REVIEW

Laparoscopic Management of the Urinary Stones

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Laparoscopic stone surgery was historically recommended only for cases involving concomitant ureteropelvic junction obstruction (UPJO), congenital abnormalities, or when other endourological procedures had failed as an alternative to open surgery. However, recent randomized clinical trials and meta-analyses involving patients with normal anatomy and large renal stones have shown that laparoscopic pyelolithotomy (LPL) has a higher success rate and lower complication rates compared to the gold standard, percutaneous nephrolithotomy (PCNL). Furthermore, stone recurrence appears to be lower following LPL compared to PCNL. Therefore, we suggest that current guidelines for stone treatment reconsider laparoscopy as an effective primary treatment for large kidney stones, rather than simply viewing it as an alternative option. Nonetheless, careful case selection and the surgeon's experience are critical for the success of this treatment.

Keywords: laparoscopy, pyelolithotomy, nephrolithotomy, ureterolithotomy, urinary stone, kidney stone, surgery, intervention, surgical treatment, complication, success rate

INTRODUCTION

Laparoscopy is a surgical technique that has been utilized for a variety of urological procedures, including the treatment of both benign and malignant conditions in the upper and lower urinary tracts. It was also introduced as an alternative method for treating large renal stones. However, laparoscopy did not gain widespread popularity because percutaneous nephrolithotomy (PCNL) was already established as the gold standard for this treatment. PCNL is more accessible and easier to teach than laparoscopy. As a result, laparoscopy has primarily been reserved for specific cases, such as those involving concomitant ureteropelvic junction obstruction (UPJO), congenital anomalies like pelvic ectopic kidneys, or cases with horseshoe kidneys. It has also been used when other endourological procedures have failed, serving as a substitute for open surgery.

Recently, some expert urologists in laparoscopy have achieved a high stone-free rate in a single session when treating large renal pelvis stones. They began to expand their patient range to include individuals with staghorn kidney stones in otherwise normal kidneys, even without accompanying renal anomalies. They compared their outcomes to those of the gold standard PCNL, noting significant advantages in terms of stone-free rates and complications. However, laparoscopic surgery has not yet been established in clinical guidelines as the primary treatment option for kidney stones.

In this narrative review, we will discuss the current role of laparoscopy in treating urinary stones, along with its advantages, limitations, and prospects. This review focuses on laparoscopic pyelolithotomy (LPL) and includes brief discussions on laparoscopic nephrolithotomy (LNL) and ureterolithotomy (LU).

1. laparoscopic pyelolithotomy (LPL)

1.1. Stone free rate

The ideal intervention goal is to remove the stone successfully in a single session. LPL has a success rate reported between 80% and 100%[1,2-5], whereas, the stone-free rate of PCNL based on CROES global study was 57% for staghorn stones on 1466 patients.[6] Moreover, meta-analyses of head-to-head randomized trials showed a significantly higher stone-free rate for LPL than PCNL.[7-10]Therefore, LPL is considered the most effective procedure for large renal stones in patients without previous surgery which provides the highest stone-free rate in a single session. To achieve the highest possible stone-free rate, we may combine laparoscopic pyelolithotomy with an endoscopic procedure. In 2009, Jose Salvado and colleagues inserted a flexible endoscope through the trocar into the pyelotomy incision to remove small calyceal stones, achieving a 100% stone-free rate.[1] Jung et al showed that the use of flexible nephroscopy during LPL for complex staghorn with calyceal stones can increase the stone-free rate significantly from 69% to 93%.[11]

1.2. Risk of the stone recurrence

Urolithiasis is a recurring condition. It is commonly believed that removing a stone without breaking it down may reduce the likelihood of recurrence. Some evidence suggests that small residual fragments, less than 4 mm, left after endourological procedures, which are often considered clinically insignificant, could serve as a nucleus for future stone formation.[12] Endourological procedures that involve stone disintegration, such as shock wave lithotripsy (SWL), retrograde intrarenal surgery (RIRS), and percutaneous nephrolithotomy (PCNL), carry potential recurrence risks. Recent reports indicate that patients with residual stone fragments smaller than 4 mm after PCNL have a significantly lower rate

