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Stones and Endourology

Review

New developments in percutaneous stone surgery



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Abstract

Percutaneous stone surgery is the gold standard in removing large renal calculi. In light of the increase in prevalence and size of renal stones being addressed in recent years, numerous advances have been made in attempts of improving the morbidity, efficacy, and technical ease of stone clearance. In this review article, we assess new advancements in percutaneous stone surgery including diagnosis and surgical planning, methods of renal access, patient positioning, tract dilation, nephroscopes, lithotripsy, and post-operative drainage and antibiotic prophylaxis.

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Introduction

Nephrolithiasis is an increasingly common condition that is the global cause of a significant amount of morbidity. Burgeoning rates of conditions such as hypertension, obesity, and diabetes mellitus have contributed to the rise in incidence of new stones. Within the past two decades, for instance, the prevalence of diabetes has increased two fold; along with it, the frequency of stone-related

Emergency Department visits has also risen from 178 in 100,000 visits to 340 in 100,000, nearly doubling in number [1,2]. Over time, an increase in the absolute size of stones diagnosed has increased as well.

In addition to medical comorbidities and genetic factors, environmental factors have been suggested to affect rates of nephrolithiasis as well. It has been demonstrated that the development and composition of stones within the in Chinese-American community differs from those of the Chinese. Chi et al. [3] has found that Chinese-Americans are more likely to have higher body mass indices (BMIs) and develop stones an average of 9 years earlier than individuals in China.

Percutaneous nephrolithotomy (PCNL) became a standard technique to address complex, large renal stones during the last two

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decades of the twentieth century [4]. Given its decreased morbidity, lower cost, and shorter duration of hospitalization compared to open nephrolithotomy, PCNL has rendered open stone extraction obsolete [5]. In an era when the demographics of the general populace are leading to the production of larger stones in unhealthier patients, PCNL is more relevant than ever.

We aim to review the PCNL literature and evaluate the most recent advances in techniques in percutaneous stone surgery.

Diagnosis

Among imaging studies used to diagnose nephrolithiasis including ultrasound (US) and plain X-ray films, computerized tomography (CT) has been accepted as the standard for pre-operative stone evaluation. CT is highly sensitive for diagnosing nephrolithiasis, easy to quickly obtain, and cost-effective [6]. In patients with a significant stone burden, CT assists in categorizing stone size, density, and location within the collecting system. CT is also extremely helpful in determining the approach for access into the kidney. If a concern over radiation exposure exists, a low-dose CT can be considered. US can reasonably diagnose renal stones as well, although with a sensitivity and specificity lower than that of CT [7].

Most recently efforts have been made to risk stratify patients with nephrolithiasis based on pre-operative imaging. One example is the S.T.O.N.E nephrolithotomy scoring system that measures five characteristics reflecting stone complexity on CT: stone size (S), tract length (T), obstruction (O), number of calyces involved (N), and “essence” or stone density (E). In an initial study at a single institution examining 117 patients, it was noted that the S.T.O.N.E score can be used to estimate operative time, estimated blood loss (EBL), stone-free rates, and length of stay (LOS) [8]. In a follow-up study, the original authors validate the use of the S.T.O.N.E score in a multi-institutional trial that confirms their initial findings: the higher a patient’s score, the lower a patient’s stone-free rate, the longer the bleeding time and greater the EBL, the longer the operative time, LOS, fluoroscopy use, and the higher the rate of post-operative complications [9]. Other examples of stone scoring systems include the Guy’s stone score and the Clinical Research office of the Endourological Society (CROES) nomogram. In comparing these three scoring systems, Labadie et al. [10] found that despite their differences, they all were able to predict stone-free status of patients.

All of these scoring systems enhance the ability of the surgeon to effectively plan for a percutaneous stone procedure and effectively counsel patients. Each system has its advantages, and we recommend use of one in an effort to streamline risk stratification among patients and assist surgeons in standardizing the dialog of the severity of a patient’s condition across institutions.

