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REVIEW

Laparoscopic and robot-assisted surgery in the management of urinary lithiasis

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KEYWORDS

Laparoscopic surgery;
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Stones;
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ABBREVIATIONS

CE, contrast-enhanced; PCNL, percutaneous nephrolithotomy; LAN, laparoscopic anatrophic nephrolithotomy; LU, laparoscopic ureterolithotomy; LP(P), laparoscopic

Abstract ***Objectives:*** To review the current role of laparoscopy and robot-assisted laparoscopy for managing urinary lithiasis.

Results: The contemporary indications for laparoscopic stone management are: anatomical variations in location or shape of the kidney (pelvic kidney, horseshoe kidney and malrotated kidney); coexisting pathologies, e.g. pelvi-ureteric junction obstruction; and stones in a renal unit with lower ureteric obstruction. The laparoscopic approach allows the simultaneous management of both the pathologies. Symptomatic stones in diverticula not amenable to endourological intervention can be treated with laparoscopy. Large impacted pelvic and ureteric calculi with a functioning renal unit are an indication for laparoscopic ureterolithotomy or pyelolithotomy. This review of current reports suggests that in a selected group of patients with complex stone disease the laparoscopic approach offers good success rates with minimal complications. There are few reports of robotic procedures in stone disease but existing data suggest that it is feasible.

Conclusion: Laparoscopic surgery is effective for complex renal stones and offers excellent stone clearance rates with minimal morbidity. Laparoscopic surgery is complementary in managing these stones. Robot-assisted laparoscopic technique of

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pyelolithotomy (with pyeloplasty); US, ultrasonography

urinary tract stone management is in its early stage of implementation and randomised trials that compare robot assisted outcomes with other minimally invasive techniques are needed.

Introduction

The surgical management of urinary stone disease has developed over recent years; treatment options include ESWL, percutaneous nephrolithotomy (PCNL) and ureterorenoscopy (rigid and flexible). Open stone surgery accounted for 5.4% of all stone cases a decade ago [1]. The indications for open surgery and the laparoscopic or robotic approach overlap. Patients who are candidates for open surgery could also benefit from laparoscopic surgery. The European Association of Urology Guidelines on Urolithiasis (2011 edition) indicate that laparoscopic surgery should be considered as a treatment option before offering open surgery, whenever expertise is available [2]. The addition of robotic technology to this choice widens the treatment options available to the treating urologist. Here we review the current role of the laparoscopic and robot-assisted laparoscopic approach to urolithiasis.

Indications

In an era where most of stones can be treated endourologically, the indications for using a laparoscopic and robotic approach are changing. Laparoscopic and/or robotic approaches have indications in extraordinary and unusual circumstances. If there are anatomical abnormalities, e.g. pelvic kidney or horseshoe kidney, an endourological approach is fraught with the risk of life-threatening complications such as bleeding, due to aberrant vascular and pelvicalyceal anatomy. In addition, a large stone bulk requires a longer nephroscopy or ureteroscopy, leading to the potential for absorption of large volumes of fluid, and risks leaving stones in the urinary system. Thus the stone burden, anatomy and surgeon experience dictate the choice of approach. The indications for laparoscopy and robotic approaches 'mirror' that of open surgery.

The contemporary indications for laparoscopic stone management are:

(1) Anatomical variations in location or shape of the kidney, e.g. pelvic kidney, horseshoe kidney and malrotated kidneys.
(2) The simultaneous management of coexisting pathologies, e.g. stones and PUJ obstruction (PUJO) [3].
(3) Symptomatic stones in diverticula not amenable to endourological intervention can be treated with laparoscopy [4].
(4) Large impacted pelvic and ureteric calculi with a functioning renal unit are an indication for laparoscopic ureterolithotomy (LU) or pyelolithotomy (LP) [5].

Surgical methods

LP

Most studies recommend PCNL as the first-line and standard treatment for staghorn and complex multiple renal stones, because of its low morbidity and good stone clearance rates [6]. LP can be done either by the transperitoneal or retroperitoneal approach. The factors which decide the choice of approach are the anatomy of the kidney and ureter, and the location and size of the stones [7]. The choice in most cases is dictated by the surgeons' experience and preference.

