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ORIGINAL PAPER

The comparison of laparoscopic pyelolithotomy and percutaneous nephrolithotomy in the treatment of solitary large renal pelvic stones

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Abstract The aim of the study is to investigate whether laparoscopic pyelolithotomy (LPL) could find a place in the management of large renal pelvic stones which are generally considered as excellent indications for percutaneous nephrolithotomy (PNL). Between 2006 and 2009, 26 consecutive patients with large (>4 cm^2) renal pelvic stones were treated by LPL and their charts were compared to 26 match-paired patients treated with PNL during the same period. The patients were matched for age, BMI, stone size and location as well as presence of congenital anomalies. Perioperative and postoperative findings were compared. The mean age, mean stone size, rate of congenital anomalies, history open renal surgery and shock wave lithotripsy were similar in both groups ($p > 0.05$). The mean operation time was 138.40 ± 51.19 (range 70–240) min in LPL group as compared to 57.92 ± 21.12 (range 40–110) min in PNL group ($p < 0.0001$). There was one (3.8%) open conversion in the LPL group due to dense perirenal adhesions making the dissection difficult. The ureteropelvic junction (UPJ) obstruction concomitant to pelvic stones was successfully repaired laparoscopically in two cases. The mean drop in postoperative hemoglobin level was 0.9 ± 0.6 (range 0–2) g/dl in LPL group and 1.7 ± 1.1 (range 0–4) g/dl in PNL group ($p = 0.024$). Hospitalization was significantly shorter in PNL than LPL group ($p = 0.0001$). Stone-free rates were similar. Laparoscopic pyelolithotomy is associated with a longer operation time, is more invasive, and requires more skills when compared to PNL. However, LPL is associated with less blood loss. Laparoscopic pyelolithotomy is indicated for congenitally anomalous kidneys and especially in patients with concomitant UPJ

Keywords Renal pelvic calculi · Laparoscopic pyelolithotomy · Percutaneous nephrolithotomy

Abbreviations

LPL	Laparoscopic pyelolithotomy
PNL	Percutaneous nephrolithotomy
UPJ	Ureteropelvic junction
ESWL	Extracorporeal shock wave lithotripsy
URS	Ureterorenoscopy
IVU	Intravenous urography
SFU	Society for fetal urology
CIRFs	Clinically insignificant residual fragments
BMI	Body mass index

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Introduction

With the advances in extracorporeal shock wave lithotripsy (SWL) and endourological procedures such as percutaneous nephrolithotomy (PNL), and ureterorenoscopy (URS), the treatment of urinary stone disease changed markedly. The indications for open renal surgery in the treatment of renal calculi are limited to several special situations and it is needed in only 0.47–5.4% of the cases [1–4]. With the development of techniques in laparoscopic surgery, guidelines and indications are further modified.

In the treatment of renal calculi larger than 2 cm in diameter, PNL with high success and low complication rates has been accepted as first-line therapy [5]. According to the guidelines, laparoscopic pyelolithotomy (LPL) is indicated in the failure of endoscopic procedures, presence of complex stone burden, renal and anatomical abnormalities, similar to open surgery [5]. There are some advantages to laparoscopy despite to its rare usage and limited indications. However, advanced experience and high skills are needed for the laparoscopic management of complex stones, such as anatrophric nephrolithotomy [6, 7].

With the increase in stone size, success, complication and additional treatment rates differ in patients treated with PNL [8]. In centers with established experience in advanced reconstructive laparoscopy, LPL can be a feasible alternative to PNL [9]. In the present study, we retrospectively cross-matched and compared PNL versus LPL in large pelvic stone and investigated place of LPL.

Patients and methods

Between June 2006 and December 2009, 26 patients with large solitary renal pelvic calculi (>4 cm^2) were treated with LPL at our institution by the same surgeon (AT). An informed consent was taken from each patient. In the same period, PNL was performed in 1112 patients by several surgeons experienced in endourology and PNL procedure over 300 cases, and 142 of them had isolated, large (>4 cm^2) pelvic stones. All patients were documented prospectively in our data base (Excel, Microsoft) including age, body mass index (BMI: kg/m^2), stone location and size.