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of being recurrence-free compared to those who were completely stone-free.[13] It can be assumed that achieving successful outcomes with zero fragmentation may reduce the recurrence rate of kidney stones. However, there are limited studies focused on the recurrence of urolithiasis following laparoscopic pyelolithotomy (LPL). In a recently published study, we prospectively evaluated the recurrence rate of urolithiasis in patients who underwent LPL compared to a matched group who underwent percutaneous nephrolithotomy (PCNL). Patients were followed biannually for three years to check for sonographically detectable stone recurrence. The results indicated that patients who underwent PCNL had a higher hazard of experiencing stone recurrence. A limitation of this study was that it was a nonrandomized study and the inclusion criteria were based on patient preference.[4] Xiao et al.'s follow-up of an RCT showed that the recurrence rate was the same between the two groups after four years of follow-up.[14] However, a prospective randomized controlled trial (RCT) will be designed to answer this question more precisely, incorporating variables such as previous interventions and stone composition.

1.3. Postoperative fever

Postoperative fever and urosepsis are well-known complications of percutaneous nephrolithotomy (PCNL). The combination of stone disintegration and irrigation can result in high intrapelvic pressures, increasing the risk of bacterial sepsis. This serious complication may occur even in patients with previously negative urine cultures. Studies have indicated that in most cases of postoperative fever, bacteremia does not take place; instead, the fever may be a systemic response to bacterial products released during stone fragmentation in PCNL. These products can enter circulation through open-ended veins.[15] High intra-renal pressure, which can occur when using smaller working sheaths in mini-PCNL or during retrograde intrarenal surgery (RIRS), may result in more significant harm. In contrast, during LPL, the stone is not disintegrated, and the intra-renal pressure remains stable. As a result, the incidence of postoperative fever and sepsis-related fatalities appears to be lower in this approach.[4] This is confirmed in metanalyses on randomized trials comparing LPL with PCNL.[7] Nevertheless, fever may occur after this procedure as well. Our results showed 15% postoperative fever in a series of transperitoneal laparoscopies.[5] Despite this, no fever was observed after the retroperitoneal approach (RLPL), highlighting the significance of an intact peritoneum.[16,17].

1.4. Hemorrhage

1.4.1. Early and delayed bleeding

Even experienced endourologists fear the unpredictable and devastating post-PCNL bleeding.[18] Sever Post PCNL bleeding occurs in 6-8 percent of cases.[19,20] This complication will result in a longer hospital stay and multiple units of blood product transfusion.[21] Due to the necessity of angioembolization in treating potential bleeding complications, PCNL is often restricted to medical centers equipped with interventional radiology facilities in many countries. For staghorn calculus cases, multiple accesses are typically required during PCNL, which increases the risk of postoperative bleeding even higher for these patients.[22] In contrast, LPL is not linked to postoperative bleeding, and meta-analyses indicate that LPL is superior to PCNL in terms of perioperative transfusion and delayed postoperative bleeding.[23]