Procedure

A preoperative evaluation should include contrast-enhanced (CE) CT and/or IVU. These investigations help to select the candidate for laparoscopic approach. A triple-phase CECT will help to delineate the pelvicalyceal anatomy and the vascular anatomy. This helps to predict the level of difficulty that might be encountered. A pelvic stone with an extension into the lower calyx or any adjoining calyx can be challenging to deal with. The surgeon in such a situation should be well versed and prepared for a nephrotomy or use of flexible instrumentation to deal with a broken stone.

Before positioning the patient in the laparoscopic suite, we use cystoscopy and retrograde urography, for two reasons; first it helps in delineating the anatomy of the ureter, and second it helps in the insertion of a ureteric catheter/JJ stent. An indwelling catheter in the ureter helps when identifying the ureter and later to spatulate the ureter. We prefer to use the transperitoneal approach; the patient is placed in a kidney position, with a 45° tilt, and all the pressure points are padded. It is the responsibility of the surgeon and the anaesthetist to ensure proper positioning. We prefer to gain access with a closed technique using the Veress needle. A 30° telescope is used. We use two 11/12-mm ports and one 5-mm port. The colon is reflected along the white line of Toldt. The ureterogonadal packet is identified by the indwelling stent. The ureter is traced to identify the stone. The

Table 1 The results of LP and LPP.

	Series, LP				LPP			
Variable	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]
No. of patients	16	9	8	5	15	19	7	8
Mean stone size (cm)	3.6	2.9	2.9	1.3	0.58	1.4	1.03	–
Access RP/TP	RP	TP	TP	4 TP/1 RP	TP	TP	TP	RA TP
Operative duration (min)	142.2	176	96	193	174	276	–	275.8
Mean blood loss (mL)	173.1	–	15	53.2	53.3	145	–	–
Conversion, n/N	2/16	–	–	–	–	–	–	–
Stone clearance rate, n/N	–	9/9	8/8	93%	12/15	17/19	6/7	8/8
Complications, n	1[a]	–	–	1[b]	1	–	–	–
Hospital stay (days)	3.8	3.7	2.15	10.5	2	3.4	–	–

TP, transperitoneal; RP, retroperitoneal; RA, robot-assisted.
[a] Stone migration.
[b] Prolonged leak.

stone is identified by the bulge or by merely 'sounding' it. The incision is 'V'-shaped, no electrocautery is used around the PUJO and the incision should be kept far away from the PUJO. If the stone is too large to be manipulated, a spatula will be useful. Care should be taken while manipulating the stone, to prevent breaking it. Once the stone is delivered the pyelotomy is closed with 3–0 or 4–0 polyglactin suture in an interrupted or a continuous fashion. In the transperitoneal approach the kidney is reperitonealised after placing a drain. The stone can be entrapped in commercially available bags such as the endocatch bag. The stones can also be entrapped in novel indigenous entrapment devices such as a 'finger stalk' of a glove (non-latex), or indigenously made bags of polythene [8].

LP with laparoscopic pyeloplasty (LPP)

The first choice for treating stones in the renal pelvis is an endourological approach, but laparoscopy and robotic surgery has a role in renal units having concomitant PUJO or renal units bearing a large stone in the pelvis.

Procedure

The positioning and the port placement is similar to any laparoscopic transperitoneal renal surgery. Once the PUJ is dissected stone removal follows, which depends on the size, number and location of the stone(s). If the stone lies in the renal pelvis it is picked up with forceps, but if it lies in a distant calyx a flexible instrument is useful. The flexible cystonephroscope can be introduced through the available working port. Usually the port that is well aligned with the pelvis or ureter should be chosen for passing the instrument. Once the stone is located it can be tackled by removing it intact or disintegrating it with a laser.

Review of previous reports

Gaur [9] described retroperitoneoscopic procedures for stones, and subsequently the feasibility of this approach was shown even in staghorn stones. Table 1 [10–17] shows the results of LP and LPP.

Laparoscopic anatrophic nephrolithotomy (LAN)

In 2003, Kauok et al. [18] were the first to report their experience with LAN in a porcine model. This large-animal model for a staghorn renal calculus was created using a polyurethane mixture. Since then several reports have been published.