Preoperative complete blood count, serum creatinine, platelet count, bleeding and coagulation profile, and urine cultures were obtained from all patients. Radiological evaluation included intravenous urography (IVU) and ultrasonography with addition of noncontrast computed tomography in selected cases. The stone burden was determined by radiographic studies, and stone configuration was basically classified as simple (isolated renal pelvis or isolated caliceal stones) or complex (partial or complete staghorn stones, renal pelvis stones accompanying caliceal stones), regardless of their size [10]. The degree of hydronephrosis was assessed according to the Society for Fetal Urology (SFU) Classification [11]. The stone surface area (cm^2) was calculated by graph-paper tracing of two-dimensional projection of the stone on a KUB film in the anteroposterior view by two investigators [12].

Technique of LPL

Initially an open end ureteral catheter was placed in lithotomy position under general anesthesia, through which a guidewire was inserted up to the renal pelvis. The patient was then moved to the full-flank position and the table was flexed for retroperitoneal approach. A standard retroperitoneoscopic approach was applied as described previously by Rassweiler et al. [13]. After the dissection of the renal pelvis, a longitudinal or curvilinear pyelolithotomy incision was done according to the size and shape of the stone. After pyelotomy was created, the stone within the renal pelvis was removed intact and placed in a specimen retrieval bag using the stone forceps. After the calculi had been removed, a Double-J stent was inserted over the guidewire advanced into the renal pelvis under laparoscopic vision. A 4-0 polyglactin suture is used to close the pyelolithotomy from the proximal to the distal edge of the incision in a running fashion. A suction drain was passed through the lateral port and placed in the peripelvic tissues, under endoscopic guidance. In transperitoneal approach the patient was placed in 30–45° modified lateral decubitus position with minimal flexion and attached to the operating table with padded fixators. In patients with UPJ obstruction concomitant to renal pelvis stone, a standardized laparoscopic Anderson-Hynes dismembered pyeloplasty was performed as previously described [14].

Technique of PNL

A standardized PNL procedure was performed in all cases as described elsewhere [15]. Briefly, a 5 Fr ureteral catheter was placed initially in a lithotomy position under general anesthesia. Percutaneous access was obtained by the surgeon at a single setting in the operating room with C-armed fluoroscopy (Sire-mobile, Siemens, Munich, Germany). The tract was dilated with a high-pressure Nephromax® (Boston Scientific, Boston, USA) balloon dilator using a Leveen® (Boston Scientific, Boston, USA) inflator and a 30 Fr Amplatz sheath placed over the inflated Nephromax® under fluoroscopic guidance. Nephroscopy was performed with a rigid 26 Fr nephroscope. Stone fragmentation was accomplished using a pneumatic lithotripter (Vibrolith, Elmed, Turkey). Fragments were removed with graspers. Additional tracts were created when indicated in the same session. Stone clearance and the integrity of the collecting system were confirmed intraoperatively by fluoroscopic screening and antegrade nephrostography. At the end of the procedure, a 14 Fr nephrostomy tube was placed in all patients. In the presence of UPJ obstruction a full-thickness incision was made using a hook knife truly lateral to the at the UPJ obstruction. A 6F Double-J stent was inserted at the end of the procedure.

Initial postoperative stone-free rates were determined by patient assessment at time of hospital discharge with radiography of the kidneys, ureters, and bladder. Afterward, follow-up stone-free rates were determined in an outpatient clinic setting at 3 months postoperatively with spiral computerized tomography. The procedure was considered successful if the patient was stone free.

Matched pair definition and statistical analysis

The data of the patients with isolated renal pelvic stones >4 cm^2 managed with LPL match-paired in terms of age, BMI, stone burden and localization, presence of congenital anomalies, previous ipsilateral open surgery and SWL with the PNL group. The matched factors are given in Table 1. The factors potentially affecting the preoperative and postoperative outcomes were compared between 26 patients in each group.

Data were processed using SPSS-16 for Windows (SPSS, Inc., Chicago, IL). Continuous variables were compared with Student *t* test, Mann–Whitney *U* and Wilcoxon tests, as appropriate. Proportions of categorical variables were analyzed for statistical significance using Chi-square test or Fisher's exact test. In all analyses, two-sided hypothesis testing was carried out, and probability values less than 0.05 were deemed significant.

Results

The mean patient age was 36.5 ± 11.1 (range 22–50) years and 37.1 ± 10.0 (range 21–52) years in LPL and PNL groups, respectively (*p* 0.85). The mean stone size was 7.5 ± 2.3 (range 5–10) cm^2 and 7.2 ± 1.51 (range 5–9) cm^2 in LPL and PNL groups, respectively (*p* 0.60). All stones were located in the renal pelvis. The mean BMI of the patients, rate of congenital anomalies, and incidence of previous open surgery and history of SWL were also similar in between groups (Table 1).