Preoperative planning

The proliferation of long-term anticoagulation and antiplatelet therapy has followed the increased use of drug-eluting cardiac stents, mechanical heart valves, and therapy for atrial fibrillation [11,12]. Resultantly, the pool of patients requiring PCNL who require these types of medications has increased as well. The length of time a patient may be safely off anticoagulation peri-operatively as well as how to address stones in those patients in whom anticoagulation may

not be suspended has not been clearly established. Patients who are too high risk to discontinue anticoagulation for any period of time may benefit from staged ureteroscopic procedures in lieu of PCNL. In high risk cardiac patients, cessation of aspirin may adversely affect cardiac outcomes due the consequential rebound effect. The literature, however, suggests that aspirin can be safely continued peri-operatively in PCNLs without any significant increased risk of bleeding [13,14].

Currently, it is recommended that patients on anticoagulation undergoing procedures that carry a high risk of bleeding, like PCNL, suspend warfarin use 3–5 days before that date of the planned procedure. One study has recommended specifically in PCNL that warfarin be discontinued 5 days before surgery and not resumed until 5 days post-operatively. In addition, low molecular weight heparin may be used to bridge patients during the period of withholding oral antiplatelet agents. These actions carry a risk of major bleeding of 7%, an acceptable value [15].

In addition to post-operative hemorrhage, sepsis from a urinary tract source is a morbid complication of PCNL that can lead to death. Deliberate steps should be taken during pre-operative evaluation by obtaining a urinalysis and urine culture (Ucx) to minimize the risk of developing this condition. Gutierrez et al. [16] assessed 5354 patients who underwent PCNL who had pre-operative urine cultures available. Findings suggested that 865 (16.2%) of study participants exhibited a positive urine culture, and of those patients with a positive culture, 18.2% developed fevers post-procedure compared to 8.8% of patients with a negative pre-operative culture. Moreover, in patients with infections caused by *Enterobacter* species, 23.8% developed a fever, as compared to only 9.7% of those with *Staphylococcus* species infections, suggesting different levels of virulence among bacterial species. When patients display a contaminated urine culture, pre-operative preparation becomes more nebulous. Leavitt et al. [17] has shown that in 291 patients with a negative urinalysis or urine dipstick analysis, none developed post-operative sepsis after PCNL. These findings infer that negative results of these tests may be sufficient in surgical planning; however, we support recommendations that a urine culture prior to PCNL is optimal to minimize the risk of sepsis.

The best predictors of post-PCNL sepsis have been stone cultures or cultures from the renal pelvis [18]. Despite negative urine cultures, stones may harbor bacteria, and even in the absence of active infections, stone fragmentation releases pre-formed bacterial endotoxins that increase the risk of sepsis [19]. Larson et al. [20] has compared stone cultures (Scx) and Ucx in patients undergoing PCNL and has found that Scx and Ucx correlate in 79% of cases. In patients with negative Ucx, Scx was positive in 12.5% of cases. Resultantly, they recommend routinely obtaining Scx to assist in appropriately tailoring antibiotics if a patient were to develop sepsis.

The duration of antibiotic therapy in patients undergoing PCNL preoperatively is also debatable. Studies have previously indicated that high risk patients may benefit from seven days of pre-operative antibiotic therapy even in the setting of a negative urine culture to reduce the risk of sepsis. Administering two versus seven days of pre-operative antibiotic prophylaxis in this cohort of patients was recently assessed [21]. Results displayed that the course of antibiotic therapy in the setting of a negative urine culture had no effect on fevers $>38.5^{\circ}\text{C}$, systemic inflammatory response syndrome (SIRS) symptoms, or rates of post-procedure sepsis. Either

two or seven days of antibiotic prophylaxis is effective in treating high risk patients pre-PCNL with negative urine cultures.