A ureteric catheter is placed and the patient placed in a lateral kidney position. The colon is reflected and the hilum is exposed. Three ports are used, as in laparoscopic renal surgery. The procedure has been described with or without hypothermia. The hypothermia can be achieved with the help of ice-slush placed in a polythene bag. The hilum is secured en bloc using a Satinsky clamp before making the incision over Brodel's line. Laparoscopic ultrasonography (US) helps to identify the exact location of the stones. Before clamping, Brodel's line is marked with electrocautery. Once the incision is made the stones are picked up with a stone grasper and collected in a retrieval bag (Fig. 1).

Review of reports and results

Deger et al. [19] reported the first use of LAN for a staghorn calculus in an adult patient. The collecting system was closed with a polyglactin 3/0 running suture and gelatin-matrix thrombin tissue sealant was used to seal the system. The cold ischaemia time was 45 min. Simforoosh et al. [20] used LAN to duplicate open AN in five patients with large staghorn renal stones who were unsuitable for PCNL. Only the renal artery was clamped, using a bulldog clamp. The stone was removed through a nephrotomy incision on Brodel's line, which was closed using 3/0 polyglactin continuous sutures, and sutures were buttressed by haemostatic clips. The authors concluded that LAN is a promising alternative for patients who are candidates for open surgery, with an acceptable stone-free rate.

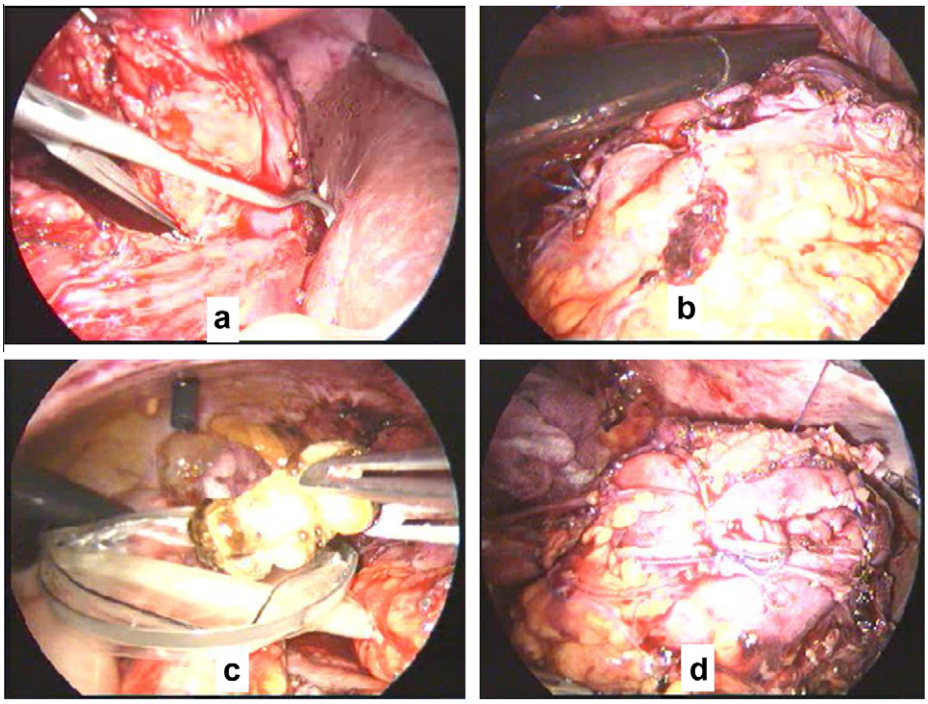

Figure 1 LAN: (a) A Satinsky is applied en bloc to the renal hilum; (b) intraoperative US helps to delineate the stones; (c) stones collected in the bag; (d) the defect is closed with surgical and Hem-o-Lok clips.

Laparoscopically-assisted PCNL in malrotated, horseshoe and ectopic pelvic kidneys

The management of calculi in a horseshoe kidney is a treatment dilemma. The aberrant location, vascular anomalies, and proximity to the peritoneal cavity, sigmoid colon and iliac vessels all contribute to the difficulty in a standard fluoroscopy-guided percutaneous approach. Calculi in the isthmus of the horseshoe kidney and a large stone burden in a pelvic ectopic kidney are indications for laparoscopy.