Perioperative and postoperative parameters were compared in Table 2. The mean operation time was significantly prolonged in LPL group than PNL group (138.40 ± 51.2 vs. 57.9 ± 21.1 min, $p < 0.0001$). The mean fluoroscopic screening time (FST) was calculated as 7.40 ± 3.60 (2–16) min in PNL group. No imaging modality was required during LPL.

In laparoscopic group, there were two major complications. One procedure (3.8%) had to be converted to open surgery because of excessive peripelvic adhesions and inability to free the renal pelvis by dissection. The other postoperative complication was prolonged urine leakage that was detected in one patient (3.8%) and resolved spontaneously at postoperative 7th day. Similarly two major complications were observed in the PNL group. A hydrothorax, which required insertion of a chest tube, developed in one (3.8%) patient who was managed with intercostal access. Another operation had to be terminated because of hemorrhage making the clear vision impossible and deterioration of hemodynamics.

The ureteropelvic junction (UPJ) obstructions concomitant to pelvic stone were successfully repaired laparoscopically in two patients. Furthermore two patients with a horseshoe kidney with large pelvic stone were managed

Table 1 The parameters for match-pair analysis between LPL and PNL

	LPL	PNL	*p* value
No. pts	26	26	
Stone location	Pelvis	Pelvis	
Stone size ± SD (cm^2)	7.46 ± 2.25 (5–10)	7.18 ± 1.51 (5–9)	0.60
Mean age ± SD (years)	36.54 ± 11.09 (22–50)	37.12 ± 10.02 (21–52)	0.85
BMI ± SD (kg/m^2)	25.34 ± 3.55	25.25 ± 3.03	0.91
Associated anomalies			
Horseshoe kidney	2	2	1
UPJ obstruction	2	1	1
Previous open renal surgery			0.72
(+)	4 (15.4%)	6 (23.1%)	
(−)	22 (84.6%)	20 (76.9%)	
History of ESWL			0.72
(+)	6 (23.1%)	4 (15.4%)	
(−)	20 (76.9%)	22 (84.6%)	

SD standard deviation

Table 2 Comparison of perioperative and postoperative data in patients undergone LPL and PNL

	LPL	PNL	*p* value
Mean operation time (min)			
Overall	138.4 ± 51.2 (70–240)	57.9 ± 21.1 (40–110)	<0.0001
No renal anomalies	126.6 ± 45.1	57.0 ± 19.8	<0.0001
Renal anomalies	203.7 ± 30.4	65.0 ± 35.0	0.05
Mean fluoroscopic screening time (min)	–	7.4 ± 3.60 (2–16)	NA
Mean hospitalization time (days)			
Overall	3.9 ± 2.5 (2–11)	2.3 ± 0.5 (2–4)	0.0001
No renal anomalies	3.3 ± 1.5	2.3 ± 0.6	0.007
Renal anomalies	7.2 ± 4.3	2.0 ± 0.0	0.05
Mean drop in hemoglobin level (g/dl)			
Overall	1.0 ± 0.6 (0–2)	1.7 ± 1.1 (0–4)	0.024
No renal anomalies	1.1 ± 0.6	1.7 ± 1.2	0.04
Renal anomalies	0.4 ± 0.3	1.6 ± 0.9	0.05
Complications			
Open conversion	1	–	
Prolonged urine leakage	1	–	
Bleeding	–	1	
Hemothorax	–	1	
Stone-free rate (%)	100	88.4	0.23

successfully in LPL group using the transperitoneal approach. A UPJ obstruction in two patients in the PNL group was managed by endopyelotomy in the same session of percutaneous stone removal.

The mean drop in postoperative hemoglobin level was 0.97 ± 0.57 (range 0–2) g/dl in the LPL group as compared to 1.69 ± 1.12 (range 0–4) g/dl in the PNL group and found to be statistically significant (*p* 0.024). However, blood transfusion was required for only one (3.8%) patient in the PNL group.

On the other hand the hospitalization period was significantly shorter in the PNL group (3.9 ± 2.5 vs. 2.3 ± 0.5 days) ($p = 0.0001$). In the follow up all patients in the LPL group were stone free. In the PNL group only one patient had residual stone. The clinical insignificant residual fragments were detected in two patients on the control spiral CT. Stone-free rates at 3 months follow-up were 100% for LPL group and 88.4% (23/26) for PNL group (Table 2).