1.4.2. In patients on anticoagulant

Recently, we have seen an increasing number of patients referred to us who are on prophylactic or therapeutic anticoagulants and require intervention for kidney stones. Some recent studies indicate that there is no significant increase in complications from PCNL in patients taking low-dose prophylactic aspirin, who undergo the procedure without stopping their medication.[24] However, when patients experience bleeding after PCNL, it is crucial to stop any anticoagulant medications. This is particularly risky for individuals who are on therapeutic doses of anticoagulants due to conditions like cardiac arrhythmias (such as atrial fibrillation) or venous thrombosis. Prolonged discontinuation of these medications can increase the risk of cerebrovascular events or pulmonary embolism. As a result, LPL is generally a better option for these patients because therapeutic anticoagulants can be resumed after the procedure with a lower risk of serious delayed bleeding. Gandhi et al. reported their experience with high-risk patients on anticoagulant therapy who underwent LPL, noting no significant complications.[25]. An alternative treatment for patients on anticoagulants is retrograde intrarenal surgery (RIRS). However, its efficacy varies widely, with success rates reported between 33% and 93% after as many as four sessions. This is significantly lower than LPL, which offers a success rate of 75% to 100% in a single session.[5,26-29] It's important to note that these fragile patients are not suitable candidates for multiple operations. LPL offers the highest success rate in a single session. However, the location of the stone significantly limits case selection for LPL.

1.5. Adjacent organ injury

To perform PCNL, the surgeon must obtain access to the kidney percutaneously. Nearby organs such as the bowel, liver, or spleen may be located in the access pathway and could be inadvertently injured during the procedure. If such injuries go unnoticed, may lead to serious complications and even death.[30] Utilizing ultrasound as an access guide for PCNL, instead of fluoroscopy, can reduce life-threatening complications, though they cannot be entirely avoided.[31-33]

Transperitoneal LPL like any other type of intraperitoneal access, is potentially associated with intraabdominal organ injury which is related to trocar placement or during bowel dissection;[34] This situation is more likely to occur in cases of previous laparotomy or peritonitis. However, since the kidneys are located in the retroperitoneal space, these complications are considerably avoided using the retroperitoneal approach with the same efficacy.[35-36,16-17,37].

1.6. Conversion to Open Surgery

In today's era of minimally invasive surgery, open stone surgery is typically reserved for cases where endourological procedures have not succeeded. Sometimes, during an endourological or laparoscopic procedure, a surgeon may decide to switch to open surgery due to complications such as vascular injury or uncontrollable bleeding.[9-11,38] or poor progression secondary to adhesions[39-41] or difficulties in removing the stone from the kidney secondary to stone migration to the calyx[39]. In cases of stone migration, using an endoscope through

the trocar can help remove the stone and prevent the need for open conversion.[1] The conversion rates for LPL and PCNL in clinical trials were similar. A recent meta-analysis indicated a 4.8% conversion rate for LPL and 2.1% for PCNL.[7] LPL is performed in the flank position, similar to that used for open stone surgery.[5] This facilitates conversion to open surgery in case of emergency without repositioning.

1.7. Postoperative urine Leakage

Prolonged postoperative urinary leakage following LPL is generally not a major concern and typically resolves within a few days. In some instances, this leakage may be caused by small residual stones that migrate to the ureter or by leakage from the pyelolithotomy incision, which can result from poor suturing techniques or heat exposure around the suture line. Urine leakage after LPL may be treated successfully by inserting a nephrostomy catheter.[17] Although there is no specific definition for prolonged urinary leakage after LPL, persistent leakage occurring more than 48 hours after the removal of the nephrostomy tube in PCNL has been classified as prolonged. Meta-analyses indicate that the occurrence of postoperative leakage is similar between PCNL and LPL.[7]

1.8. Difficulty and Learning Curve

The laparoscopic procedure has a steep learning curve, and there are challenges involved in removing staghorn stones from the pyelotomy incision, performing intracorporeal suturing, and placing a JJ stent. Since LPL is typically performed by surgeons who are already experienced with advanced laparoscopic techniques, there is no available data on its learning curve. In contrast, studies show that an inexperienced surgeon may need about 60 cases to achieve competence in PCNL.[42] Kashi et al. showed the performance and maturation of transperitoneal LPL over 18 years. They observed shorter operation and hospitalization durations, suggesting an improvement in surgical techniques at a referral teaching hospital.[43]

