilation is then performed, followed by nephroscopy and stone removal. The mean blood loss in these patients was 450 mL with a transfusion rate of 45%. The stone-free rate was 87%. Again, it is evident that the more renal parenchymal punctures there are, especially transverse parenchymal punctures, the higher the likelihood of significant bleeding necessitating transfusion.

TUBELESS PCNL VS SMALL LUMEN TUBES

Selection of the appropriate drainage most suitable for a given patient undergoing PCNL can be challenging. Many factors, including presence of gross residual stone, anticipated likelihood of bleeding, difficulty of access, advantages and disadvantages of site selected for access, and patient factors can guide the decision.

With the advent of the newer hemostatic agents, several groups are advocating their use for sealing the nephrostomy tract and thusomitting the need to place a nephrostomy tube for hemostatic reasons.

To this end, Mikhail and Bellman and colleagues[23] in 2003 first described the clinical use of fibrin glue to seal the nephrostomy tract following PCNL. They injected 2 to 3 mL of fibrin glue into each of 20 nephrostomy tracts, just after the sheath had been removed from the collecting system, to avoid inadvertent injection into the collecting system. This group of patients was compared with 23 consecutive patients undergoing PCNL without fibrin glue (tubeless). Although the total analgesic requirement tended to be less in the fibrin-glue patients, it did not reach statistical significance; the hematocrit decrease was also not significantly different.

Shah and colleagues[24] in 2006 reported a statistically significant (P ¼ .05) decrease in the mean analgesic requirement for 17 consecutive patients undergoing tubeless PCNL with fibrin-glue injection, via a similar technique to that of Mikhail and Bellman, when compared retrospectively to a control group of 25 consecutive patients undergoing tubeless PCNL without fibrin glue.

THE MINI-PERC

Jackman and colleagues[25] in 1997 first described the so-called "mini-perc'' technique. This approach was applied to the pediatric population, with body weight ranging from 5 to 24 kg, using an 11–F-catheter peel-away vascular access sheath. Seven patients were treated and the stone-free rate at 12 weeks was 85%. There were no procedure-related complications. Jackman and colleagues[26] subsequently employed this technique, albeit with a 13–F catheter ureteral access sheath, in the adult population. They treated nine patients aged 40 to 73 years with stone burdens greater than or equal to 2 cm. The mean operating room time was 176 minutes, mean hospital stay 1.7 days, and the stone-free rate was 89%.

Feng and colleagues[27] in 2001 conducted a prospective randomized trial of standard PCNL, mini-PCNL and tubeless PCNL. They found no advantage to mini-PCNL versus standard PCNL. Indeed, the mini-PCNL was disadvantageous with regard to visibility and optics during the percutaneous procedure. This group's version of the mini-PCNL involved dilation of the tract to 22 F catheter to facilitate placement of a 26–F-catheter sheath. Thus, the size of the access tract was much larger than in the Jackman series and this may have accounted for the increased analgesic requirement (24 mg versus 14 mg). Also, despite a larger stone burden of 4.9 cm versus 1.5 cm in the Jackman series, there was a significantly shorter mean procedure time in the Feng series, again likely related to the tract and instrument sizes (130 versus 176 minutes).

Sung and colleagues[28] in 2006 conducted a retrospective review of 72 consecutive patients who underwent a mini-perc using a 14–F-catheter peel-away sheath similar to that used in the initial description of the technique by Jackman and colleagues. The cumulative stone burden ranged from 0.24 to 39.5 cm. Although no total operative time was reported, the stone-free rates for stones less than 6 cm was 95.7% (n ¼ 47) and, for those greater than 6 cm, it dropped to 52% (n ¼ 25). They also noted that if the longest stone measurement was less than 2.5 cm, the stone-freerate was 97.8% versus 51.9% if the longest length was greater than 2.5 cm.

Overall, the mini-perc, except in children, appears to be of little value. It does not necessarily result in a shorter hospital stay or in a quicker operation. While the mini-perc may cause less discomfort in some series, the same reduction in discomfort can be achieved today through the use of a large percutaneous tract, which facilitates the procedure, and then, through the use of a hemostatic agent, no tube needs to be left. Thus, the only potential advantage of a mini-perc approach is to create less renal damage; however, this is such a minimal difference that it is clinically insignificant.

MODES OF FASCIAL DILATION

Many products are available for dilation of the nephrostomy tract. These range from mechanical dilators (eg, Amplatz and Alken dilators), to the more widely used balloon fascial dilators. It has been shown that there is potentially less renal parenchymal damage and less blood loss with balloon dilation as compared with the shear injury caused by sequential mechanical dilation[29,30]. Indeed, in one study, the transfusion rate among 50 balloon-dilated patients was only 10% versus 50% in 100 patients undergoing PCNL with the use of Amplatz dilators[31].

Important considerations in the selection of the balloon are its length, diameter, and pressure rating. When treating stones in patients who have undergone prior open or percutaneous stone removal, selection of a balloon with a higher pressure rating is suggested and the authors recommend using a fascial incising needle in these cases as it provides a 4.5-mm–diameter fascial opening that may facilitate subsequent inflation of the balloon.