Maheshwari et al. [21] described stone fragmentation and clearance of stone in the isthmic calyx. The obvious technical difficulties with the endourological approach include the awkward angle of access and the need for expertise.

After placing a ureteric catheter the patient is placed supine with flank elevation. An 11-mm port is placed in the suprapubic region, and two additional ports are placed, one in the left iliac fossa and one in the axillary line above the umbilicus. Once the bulge of the horseshoe kidney is identified, the bowel is reflected from the area of concern. The affected calyx is opacified and access gained just below the umbilicus. The tract is dilated sequentially with metal dilators. Simultaneous fluoroscopic and laparoscopic monitoring helps to prevent bowel injury and accurate tract dilatation.

In one of our patients (Fig. 2), there was a large calculus lying over the isthmus of the horseshoe kidney. CECT confirmed the awkward position of the stone in relation to the pelvicalyceal anatomy, a laparoscopic pyelolithotomy was planned and the stone was removed intact.

In the pelvic kidney, the various options available for managing these stones include flexible ureterorenoscopy, US-guided percutaneous stone removal and laparoscopic-assisted stone removal. The treatment option should be tailor-made and depends on the surgeon's experience, stone bulk and the anatomy.

Lee and Smith [22] described a technique to access stones in pelvic kidneys. The approach involves retrograde access using the Hunter Hawkins system. Laparoscopy is used as an adjunct to move the adjacent bowel to a safer location. The needle is passed retrogradely and grasped laparoscopically. The needle is pulled through the anterior port with the catheter, and thus a through-and-through access is gained. The rest of the procedure proceeds as a standard PCNL.

Eshghi et al. [23] were the first to use the laparoscope to visualise a pelvic kidney and guide percutaneous nephrostomy access. There have been subsequent similar reports, the largest including 15 patients, by Holman and Toth [24]. Peripelvic inflammation and several aberrant vessels might be found while dissecting the pelvis, and this requires expertise in laparoscopic dissection. Toth et al. [25] reported the removal of a renal stone by laparoscopically assisted transperitoneal PCNL in a pelvic dystopic kidney. They used laparoscopy to guide the puncture and retract the bowel. Harmon et al. [26] reported the removal of a renal calculus laparoscopically through the peritoneal route in a pelvic kidney. El Kappany et al. [27] showed the feasibility of the

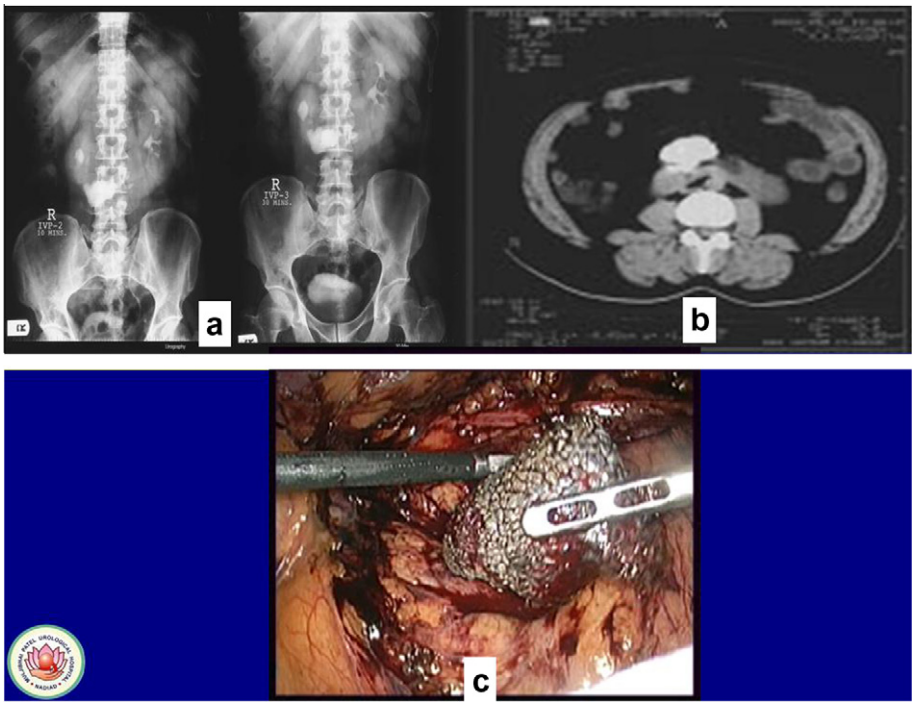

Figure 2 LP: (a and b) appropriate imaging in the form of IVU and CT help to ascertain the anatomy of the pelvicalyceal system and the vascular anatomy. (c) The incision is made over the pelvis and the stone removed.

combination of laparoscopy and nephroscopy in managing stones in pelvic ectopic kidneys in 11 patients, with good results.