Access

Renal access during PCNL can be achieved prior to the procedure with the placement of a nephrostomy tube by interventional radiology (IR), or by the urologist at the time of definitive stone management. The decision to obtain access via either route is based on both physician preference and experience; surgeons who perform less PCNLs may opt for pre-operative IR access, whereas endourologists would be more comfortable gaining access themselves. Differences in IR access and access obtained at the time of PCNL have been studied to elucidate any variations in outcomes and stone-free rates between each method [22]. It has been noted that urologists are much more likely to achieve access in the 10th or 11th intercostal spaces than interventional radiologists (47% vs. 14%, $p < 0.01$). Patients who underwent pre-procedure access with interventional radiology were significantly more likely to necessitate secondary procedures to become stone-free (38 vs. 21%, $p < 0.01$). No difference was observed in the complication rate between each group, including failed access, transfusion, or a clinically significant pneumothorax or hemothorax requiring intervention. In summary, access may be safely obtained by either interventional radiologists or urologists. The data supports the conclusion that when a urologist gains access at the time of PCNL, he/she is more likely to only perform one procedure before the patient is deemed stone-free. We can attribute this success in part due to the strategic access points an endourologist pursues to best remove the entire stone burden instead of simply gaining entry into the collecting system for drainage.

In an effort to curb the length of fluoroscopy time and radiation exposure associated with gaining access for PCNL, the tradition “bull’s eye” technique has been reimagined using adjunctive tools to make the process safer and more efficient. The IPAD-assisted puncture has been described [23,24], which employs a marker-based tracking system to achieve access into the collecting system. A preoperative multi-slice CT is obtained in the prone position from which three-dimensional models based on segmentation of the kidney and pertinent surrounding structures are rendered. On the operating table, the iPad is used to align the three-dimensional models configured from the CT onto the body of the patient. The virtual anatomy on the iPad correlates with the real anatomy and is used to assess the ideal position for needle puncture. The technique’s feasibility has been studied in three patients followed by a comparative matched-pair analysis. Safety and efficacy of the technique was supported, however, there was no significant improvement in puncture time and radiation exposure. This is attributed to the novelty of and lack of experience with the technology. Further studies are required to test the practicality of the method with increased experience and in combination with tracking of the puncture needle [25].

Additionally, Dyna-CT (Siemens Medical Solutions, Erlangen, Germany), a digital angiography unit, has been purposed in the urologic setting. The device produces an image similar to that of a CT, and segmentation of the imaging allows for a three-dimensional reconstruction of targeted systems, namely the kidney and collecting system, via the Artis Zee Celang software. Based on the traditional “bull’s eye” premise for access, a laser guide (syngo iGuide) marks the area of puncture on the patient and provides the trajectory for needle insertion. Ritter et al. [26] recently applied this technique

while attempting *in vivo* access in 27 patients. All patients in the study were deemed “complex” access cases in which the ultrasound findings were unclear or there was suspicion of injuring nearby bowel. 24 patients had successful percutaneous access obtained with this technique; there were no major complications noted, however, the technique employs more radiation than traditional fluoroscopic access and is a time-consuming endeavor. The radiation exposure, though, is less with Dyna-CT than with other imaging alternatives for complex access patients (i.e. CT-guided percutaneous access) and improves on locating residual stones during the case.

Electromagnetic tracking (EMT) uses a magnetic field that is generated around the patient to decipher to the location of ferromagnetic structures *in vivo*. For percutaneous renal access, a ferromagnetic sensor tip at the end of a ureteral catheter is endoscopically targeted into the calyx into which access is desired. The AURORA tracking system (Waterloo, Canada) is then coupled with the open source Medical Imaging Interaction Toolkit (www.mitk.org) to integrate information of the ureteral catheter sensor and on the access needle via a graphical user interface. Three widgets are used to assist in needle placement. Widgets I and II indicate the position and orientation of the two sensors in a three-dimensional image from differing camera angles, and Widget III shows the ureteral catheter imaged as a sphere from the position of the sensor tip needle to better perceive depth. In a proof-of-principle study, Huber et al. [27] performed access into 90 renal tracts in 6 porcine kidneys with 100% success rate. 91% of tracts were accessed with a single puncture, whereas the additional 9% needed a second puncture. Location of the calyx had no effect on the success of the technique ($p = 0.64$). Access using this method, however, would be difficult in patient in which retrograde calyceal access may be limited due to an obstructing stone or significant stone burden.