Discussion

With the advances in endourological techniques, the indications for open surgery have decreased markedly [1–5]. Laparoscopic surgery is the procedure mimicking principles of open surgery via a trocar. Therefore, laparoscopic surgery has some advantages to open surgery such as low-postoperative morbidity, reduced hospital stay and minimal blood loss [5]. And it is clearly underlined that when expertise is available, laparoscopic surgery should be considered before proceeding to open surgery [16]. There are limited number of studies comparing the LPL and the PNL in the management of urinary stone disease [17–19]. Therefore, we analyzed the outcome of LPL and compare the results with PNL using a matched pair analysis. After adequate experience with laparoscopic renal surgery in over 500 cases, we decided to perform LPL in selected cases that were also suitable for PNL, which is carried out in high volume and success rates at our institution [15].

When compared with PNL, one outstanding advantage of LPL is that it is harmlessness for parenchyma. Therefore, the risk of bleeding is higher in PNL related to the access localization and dilation technique. Bleeding is the most important and frequent complication in PNL. In general, they are managed conservatively; however, arterial embolization may be required in some cases. In a study where PNL was compared with LPL, significant venous bleeding was reported in 3 of 16 patients managed with PNL [18]. Drop in the postoperative hemoglobin level was found to be more significant in PNL group (0.6 vs. 1.8 g/dl). Also in our study the mean decrease in hemoglobin levels was significantly less in the laparoscopic group (*p* 0.024).

Another advantage of laparoscopy is that hard stones, especially cystine and brushite stones can be extracted as a whole. So the LPL has a high success rate in patients with solitary kidney stones. PNL increases rates of complications such as bleeding and perforation during fragmentation of hard stones. The scattering of stone fragments may lead to low success rates. In addition, re-PNL, SWL or follow-up can be required for residual fragments after PNL treatment, while with LPL the stone can be removed as a whole in one session. To prevent the scattering of residual fragments during PNL, Hemal and colleagues [20] suggest the usage of pneumatic lithotripsy in single pulse settings. The scattering of the stone fragments can be prevented by the usage of an ultrasonic lithotripter with continuous suction [21]. In the present study, all stones were fragmented with pneumatic lithotripter in multiple settings.

In the presence of easily fragmented stones such as struvite stones, stone can be disintegrated by the forceps manipulation during stone removal. And the fragments can migrate to the calices or retroperitoneum during LPL. In this situation flexible endoscope introduced through the trocar can be used to explore under fluoroscopic guidance. However, we did not require any fluoroscopic or endoscopic control to assess the stone clearance in LPL group. All patients had single large pelvis stones that were completely removed in LPL group. In our series, flexible devices were used in several cases when indicated during PNL. Although there are series using guidance of ultrasonography, in our series all steps of PNL were performed under fluoroscopic guidance [22]. The radiation exposure of the operation team and the patient is another disadvantage of PNL.

On the other hand, the impairment of urinary tract integrity is another disadvantage of the LPL. Urine leakage can be seen due to incomplete closure of the renal pelvis after LPL. This phenomenon can prolong hospital stay and time of catheterization. Besides, in patients with intrasinusoidal pelvis, closure of the pelvis is technically difficult during LPL, and the risk of postoperative urine leakage is higher. Harmon et al. [23] described the first LPL experience in a pelvic kidney and reported that the hospital stay prolonged up to 7 days due to incomplete closure of the renal pelvis. In another study, Sinha et al. [24] reported their LPL experiences in 20 patients with solitary pelvic renal stones. In their study, retroperitoneoscopic approach was preferred, the authors reported prolonged urine leakage in 2 of the first 14 patients, where the pyelotomy was not sutured and in none of the remaining later 6 patients where pyelithotomy incisions were closed with intracorporeal sutures, they could not detect urine leakage. But this complication has been minimized with advances in intracorporeal suturing techniques. In our study, average hospital stay in the LPL group was 3.9 ± 2.50 days. In one patient, prolonged urine leakage was detected which stopped spontaneously at 7th day postoperatively. To avoid this complication we placed a double-J stent to all patients in LPL group. But additional cystoscopy for stent removal increases the costs of the procedure and causes patient discomfort after LPL. In addition, the LPL procedure increases the formation of dense adhesions and scarring around the renal pelvis. This scarring may challenge the next open or laparoscopic renal surgeries. This point may be considered as another disadvantage of LPL procedure.