Laparoscopic management of ureteric calculi (LU)

Before the advent of ESWL and ureteroscopy, the management of ureteric calculi was largely by an open surgical approach. Since the introduction of ESWL and ureteroscopy for managing ureteric calculi the routine use of an open surgical approach for removing ureteric calculi has rapidly declined. The indications for LU include stones which either cannot be accessed ureteroscopically or cannot be fragmented. The main advantage of LU for large upper ureteric stones is the high stone-free rate after one procedure, thereby allowing the patient an early return to regular activities. The disadvantages include a longer hospital stay and the risk of injury to intra-abdominal structures inherent in the laparoscopic approach. LU can be done transperitoneally or retroperitoneally.

The advantages of retroperitoneoscopic surgery over transperitoneal access include avoidance of contamination of the peritoneal cavity, no shoulder-tip pain after surgery, previous abdominal surgery not precluding this approach, and a lower incidence of long-term complications, such as port-site hernia and bowel obstruction. In addition, bowel mobilisation is not required, and thus the risk of inadvertent bowel injury or ileus is minimised in the transperitoneal approach to give excellent working space.

The location of the stone dictates the exact site of port placement. When the stone is in the proximal ureter, the port positions and patient position are similar to kidney surgery. However, if the stone is in the lower ureter the ports should be shifted caudally. Once the ureter is identified the stone is identified by a bulge or by sounding the stone. The ureter is supported by a sling, as this helps to prevent stone migration. If the stone is small it can be removed with a grasper, but larger stones tend to break when using the grasper. If the area around the impaction is narrow it can require spatulation and a uretero-ureterostomy. The ureter is sutured with 4–0 polyglactin and a retroperitoneal drain placed after suturing (Fig. 3). Table 2 [9,28–30] shows the results for LU.

Laparoscopic nephrectomy and nephroureterectomy for calculus disease

Laparoscopic nephrectomy for xanthogranulomatous pyelonephritis is a technically challenging procedure, because of the distorted anatomy and the coexisting adhesions.

For the transperitoneal approach, once standard laparoscopic ports are inserted the colon is reflected medially. Placing a ureteric catheter on the ipsilateral side before surgery facilitates the identification of the ureter and the pelvis, which are raised to assist exposure of the renal hilum. The renal hilum is dissected using an electrocautery hook and harmonic scalpel. Renal hilar vessels are secured with Hem-o-Lock clips. Dense