Along the same concept, Kawahara et al. [28] recently examined the ability to utilize ureteroscopy to gain renal access. This group utilized a nephrostomy puncture wire through a ureteroscope to achieve retrograde access into the collecting system. A success rate of 77.3% is reported using this technique, although there is no comment on fluoroscopy time or the extent of radiation exposure this technique employs compared to traditional renal access methods.

Position

Percutaneous nephrolithotomy is most commonly approached from the prone position. This necessitates a cystoscopy and placement of a ureteral catheter at the beginning of the procedure in a supine position followed by repositioning into the prone position. The procedure can be started with the patient prone and using the less practiced method of placing a ureteral catheter from this position as well. The alternative approach is to perform a PCNL from a supine position, thereby allowing access to work from both an antegrade and retrograde position simultaneously with ease.

A major criticism of the prone position has involved its safety and the effects on a patient’s cardiovascular status, especially those who are obese. Findings reported by Siev et al. [29], however, rebut this claim. In 101 patients who underwent prone PCNL, peak inspiratory pressure (PIP) was measured in both supine and prone positions and throughout various time points of the surgery. They report obese patients at baseline do have higher PIP values relative to non-obese patients ($p < 0.01$); however, there was no reported

change in PIP values in either cohort between supine or prone positioning.

There is controversy as to which technique provides the optimal position from which to perform a PCNL in terms of operative time, complications, and stone-free rates. Findings from the global, multi-institutional CROES study has recently reported on 1311 patients who underwent both supine ($n = 232$) and prone ($n = 1079$) PCNL. The study found that in patients who underwent a prone PCNL, the stone-free rate was greater ($p < 0.001$), and the operative time was shorter ($p < 0.001$). There was no difference in the complication rates between the patients who were operated on from either position. Contrastingly, other studies have examined the differences in positioning during PCNL as well and have noted that the operative time is shorter with supine PCNL. Additionally, the literature confirms similar complication rates [30–33], transfusion rates and estimated blood loss [30,32,33], and stone-free rates [30–33] between the two positions.

Special considerations in supine positioning are that the tract with this access modality is much longer than with prone PCNL, and consequentially, the nephroscope is limited from easily traversing between calyces. As a result, the use of flexible ureteroscopy is indispensable as a tool with which to access the more acutely angled or inaccessible renal poles. From these areas, stones may be grasped with a basket and pulled into the renal pelvis where they may be definitively addressed with the nephroscope. We believe that each position has its merits and that endourologists should be deft at performing PCNL using both modalities.

Tract dilation

Conventional tract dilation involves the use of successive graded Amplatz or Alken dilators. Newer methods of dilation involve the use of balloon dilators that are placed over a wire and rapidly expand under pressure in a faster method and one that involves less manipulation. Balloon dilation is thought to translate into a less traumatic access and one in which the safety wire is at less risk of becoming dislodged [34]. Given these factors, especially in the obese population, use of balloon tract dilators is more common practice than more traditional methods [35].

Early models of balloon dilators have been scrutinized because of a low burst pressure of 17 ATM. Newer balloon models have improved on this and can accommodate pressures of 30 ATM before there is any concern for bursting. The newer generation balloon dilators have reported good success rates. Hendlin and Monga [36] surveyed 60 tracts they dilated using a Bard X-force 30 ATM balloon and experienced a 100% success rate, a significant improvement over the 5–10% failure rate reported with standard 17 ATM balloons.

Reducing the two steps of dilating the access tract and then placing an access sheath over the dilator into one step, the pathway access sheath (PAS) is a device that allows for tract dilation and sheath placement at the same time. Pathak and Bellman [37] compared the outcomes of the device when compared to a standard balloon dilator. Results indicated that there is a significantly reduced access time in a tract dilated with the PAS system (3.7 min vs. 5.7 min) without a significant increase in cost or estimated blood loss. These findings are optimistic, but they require study in a larger, prospective trial to better confirm these results.