The transperitoneal approach is generally easier due to the wider working space, which facilitates suturing and offers more recognizable anatomical landmarks. This is particularly important in academic settings where procedures are being taught to less experienced surgeons. Abet et al. compared the outcomes of retroperitoneal versus transperitoneal laparoscopic ureterolithotomy performed by two recently graduated surgeons. They found that the success rates and complications were comparable between the two groups. However, the operating time was longer in the transperitoneal group, while the hospital stay and instances of urine leakage were shorter. The study had limitations, including its retrospective design and significant differences in stone sizes that favored the retroperitoneal group.[44] Another study on laparoscopic pyeloplasty suggests that the transperitoneal approach is preferred for young urologists during the learning curve of laparoscopy.[45]

1.9. Cosmetic results

The cosmetic results of LPL are superior to those of traditional open stone surgery; however, they are not as favorable as those achieved through PCNL. The retroperitoneal approach may offer better cosmetic outcomes compared to the transperitoneal approach, as the resulting scars are typically located more laterally and posteriorly. Additionally, by disintegrating the stone within the surgical removal bag, the surgeon can often avoid extending the incision for the extraction of large staghorn stones. To further enhance cosmetic results, techniques such as Natural Orifice Transluminal Endoscopic Surgery (NOTES) via vaginal incisions have been employed.[46]. In addition, small-sized single-port robots may improve the cosmetic outcomes of this procedure in the future.

1.10. Kidney injury loss of function

PCNL involves accessing the renal parenchyma to reach the calyceal system. During this procedure, the tract is dilated, and although no tissue is extracted, some nephron loss may occur. Long-term studies using nuclear imaging have generally shown that significant renal damage is uncommon;[47] There is still some controversy on this topic, especially regarding multiple access methods or different tract dilation techniques. [48-50]
In contrast, LPL does not violate the renal parenchyma. As long as the renal blood vessels remain undamaged, this procedure does not negatively impact renal function; in fact, it can enhance it by removing the obstruction.[51] Therefore, it may be preferred for patients with borderline renal function.[52] This becomes especially important when angioembolization becomes necessary due to severe bleeding after PCNL in these fragile patients.[53]

1.11. In previously operated patients

1.11.1. Previous PCNL or open surgery

Reoperation poses a challenge in both open and laparoscopic surgery, especially when it comes to dissecting tissue planes. However, LPL can be successfully performed even in cases of reoperation. Robotic-assisted laparoscopic surgery has been reported in a limited number of previously operated patients with acceptable results.[54] Radfar et al. shared their experience with transperitoneal LPL involving 27 patients who had a history of previous percutaneous or open surgeries. They compared their outcomes with those of 168 patients who had not undergone any prior surgeries. The study found no significant difference in the stone-free rates between the two groups.[55] Overall, the operation time was 204 minutes in the study group compared with 151 minutes in other patients ($p = 0.05$). These patients were hospitalized about 2 days longer (5.5 days compared with 3.7 days) and their hemoglobin dropped 1.7 g/dl compared with 0.7 g/dl ($p = 0.07$) in patients without a history of operation. Although the differences observed did not achieve statistical significance, it appears that the complication rate may increase if a larger number of patients are included. Conversely, PCNL and other endourologic procedures can be performed multiple times on patients who have previously undergone these operations. Given the tendency for the stone disease to recur, an endoscopic approach is preferred for recurrences, especially in less experienced hands.

1.11.2. Intraabdominal surgery on other organs

Laparoscopy was previously discouraged for patients with a history of peritonitis or extensive adhesions from prior intraperitoneal surgeries or mesh placements. However, studies have indicated that this procedure can be performed successfully in these patients.[56] In such cases, the retroperitoneal approach is considered safer and may even be used as a route for trocar placement for transperitoneal approach.[57] Notably, previous abdominal surgeries do not significantly impact the outcomes

of PCNL, provided that the bowels or other organs are not displaced posterior to the kidney.

1.12. Renal pelvis anatomy

One major drawback of LPL is that not every stone can be removed through the incision. In some cases, access to the renal pelvis is limited due to anatomical variations, such as intrarenal pelvis anatomy. This makes it challenging to remove large stones through a small incision.