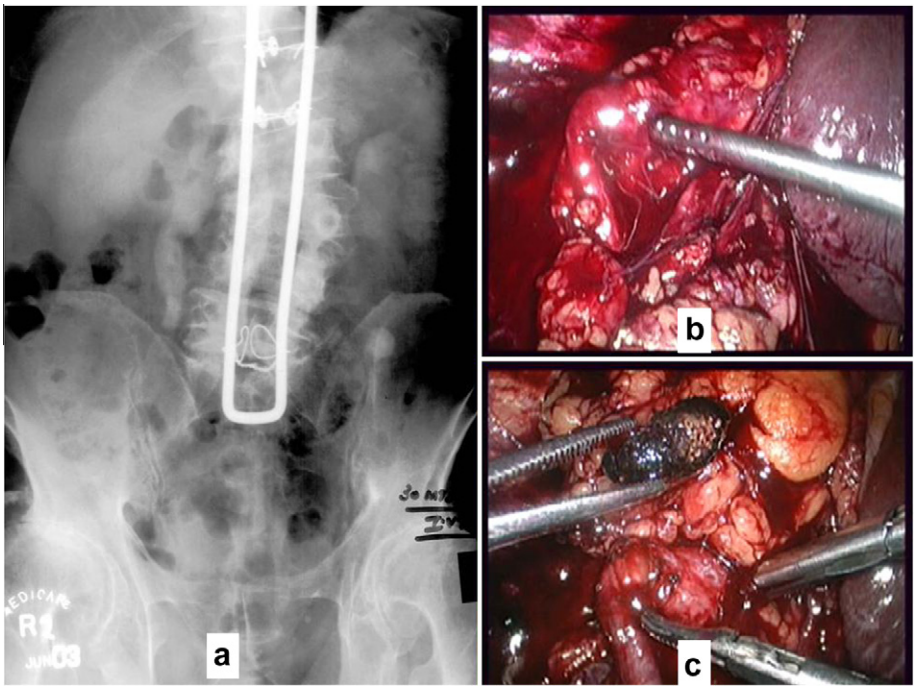

Figure 3 LU: (a) IVU showing an impacted upper ureteric calculus. (b) The ureter is dissected and the incision made over the stone. (c) The stone is extracted with stone-holding forceps.

Table 2 Results of LU.

	Series			
Variable	[9]	[28]	[29]	[30]
No. of patients (procedures)	12	25 (27)	40	21
Mean stone size (cm)	–	1.9	–	–
Access RP/TP	RP	TP	RP	TP
Operative duration (min)	40	145	106.3	90
Mean blood loss (mL)	–	62.5	69.8	–
Conversions, n/N	3/12	–	10/40	–
Stone clearance rate, n/N (%)	9/9	27/27 (100)	30/40 (75)	19/21 (90)
Complications, n	–	1[a]	1[b]	–
Hospital stay (days)	1	4.1	3.76	–

TP, transperitoneal; RP, retroperitoneal.
[a] Postoperative leak, required JJ stenting.
[b] Vascular injury.

adhesions, when present at the upper pole, are dissected with the harmonic scalpel. Extra-Gerotal dissection is preferred to prevent entry into the infected renal unit, but at times subcapsular nephrectomy is required. Spillage of pus or infected urine is avoided by applying clips on either side of the ureter before it is divided. The specimen is placed in an indigenously-made specimen-retrieval bag. The specimen is extracted through extension of 11-mm port or iliac fossa incision.

The risk reduction strategies to be used are: (1) placing a percutaneous nephrostomy in selected patients; (2) preoperative CECT to identify the anatomy of the renal hilum, as well as its relationship with surrounding structures; (3) preoperative placement of a ureteric catheter in patients with a history of intervention, especially open surgery; (4) intraoperatively identifying landmarks to maintain an adequate tissue plane and to avoid major complications; (5) extra-Gerotal dissection; (6) adrenal-sparing subcapsular upper-pole dissection; (7) avoiding spillage of infected contents by double clipping the ureter before division.

Occasionally the lower pole is rendered non-functioning because of calculus pyelonephritis. A lower-pole partial nephrectomy would be the preferred treatment option in such cases (Fig. 4).

The laparoscopic approach in properly selected and prepared patients with a non-functioning kidney is associated with reduced hospital stay, blood transfusion