Nephroscopes

The standard rigid nephroscope requires a tract that is dilated to 26–30 F, either via balloon or serial fascial dilation. Given its large size, the generous diameter of the scope allows for copious, rapid flow of irrigation providing excellent visualization and a large visual field. The scope is able to accommodate standard PCNL instruments, including ultrasonic lithotripters and rigid graspers that are effective in removing large stones efficiently. The 30 F tract allows for the removal of sizeable stones in one piece, reducing the amount of blood loss and the time to stone clearance. A standard nephroscope, however, has its disadvantages as well. The size of the tract possibly causes the most renal trauma of any of the alternative options, which may lead to a higher risk of intraoperative and postoperative complications. Traditional PCNL may predispose patients to a higher risk of operative blood loss, postoperative pseudoaneurysm or arteriovenous fistula formation, especially if multiple percutaneous tracts are needed for stone clearance.

Flexible nephroscopy allows the surgeon to survey calyces within the kidney that are inaccessible with a single tract obtained with a standard rigid nephroscope. Using a standard flexible cystoscope through the access tract, residual stones can be identified, removed in one piece with a basket, or pulverized with laser lithotripsy before basket stone extraction. If there is a significant stone burden that cannot be readily reached even with flexible nephroscopy, a second tract can be made to remove the residual stone burden. One should observe caution when creating a second tract because of the increased risk of bleeding. Although imperfect, in skilled hands, flexible nephroscopy in combination with rigid nephroscopy can remove a significant stone burden while limiting the number of percutaneous tracts needed for the procedure.

Smaller caliber instruments were originally developed to address in special situations, like in children or stones in a diverticulum. Recently smaller and smaller instruments have been developed as ultrasound and Holmium-YAG-laser lithotripters have improved as has our understanding of hydrodynamics and stone fragmentation. A “mini”-perc has been coined to describe a PCNL utilizing an access tract dilated to 12–14 French. This size is large enough to accommodate a ureteral sheath and both flexible and rigid ureteroscopic instruments. A pediatric cystoscope can be used in addition to a 12 French rigid nephroscope. Li et al. [38] has described an irrigation method of effectively clearing stone fragments using these smaller scopes. An endoscopic pulsed perfusion pump is combined with retrograde pressurized flushes of the collecting system using a previously placed ureteral catheter. The pump irrigating through the endoscope generates a pressure increase up to 300 mmHg for 3 second intervals interrupted with 2 s of rest. The 2 irrigation modalities distend the collecting system, and when properly timed, the removal of the endoscope creates a vacuum within the sheath, forcing out smaller fragments. A concern with this irrigation method is the risk for pyelovenous backflow. Guohua et al. [39] in studying this device noted that the intra-renal pressures that developed were in fact lower than those required for pyelovenous backflow. In addition, when the peak pressure was reached, it was not sustained, and as the fluid was evacuated, the pressure was soon relieved.

Indicated for stones <2 cm in their greatest dimension, the mini-perc has some advantages over the standard PCNL. The smaller tract it utilizes has the potential to cause less renal trauma and therefore suggests a lower risk of bleeding both during the procedure and

afterwards. A smaller tract may also decrease the amount of narcotic pain medicine the patient requires post-operatively and the length of hospital stay. Disadvantages of the smaller tract include poorer visualization of the collecting system and therefore less efficient stone lithotripsy. The decreased size of the working channel limits the type of instruments that can be utilized including lasers, baskets, small suction devices, and small grasping forceps.

The combination of the standard and the mini-perc together may provide more efficient means by which to maximize stone free rates in patients with staghorn calculi or significant stone burden. In patients who require a second access channel, a smaller tract provided by the mini-perc can assist in minimizing trauma and bleeding. Wang et al. [40] evaluated a standard PCNL cohort with a PCNL/mini-perc group showing a greater likelihood of developing stone free rates with the PCNL/mini-perc. Rates of operative time, complication time, and reoperation rate were similar between the two groups.