While there is currently no standardized grading system for intrarenal pelvis anatomy, Tomaszewski et al. suggested a Renal Pelvic Score (RPS) that may help predict the likelihood of urine leakage after partial nephrectomy. The RPS is calculated based on the percentage of the renal pelvis area contained within the volume of the renal parenchyma seen on a reconstructed CT scan. Each renal pelvis can then be classified as intrarenal (RPS >50%) or extrarenal (RPS <50%).[58] Using this score, Simforoosh et al. reported on 28 patients with intrarenal pelvis anatomy who were successfully treated with transperitoneal LPL. However, three patients (10%) experienced prolonged urine leakage lasting more than a week, and five patients reported having a fever. In 6 patients (20%), placing a JJ stent antegradely was difficult, leading to the decision to forgo stent placement. This resulted in one case complicated by prolonged leakage and fever, which required delayed stent placement.[59] It has been shown that stentless laparoscopic ureterolithotomy (LU) does not have a higher complication rate.[60] Nonetheless, data on stentless procedures for LPL is limited. In cases where JJ stent insertion is difficult, we recommend changing the position to lithotomy and using a ureteroscope for stent placement to avoid the need for reoperation.

Removing larger staghorn stones can be challenging, even with extrarenal pelvis anatomy. In such cases, an extended pyelotomy, such as a Bois incision, may be beneficial[61]. Occasionally, the surgeon may choose to disintegrate the stone horns and remove them separately. Pastore et al. utilized this technique and confirmed the complete removal of the migrated particles in the peritoneal cavity using fluoroscopy[62]. However, it's advisable to avoid this approach in transperitoneal surgeries, as the irrigation may spread stone particles throughout the peritoneum, potentially leading to peritonitis, especially in the case of struvite stones.

1.13. Concomitant calyceal stones

The ideal scenario for LPL involves a single stone primarily located in the renal pelvis, especially if calyceal branches are interconnected with the main pelvic stone. In contrast, removing a calyceal stone through a pyelotomy incision presents significant challenges. It is generally not advisable to make an additional nephrotomy incision solely for the extraction of calyceal stones during LPL.

Salvado et al. introduced the use of a flexible nephroscope as an adjunct for pyelolithotomy in cases of staghorn stones, achieving a success rate of nearly 100% in removing calyceal stones[1]. Additionally, Jung et al. reported on 47 cases involving complex renal stones in a retrospective analysis, which revealed that the incorporation of a flexible nephroscope increased the stone-free rate from 70% to 95%[11].

While fever was not a common complication in the transperitoneal combined endo-laparoscopic approach [11], it is important to consider that using a flexible nephroscope during transperitoneal laparoscopy may elevate the risk of infected urine or small stone fragments leaking into the peritoneal cavity, potentially leading to postoperative fever. Although this complication has not yet been documented, it is recommended that a retroperitoneal approach be preferred when intraoperative nephroscopy is planned, as it has shown lower rates of postoperative fever in comparative analyses.[16,17]To address this concern, Garcia et al. suggested using CO_2 instead of irrigation fluid, which may be a safer alternative[63].

1.14. In concomitant UPJO or other kidney malformations

For individuals with concomitant ureteropelvic junction obstruction, LPL remains an effective treatment and has been one of the earlier applications of LPL.[64]

Calyceal diverticula, particularly those located anteriorly, are a known indication for laparoscopy.[3,65] However, challenges in localizing these diverticula, the need for intraoperative ultrasonography, and the necessity of nephrolithotomy can complicate the procedure unless in cases with thin renal parenchyma. With advancements in flexible ureteroscopes, patients may benefit from retrograde intrarenal surgery instead.[66] In challenging cases, when removing large dilated calyceal diverticula with thin parenchyma is necessary, laparoscopy is the optimal choice and can substitute open surgery.[67,68]