ULTRASONOGRAPHY – GUIDED PCNL

PCNL mainly relies on fluoroscopy, exposing both the patient and the surgical team to radiation. Although surgeons use protective gowns during fluoroscopy – guided PCNL, this protection is nowhere near complete. Radiation exposure in the absence of complete protection can affect the surgical team long term, and it is not dose dependent.

Karami and associates[35] reported PCNL under US guidance in 40 patients in the lateral position with an access rate of 100% and complete stone removal rate of 85%. In this study, PCNL in patients in the lateral position under US guidance was introduced as a safe and convenient procedure.

OUTCOME OF PERCUTANEOUS PROCEDURE

The method of determining stone-free status is important in assessing the true outcome of the percutaneous procedure. Numerous investigators have described various approaches. The simplest methods involve plain abdominal radiograph with or without tomograms if the original stone was radio-opaque.

Denstedt and colleagues[32] in 1991 compared the sensitivity of plain abdominal radiograph alone versus plain abdominal radiograph and tomograms with flexible endoscopy, the latter being the gold standard. They found that plain abdominal radiograph was largely unreliable and that even when combined with tomograms the false-negative rate was 17%. Today, the gold standard for imaging is no longer tomograms but instead the noncontrast CT scan with 1- to 2-mm axial sections. Pearle and colleagues[33] in 1999 compared plain abdominal radiograph, noncontrast CT, and flexible nephroscopy for detection of clinically significant residual stone fragments. CT was 100% sensitive and 62% specific compared with plain abdominal radiograph, which had a sensitivity of only 46% and specificity of 82%. Portis and colleagues[34] recently reported that high-magnification rotational fluoroscopy combined with aggressive flexible nephroscopy can identify residual fragments, which can then be removed at the same time. As a result of the previous studies, the authors recommend meticulous, thorough flexible endoscopy before concluding a percutaneous procedure; this is combined with fluoroscopic images that are compared with the initial fluoroscopic scout image taken at the outset of the procedure. Because the authors employ a dual endoscopic approachd both antegrade nephroscopic and retrogradeureteroscopicdcalyces inaccessible through the percutaneous tract can be accessed ureteroscopically If the patient appears to be stone free both endoscopically and ureteroscopically, then a tubeless technique is used. On postoperative day 1, all patients have a noncontrast CT to further assess for any residual fragments and plan further treatment if necessary. If the followup CT scan shows no or only a few small microliths (3 mm), then the stent is pulled in a week in the office. If the follow-up CT on postoperative day 1 shows any fragments larger than 3 mm, then the next step is outpatient flexible ureteroscopy and holmium: YAG laser lithotripsy. Such outpatient procedures are very much facilitated by the indwelling stent, which dilates the ureter so that placement of an access sheath is easier, thereby facilitating the procedure.

FUTURE DIRECTIONS

The age of imaging is rapidly giving way to the age of robotics in surgery. The day is fast approaching when all percutaneous access and conceivably all ureteroscopic access will be gained via a robotic interface, thus limiting the technical expertise required to obtain accurate puncture and controlled destruction of renal and ureteric calculi. A console capable of operating a variety of endoscopic and lithotripsy equipment within the patient will likely soon arrive, so that the stone surgeon, like the prostate cancer surgeon, will be able to sit comfortably while remotely performing even the most complex percutaneous procedures.

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LITERATURE REVIEW

Different clinical outcomes for cardiovascular events and mortality in chronic kidney disease according to underlying renal disease: the Gonryo study

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Chronic kidney disease (CKD) can result from a wide variety of diseases, but whether clinical outcomes differ in the same CKD stages according to the underlying renal disease remains unclear. Clarification of this issue is important for stratifying risk of cardiovascular disease (CVD) and death in patients before dialysis. The study comprised 2,692 patients recruited from 11 outpatient nephrology clinics, classified by underlying disease of primary renal disease (PRD) (n = 1,306), hypertensive nephropathy (HN) (n = 458), diabetic nephropathy (DN) (n = 283), or other nephropathies (ON) (n = 645). Risks of events such as ischemic heart disease, congestive heart failure, stroke, and all-cause mortality within 12 months were examined by logistic regression analysis in each group. During the 12-months' observation from recruitment, 200 cases were lost to follow-up, and 113 cases were introduced to chronic dialysis therapy. A total of 69 CVD events occurred (stroke in 27 cases), and 24 patients died. In total, increased odds ratios (OR) for the events by CKD stage (cf. CKD1 + 2: unadjusted) were CKD3, 1.29 [95% confidence interval (CI), 0.70–2.17]; CKD4, 2.73 (1.55–4.83); and CKD5, 4.66 (2.63–8.23). Regarding events in respective groups, no significant differences were seen by CKD stage except for the group with HN, but significant differences were seen by underlying diseases (cf. PRD: adjusted for confounding factors, including estimated glomerular filtration rate): HN, 2.57 (1.09–6.04); DN, 12.21 (3.90–38.20); and ON, 4.14 (1.93–8.89). ***Conclusion:*** *Risk of CVD and mortality due to CKD needs to be stratified according to the underlying renal diseases.*