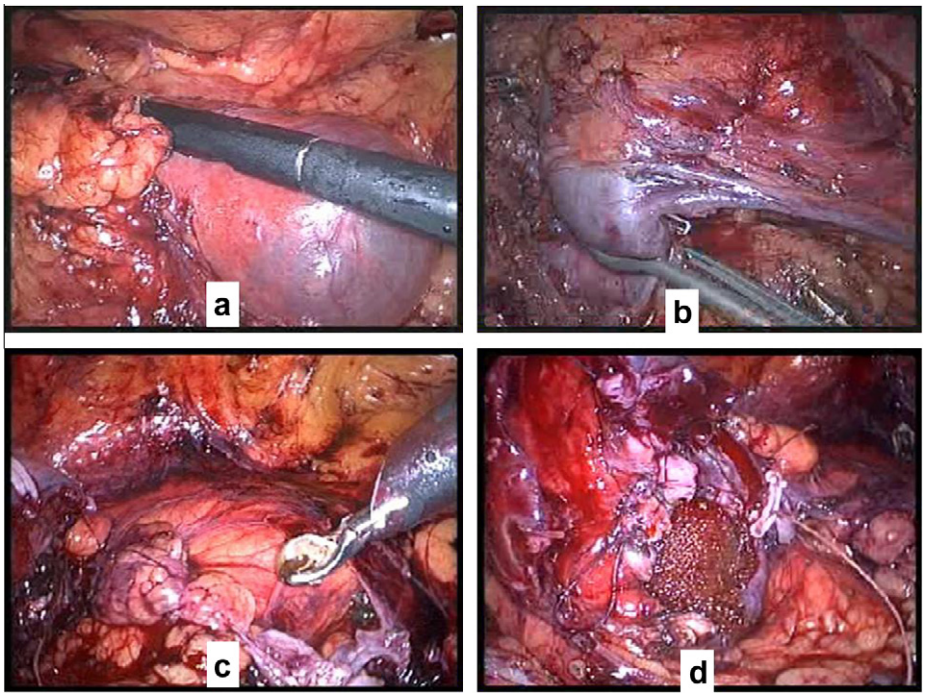

Figure 4 Laparoscopic lower-pole nephrectomy: (a) intraoperative US; (b) securing the hilum; (c) incising the lower pole and stone removal; (d) closure of the lower-pole defect.

rate, shorter convalescence and better cosmesis than with the open approach. The laparoscopic approach requires proper placement of ports for meticulous surgical dissection. Preoperative plain and CECT helps to identify the renal hilar anatomy and relationships with surrounding structures. Placing a percutaneous nephrostomy before surgery helps to identify kidney anatomy and facilitates hilar dissection by anchoring the kidney at the lateral abdominal wall.

Application of robotics in managing upper tract calculi

There are few reports of using robotic surgery in patients with urolithiasis. A meta-analysis [31] suggested that before embarking on robot-assisted procedures for upper urinary tract stones, the selection of patients should be appropriate. That analysis suggested that robot-assisted surgery is useful when the patient is undergoing simultaneous upper tract reconstruction, such as pyeloplasty.

There is a clear advantage to this approach in reconstructive surgery because of the endo-wrist instrumentation, seven degrees of freedom, excellent visualisation and tremor filtration. The obvious disadvantage of this approach is cost. Robot-assisted pyeloplasty is 2.7 times more expensive than the laparoscopic approach. The cost increases mainly due to longer operative times, higher consumables and depreciation of robotic equipment. The performance of concomitant procedures, i.e. pyelolithotomy and pyeloplasty, might decrease the expense of the robot, as the procedures are combined [31].

Although robotic procedures essentially duplicate the laparoscopic approach, there are a few inherent differences in port positioning. Lee et al. [32] described a procedure with the patient in a modified flank position with minimal to no flexion of the operating table. Three ports were used; one 12-mm camera port, an 8-mm port in the midline supra-umbilically and one port in the midclavicular line infra-umbilically. In addition, a 12-mm assistant port was used, and on the right side a 5-mm port was used for retraction. Once the pelvis was dissected and the colon reflected, the renal pelvis was opened with a cold scissors. The pelvic stone was removed with a robotic grasper and the remaining calyces inspected with a flexible ureteroscope. Badani et al. [33] described using a nephrotomy incision for retrieval of the stone. The coexisting PUJO was repaired with 7–0, 6–0 or 5–0 poliglecaprone running or interrupted sutures 12–14 cm long. In the experience of Mufarrij et al. [34], the cephalad robotic arm was temporarily undocked to allow the passage of a flexible ureteroscope for stone removal.

There are few reports of robotic procedures for upper tract stones. In a large series of robot-assisted pyeloplasty by Mufarrij et al. [34], 9.3% patients had the stone extracted. Although the blood loss and operating room time were reasonable in robotic series, the data were not uniform for variables such as stone size, number and location. In addition the series by Lee et al. [32] and Badani et al. [33] suggest that robotic extraction of staghorn stones is challenging, with a high chance of open conversion.

Conclusion

The laparoscopic and or robotic approach has its indications in extraordinary and unusual circumstances, e.g. anatomical abnormalities like a pelvic or horseshoe kidney. Laparoscopic surgery is effective in these complex renal stones and offers excellent stone clearance rates with minimal morbidity. Robot-assisted laparoscopic techniques for urinary tract stone management is in its early stage of implementation, and randomised trials that compare robot-assisted outcomes with other minimally invasive techniques are needed.

Conflict of interest

The authors have no conflict of interest to declare.

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