In the case of pelvic ectopic kidneys, both LPL and laparoscopic-assisted PCNL are good options.[69] Additionally, for patients with large stones in horseshoe kidneys, percutaneous access may be impossible due to the position of the retro-renal colon, making laparoscopy a viable alternative to open surgery.[70]

1.15. Skeletal abnormality; kyphoscoliosis

Positioning can be difficult in patients with severe skeletal abnormalities, and using fluoroscopy or ultrasound for access during PCNL poses significant challenges. An alternative option for these patients is retrograde intrarenal surgery (RIRS). However, the success of RIRS is dependent on the size of the kidney stones. Additionally, skeletal anomalies can obstruct fluoroscopic views, making it harder to guide the procedure. Some patients may also be unable to adopt the lithotomy position, which is traditionally used for these types of surgeries.

LPL offers a solution, as it is usually done in a flank position and can be performed in supine, or even prone positions without needing the lithotomy position. This flexibility is beneficial, especially when adjacent organs hinder direct access to the kidney, as LPL helps to minimize the risk of organ injury.

1.16. Patient positioning

LPL is usually performed in the flank position which is the same as the position that has been used for open stone surgery.[5] This facilitates conversion to open surgery in case of emergency without delay. Moreover, this position is well tolerated by patients with other comorbidities.

1.17. Cost and availability

Laparoscopic equipment is now widely available in almost every medical center. This equipment can also be utilized for various urological procedures, and it may be used by other medical specialties as well. However,

PCNL requires a fluoroscopy C-arm, which is relatively more expensive and requires maintenance that should be included in cost estimations for studies.
Xiao et al. reported that the surgical costs for laparoscopy are significantly higher compared to PCNL. Nonetheless, various factors influence these surgical costs.[14] For instance, using a balloon dilator can substantially increase the cost of PCNL.[71]
Surgical costs can potentially be reduced by using reusable trocars and laparoscopic instruments. Additionally, the duration of hospitalization is an important aspect to consider in cost estimations. Length of hospital stay is particularly significant in countries with considerable hospital costs. A study by Kashi et al shows that the length of hospitalization decreased over 10 years from 4.5 days in the first 3 years to 3.6 days in the recent 3 years in a single center by increased experience and confidence during time.[43] Recent reports, including a meta-analysis, indicate that the length of stay for LPL is comparable to that of PCNL.[7] It is worth noting that PCNL can be performed in an ambulatory setting, potentially significantly decreasing costs for selected patients.[72,73] Furthermore, a JJ stent is typically placed after LPL; however, it may be omitted in some uncomplicated cases following an uneventful PCNL, which would reduce costs associated with JJ stent removal.[74]
On the other hand, if severe complications such as significant bleeding occur after PCNL, angioembolization can be an extremely expensive procedure, particularly in less developed countries.