Even finer than the mini-perc is the “micro”-perc designed to work with an even smaller channel. Micro-PCNL employs a 4.85 F optic needle, named the “all-seeing needle”, that was first designed as a method of more efficiently obtaining calyceal access prior to dilation. Given the access needle itself provides images to guide the case and, there is no need for dilation, thus obviating the risk of accruing the complications with which it is associated [41]. Because of the small size of the micro-PCNL instrumentation, it is best suited for small and moderate sized stones. This PCNL modality has unique advantages. It is most useful for stones that are difficult to access ureteroscopically and in lower pole stones that have a poor clearance rates with ESWL.

Lithotripsy

There are an array of options for intracorporeal lithotripsy that can be used with PCNL. The most commonly used devices are the Holmium:YAG laser, pneumatic and ultrasonic lithotripter, or devices that combine each of these technologies. Each modality has its advantages, and all are safe, causing limited damage to the native tissue during use.

As stand-alone devices, ultrasonic lithotripters are the most efficient for clearing stones and historically the most favored devices. They have the ability to simultaneously fragment and clear stones less than 2 mm through their suction apparatus [42]. Despite pneumatic lithotripters being more powerful and effective at breaking hard stones than ultrasonic lithotripters, they cause a significant amount of retropulsion that disperses the fragment of varying sizes throughout the collecting system. Thus, the time required to retrieve and clear the migrated stone fragments from distant calyces decreases the efficacy of stone clearance of these devices [43]. The least efficient method for clearing stones is laser lithotripsy. El-Nahas and associates [44] compared of high powered holmium laser use (2 J, 20–30 Hz) to ultrasonic lithotripsy during PCNL for complete staghorn calculi and showed that use of the laser leads to a significantly longer operative time (148 vs. 130 min, $p=0.03$) with no change in postoperative complications or stone free rates at 3 months of follow-up. In contrast to its poorer efficiency, the laser’s unique advantage over the other methods is its flexibility. It can be used to address stones during flexible ureteroscopy or nephroscopy.

The most modern lithotripters combine multiple lithotripsy technologies and have been shown to significantly improve the efficiency of stone clearance than either modality by itself [45]. As such, they are the most commonly used devices for intracorporeal lithotripsy in PCNL. Popular examples include the CyberWand (Olympus Corporation, Tokyo, Japan) – a dual probe ultrasonic lithotripter and the LithoClast Select (Boston Scientific, Marlborough, MA) – a dual ultrasonic and pneumatic lithotripter. Currently, there is a lack of evidence showing the superiority of one combination device over another [46].

New developments in intracorporeal lithotripsy aim to further improve on the efficiency of stone clearance. One novel device is the PercSac, a polyethylene sack used to ensnare the stone and contain all of its fragments during lithotripsy. In *in vitro* models, the device has been shown to improve stone fragmentation efficiency and stone clearance rates [47]. Recently, The UreTron (Med-Sonics, Eerie, PA), a new single probe ultrasonic lithotripter, received Food and Drug Administration (FDA) approval for use in the United States. This device employs improved vibratory and control features that unlike previous generations of ultrasonic lithotripters is aimed at improving performance in pulverizing all types of stones without compromising suction. In an initial study of the device, Borofsky et al. [48] showed improved stone clearance rates using the UreTron compared to dual probe lithotripters (51.0 vs. 36 mm²/min, $p=0.02$) with no change in postoperative complications or outcomes.

Exit strategies

Standard drainage of the kidney at the end of a PCNL involves leaving a nephrostomy tube in place. Over time, the caliber of these tubes has decreased with a subset of patients being left tubeless altogether. These drainage methods can be separated into three different types: large nephrostomy tubes, small nephrostomy tubes, and a “tubeless” approach involving the placement of only a ureteral catheter at the end of the procedure.

The most common nephrostomy tube used is a 24 F malecot re-entry nephrostomy tube. The tube is positioned within the access tract. Its size provides a tamponade effect to minimize bleeding and a low pressure conduit through which the kidney may drain. The drain is held in position by the malecot tip that rests in the renal pelvis. The tapered, most distal ureteral portion allows for the passage of a wire into the bladder with ease for through-and-through access. This advantage is exceedingly helpful in patients in which staging or reoperation is necessary, with significant blood loss, when significant stone burden must be left at the end of the case, or in a patient with complex anatomy [49].