The most outstanding advantage of PNL is probably the short duration of the operation. In this study, in the PNL group mean duration of surgery was 57.92 min, while in the LP group it was 138.40 min in the present study. However, the additional pyeloplasty procedure prolongs the mean operation time in the LPL group. Previous acute pyelonephritis and history of SWL or renal surgery complicates pelvic dissection during laparoscopy and prolongs the operation time. Furthermore, similar to the results of our study, authors that excluded the patients with kidney malformations and UPJ obstruction, found that operation times in the LPL group were longer than observed in the PNL group in patients with renal pelvic stones [17, 18]. Not only technical differences but also discrepancies in the reinstallation of the patient contribute significantly to disparities between operation times.

In terms of cosmetic outcomes, LPL that requires three or four trocar placement is less cosmetic compared to PNL where only a single percutaneous access was performed in all cases in the current study. With the development of multichannel single-access ports and articulating instruments that allow the laparoscopic procedure to be performed through a single skin incision and the usage of these new technologies in the treatment of urinary stone disease, the cosmetic outcomes will probably be better. Moreover, LPL is a more invasive procedure due to its transluminal nature compared with the endoluminal nature of PNL. Thus, it is underlined that the convalescence period following PNL is shorter as compared to LPL [17].

In recent years, an increasing numbers of publications have demonstrated the efficacy of laparoscopy especially in cases with concomitant presence of UPJ stenosis, ectopic and horseshoe kidneys. Stein et al. [25] evaluated 117 patients who underwent laparoscopic pyeloplasty and detected that in 15 patients (12.8%) concomitant ipsilateral pyelolithotomy was performed during laparoscopic pyeloplasty. Preoperative, intraoperative and postoperative data of these patients were compared with 15 patients who underwent laparoscopic pyeloplasty matched by age, renal function and degree of hydronephrosis. The authors reported stone-free rate as 80%. When compared with the control group, statistical difference between mean operation times was not detected. In fact, the presence of UPJ obstruction in the presence of a large obstructing pelvis stone is always debatable. In the present study, UPJ stenosis accompanied 2 of 26 patients who underwent LPL. The laparoscopic approach is an effective procedure for the surgical treatment of renal stones associated with UPJ stenosis without increasing morbidity and operative times with higher stone-free rates. In our study, 2 of 26 patients who underwent LPL had horseshoe kidney, and all of them were treated successfully with transperitoneal laparoscopic approach. Similarly, in the PNL group, two patients had horseshoe kidneys with pelvic large stones and they were successfully treated. The success and complication rates of PNL in the treatment of calculous horseshoe kidneys were reported to be similar to those with normal kidneys [26, 27]. However, the presence of aberrant vessels and anatomic abnormalities causing abnormal caliceal orientation complicates percutaneous approach into the lower calyx. Therefore, in horseshoe kidneys upper pole access is frequently preferred for the percutaneous treatment [28]. However, access into the upper pole often causes elongation of the tract, and as a result in obese patients, the length of nephroscope might not be adequate for the patients with stones extending from pelvis to isthmus [28]. On the contrary, laparoscopy is especially helpful for the elimination of large stone burden localized in the pelvis as well as in the isthmus. In addition, during PNL, the risk of colonic injury is higher in patients with horseshoe kidney. This phenomenon is explained by retrorenal or posterolateral colonic position [29]. Ectopic location of the kidney together with the defect in the development of lateroconal fascia shifts the colon posteriorly and increases the risk of injury.

The retrospective nature of the present study is limitation factor. Although the outcomes of PNL and LPL are compared in the present study, the lack of comparison in terms of cost effectiveness is another limitation factor.

Conclusions

Although laparoscopic surgery has gained acceptance as a standard management in many urological disorders, the role of open and laparoscopic surgery in the treatment of urinary stone disease is still limited due to the advances in endourological techniques. Furthermore, LPL is associated with longer operation and hospitalization times. However, LPL is not potentially harmful to the renal parenchyma and is associated with less blood loss. Under the objective view of all advantages and disadvantages of both techniques, we prefer PNL as the first-line treatment modality for primary simple or complex renal stones. LPL should be performed in special circumstances such as renal stones concomitant UPJ obstruction and renal abnormalities such as pelvic or horseshoe kidneys.

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