1.18. Transperitoneal vs retroperitoneal approach

LPL can be performed using either a transperitoneal or a retroperitoneal approach. The transperitoneal approach has clear anatomical landmarks, making it easier for teaching purposes. Moreover, the limited working space in the retroperitoneal approach can complicate intracorporeal suturing and stent placement. In the Al-Hunayan series, it was found that 33% of the pyelotomy incisions were left unclosed when using the retroperitoneal approach, compared to 18% for the transperitoneal approach.[36] Similarly, Abat's report on ureterolithotomy noted that a JJ stent was not placed in 32% of patients in the retroperitoneal group, which may have led to prolonged leakage in that group.[44]
However, violating the peritoneal barrier to treat a retroperitoneal condition may result in potential complications. Al-Hunayan reported a case of peritonitis due to an unrecognized migrated stone entering the peritoneal cavity during transperitoneal LPL. The team had to perform an open laparotomy to remove the infected collection. Additionally, the incidence of postoperative ileus appears to be higher following transperitoneal LPL.[36]
Currently, no prospective clinical trials are addressing this topic. Pakmanesh et al. compared the outcomes of two groups—retroperitoneal LPL (RLPL) and transperitoneal LPL (TLPL)—in a study of 104 patients operated on by a single surgeon. After performing TLPL for five years, the surgeon switched to RLPL. The study demonstrated that RLPL was associated with a shorter hospital stay, quicker initiation of oral intake, and less hemoglobin drop. Furthermore, the RLPL group showed a lower rate of fever compared to the transperitoneal group.[17] This finding was consistent with a multicentric report involving 273 patients from three referral centers. However, other variables such as hospital stay, hemoglobin drop, and stone-free rates did not significantly differ between the two groups.[16] While the later study did not evaluate postoperative ileus, the lower rate of fever in the RLPL group in both studies highlights the significance of maintaining an intact peritoneum to prevent leakage of potentially infectious stone debris, urine, irrigation fluid, or blood, which could lead to inflammation or peritonitis.
Given the absence of clinical trials, the current data suggest that when the surgeon is proficient with the retroperitoneal approach, it is preferred due to similar outcomes and a lower risk of complications.

1.19. Radiation exposure

Concerns about the harmful effects of radiation exposure during endoscopic and diagnostic procedures are growing.[75] Among all treatments for urinary stone disease, PCNL poses the highest risk of radiation exposure for both surgeons and nurses.[76] Many medical centers have incorporated ultrasound into their techniques and obtained ultrasound-guided PCNL skills to reduce radiation exposure for operating room personnel and patients.[32,77] This is particularly important when treating young patients or pregnant women.[78,79] Additionally, older patients are at risk because they often have recurring kidney stones and may have already accumulated significant radiation exposure from previous diagnostic procedures. LPL is a viable alternative that effectively treats kidney stones without the need for harmful fluoroscopic guidance.

2. Laparoscopic Nephrolithotomy (LNL)

Open nephrolithotomy was previously used as a treatment option for staghorn stones before the advent of PCNL. Some authors have attempted to perform this procedure laparoscopically in cases of large staghorn stones, where PCNL was unlikely to result in a stone-free outcome in a single session, and pyelolithotomy was not feasible due to the stone's anatomy and shape. Deger et al. first reported laparoscopic nephrolithotomy in 2004.[80] In 2008, Simforoush et al. reported on five patients treated with laparoscopic nephrolithotomy. The mean warm ischemic time was 30 minutes, and there was no significant blood loss. The stone-free rate for these patients was 60%.[81] Giedelmanet al. shared their experience with anatrophic nephrolithotomy involving eight patients in 2012. The mean warm ischemic time ranged from 13 to 30 minutes, with blood loss varying between 100 to 600 ml. The stone-free rate was recorded at 66%, and patients were typically hospitalized for three to five days.[82]
This technique involves arterial clamping, which can lead to renal ischemia and the incision of the parenchyma, potentially affecting renal function and causing nephron loss. El Nahas et al. followed 50 patients who underwent nephrolithotomy, using the estimated glomerular filtration rate (GFR) measured by MAG3 nuclear scans. They found that renal function decreased during a median follow-up of 2.7 years after the procedure, regardless of whether the patients were stone-free afterward[83]. This study included patients who had the procedure performed under cold ischemia. In contrast, the two laparoscopic nephrolithotomy procedures mentioned earlier were conducted under warm ischemia, which is linked to a higher risk of nephron loss. Additionally, suitable cases are limited to those documented in case series and have only been performed by experts.