Compared to the 24 French re-entry tubes, smaller nephrostomy tubes have been associated with lower postoperative pain levels, and resultantly they have been explored as a more ideal alternative [50]. These alternate tubes vary in size from 8–14 F, and after uncomplicated cases, these smaller tubes are viewed as a safe alternative for drainage.

A “tubeless” PCNL is another safe, viable option for avoiding placement of an external drainage tube. This is performed by leaving a ureteral catheter and a Foley catheter. A “modified tubeless” PCNL is one in which instead of a ureteral catheter, a double-J ureteral stent and Foley catheter are left after surgery. With the latter tubeless

method, the Foley catheter is removed on the first day after surgery, while the ureteral stent is removed 5–10 days later. With the former true tubeless method, both the ureteral catheter and the Foley catheter are removed 24–48 h after surgery. The outcomes using tubeless PCNL in straightforward, uncomplicated cases have been extremely favorable. Zilberman et al. [51] studied the tubeless PCNL technique and noted that patients undergoing this procedure necessitated a decreased amount of narcotic pain medication, experienced a shorter hospital stay, and had a reduced duration of recovery compared to a standard PCNL without any increase in complications.

In an effort to promote hemostasis and reduce the amount of urinary extravasation, tract sealants have been utilized in the final stages of tubeless PCNLs in lieu of nephrostomy tubes. Examples of these compounds applied to calyceal tracts include fibrin glue and FloSeal, however, the efficacy of these products is debatable. In a prospective randomized trial assessing the use of fibrin sealant after PCNL to a control arm without any sealant, there was no difference in rates of blood transfusion. In addition, although there was a trend toward less postoperative pain and analgesic requirement in the sealant cohort, the results were not significant [52].

Like tract sealants, cryotherapy has also been proposed to facilitate improved outcomes with tubeless PCNL. Okeke et al. [53] used the technique to freeze the renal parenchyma outside the collecting system using a cryoprobe. A 10-min freeze/thaw cycle was performed before the skin incision was closed. Results indicated that cryotherapy of the surgical tracts shortened the length of hospital stay and reduced the rate of delayed bleeding and urinary leaks.

The optimal methods of calyceal drainage after a mini-perc have also been contested. Sabnis et al. [54] conducted a randomized controlled trial examining three different exit strategy options: a modified tubeless option with a double-J stent and a Foley catheter, a tubeless option with a ureteral catheter and a Foley catheter, or a tubed option with a 14 F nephrostomy tube, ureteral catheter, and Foley catheter. Results indicated that the patients best tolerated tubeless procedures in which a ureteral catheter and Foley catheter were left in place. There was no difference in the drop in hematocrit, rates of urine leak, or perioperative complications between the three groups.

Postoperative antibiotics

There is no concrete evidence to support a guideline on the type or duration of antibiotic therapy after PCNL. In patients who have positive urine or stone cultures, the antibiotic of choice should be tailored to the offending organism that can be identified. If a patient develops sepsis, he/she should be treated based on pre-established clinical guidelines without change in management based on the source of the infection. Current American Urological Association (AUA) guidelines recommend a perioperative prophylactic antibiotic dose followed by an additional 24 h of antibiotics. Some consideration is given to extending the antibiotics course when manipulating an indwelling Foley catheter or nephrostomy tube [55].

Conclusions

The techniques involved in percutaneous stone surgery are consistently changing in a direction to improve both the ease of conducting these procedures as well as reducing the morbidity with which they are associated. Although there are a variety of promising

technologies, many require further study to assess if they are of any significant benefit and may provide a cost-effective alternative to current standards of care. It is imperative that urologic surgeons performing these procedures be familiar with these advancements in order to assess if any new developments would be suitable to incorporate into their practices to improve patient outcomes.

Authors' contributions

Samir Derisavifard MD, primary author, drafted the manuscript.

Christopher Hartman MD, secondary author, drafted the manuscript.

Nikhil Gupta MD, secondary author, drafted the manuscript.

David Hoenig MD, secondary editor.

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Conflict of interest

The authors declare that they have no conflict of interest to disclose.

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