The limited time available due to arterial clamping does not permit the introduction of a flexible nephroscope to remove all small residual stones effectively. Therefore, it is advisable to select cases where the stone can be extracted as a single large piece.
Additionally, the stone-free rate in these studies was approximately 60%, which is only slightly higher than the 57% stone-free rate reported in the PCNL Global study involving 1,466 staghorn stones[6]. This procedure has not gained widespread popularity due to its requirement for advanced expertise and the potential risk of nephron loss, along with the lack of guaranteed complete stone clearance. However, it may be beneficial in cases with thin renal parenchyma or in patients with ectopic kidneys, where PCNL carries a high risk of bowel injury.[84] However, even in these cases, laparoscopic-assisted PCNL may be performed without arterial clamping.[69,85]

3. *Laparoscopic ureterolithotomy (LU)*

In a study by Ozturk et al., the effectiveness of LU, RIRS, and SWL were compared for treating large ureteral stones using a randomized method[86]. The success rate for the LU group was 96% which was significantly higher compared to 79% for RIRS and 81% for SWL. The complication rates were similar for LU and SWL, both at 7%, while RIRS had a lower complication rate of 4%. Additionally, a retrospective study by Guler et al. reported that the success rates for LU or LPL were higher for ureteral or pelvic stones larger than 15 mm when compared to RIRS (90% vs. 76%). This study included 121 patients and found similar complication rates between the two groups; however, seven cases of severe sepsis (grade 4b) were observed in the RIRS group (12%), and 24% of the RIRS group required an ancillary procedure[87]. This finding highlights the advantages of LU, as it does not increase renal pressure or the risk of sepsis.
One notable benefit of laparoscopic surgery for ureteral stones is its ability to reveal anatomical causes of stone lodgment, such as ureteral stenosis or external pressure effects on the ureter, which are not visible using ureteroscopy. Radfar et al. carefully examined the location of stone lodgment in patients undergoing laparoscopic ureterolithotomy for stones larger than 10 mm. They found that in 73% of cases, the stone was lodged at the level where the gonadal vessels cross the ureter, concluding that the gonadal vessels could be a cause of extrinsic ureteral narrowing.[88]

4. *Guidelines*

According to the EAU guidelines, PCNL is the first choice for the treatment of complex renal stones. Interestingly, the guidelines strongly recommend offering either laparoscopic or open surgical stone removal in rare instances where shock wave lithotripsy, retrograde or antegrade ureteroscopy, and PCNL have failed or are unlikely to be successful. They mentioned that laparoscopy can be considered an alternative to PCNL for treating renal pelvis stones larger than 2 cm. Additionally, retroperitoneal laparoscopic pyelolithotomy (RLPL) is recommended for managing staghorn stones in patients with extrarenal pelvis anatomy. In specific cases, laparoscopic ureterolithotomy (LU) can also be a viable alternative to retrograde ureteroscopy.[89]
The AUA guidelines advise against open, laparoscopic, and robotic surgery as first-line treatments for upper tract stones but suggest these procedures as alternatives in a limited number of cases where an endoscopic or SWL approach may not have a reasonable chance of achieving complete stone removal with a practical number of procedures.[90] In our opinion, the recommendations for laparoscopic procedures should differ from those for open surgery, as laparoscopy is considered a minimally invasive approach.
Recent reports indicate that less invasive endoscopic methods can lead to severe complications. Therefore, it is crucial to evaluate the invasiveness of a procedure based on the severity of its complications rather than just the skin incision. LPL has demonstrated a significantly higher success rate in treating large kidney stones compared to standard PCNL. It requires fewer additional procedures and has an acceptable complication rate, as confirmed by meta-analyses.[7] We suggest that current guidelines for stone treatment reconsider laparoscopy as an effective primary treatment for large kidney stones, rather than simply viewing it as an alternative option.

CONCLUSIONS

Recent randomized clinical trials and meta-analyses involving patients with normal anatomy and large renal stones have shown that LPL has a higher success rate and lower complication rates compared to the gold standard, PCNL. Furthermore, stone recurrence appears to be lower following LPL compared to PCNL. Therefore, we suggest that current guidelines for stone treatment reconsider laparoscopy as an effective primary treatment for large kidney stones, rather than simply viewing it as an alternative option. Nonetheless, careful case selection and the surgeon's experience are critical for the success of this treatment.

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