Experience with robotic assisted laparoscopic surgery in upper tract urolithiasis

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Objective: *Early results indicate that robot assisted laparoscopic surgery (RALS) may be useful in managing upper tract (UT) urolithiasis. We reviewed our experience of managing 50 cases of UT urolithiasis with or without reconstruction using RALS.*

Materials and methods: *We performed a record review of 50 cases of RALS for UT urolithiasis performed in two institutions from July 2006 to June 2009. The RALS procedures included pyeloplasty with pyelolithotomy (29 cases), ureterolithotomy, tailoring and reimplantation for megaureters (5 cases), ureterolithotomy with ureteral stricture reconstruction (1 case), primary UT stone surgeries (8 cases), partial nephrectomy (1 case) and ablative surgeries (6 cases). Data pertaining to indications, operative details, and complications were analyzed.*

Results: *The average operating time was 105 min (86 min-135 min) for pyeloplasty with pyelolithotomy, 140 min (115 min-195 min) for ureterolithotomy, tailoring and ureteroneocystostomy and 106 min (88 min-174 min) for extended pyelolithotomy (5 cases). Mean blood loss was 77 mL (50 mL-250 mL). Stone clearance rate was 93.2%. One case of extended pyelolithotomy had hematuria requiring selective angioembolization. There was one conversion and no other major complication.*

Conclusions: *RALS for UT urolithiasis is safe and efficacious. It is particularly useful when stone removal is combined with reconstruction. It is a reasonable alternative for treating a solitary partial staghorn or a large pelvic stone including those in pelvic/anomalous kidneys. RALS did not seem substantially better than pure laparoscopy for isolated ureterolithotomy and for nephrectomy for a nonfunctioning kidney. Its role in the treatment of large, multiple or complete staghorn calculi needs further investigation.*

Key Words: kidney, urolithiasis, ureteral stone, pelvic kidney, ureteropelvic junction obstruction, laparoscopy, megaureter, nephrectomy, nephroureterectomy, pyelolithotomy, ureterolithotomy, ureteric stricture

Introduction

Endourological techniques like ureteroscopy and percutaneous nephrolithotomy (PNL) and extracorporeal shockwave lithotripsy (SWL) are the procedures of choice for most upper tract urinary calculi. Open renal surgeries are a rarity and very few centers perform many anatrophic nephrolithotomies. Nevertheless there is still a place for open surgery not only in the management of urolithiasis associated with anatomical obstruction that require adjunctive reconstructive procedures like ureteropelvic junction obstruction or primary obstructive megaureter but also in patients with large staghorn calculi. Open stone surgery, but for its morbidity, has the advantages of a high stone free rate in a single session, often without the need for fragmentation, even in the presence of a large stone burden. Recent feasibility studies indicate that laparoscopic techniques and more recently robotic techniques may be used to combine the advantages of a minimally invasive approach with the high success rates

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of open surgery in selected patients with renal calculi who are unsuitable for the endourological approach.[1-3] The da Vinci (Intuitive Surgical, CA, USA) robot has been shown to facilitate laparoscopic intracorporeal reconstructive procedures and has been used to great advantage in procedures like radical prostatectomy[4] and pyeloplasty.[5,6] With a view to assess the safety, efficacy and the extent to which robot assisted laparoscopic surgery (RALS) can be used in the management of upper urinary tract urolithiasis and to find its potential status , we reviewed our experience of 50 cases of upper urinary tract calculi that were managed by RALS.

Patients and methods

All cases of RALS performed in patients with upper urinary tract stone disease, that the primary author was associated with, in two different institutions from July 2006 to June 2009 were included in this record review. IRB approval for the study was obtained at one institution but was not mandated in the other for retrospective studies. RALS was performed on all consenting patients on whom open rather than endourological surgery was indicated. Specifically, the patients undergoing surgery primarily for upper tract stones had been explained the pros and cons of open/minimally invasive surgery as well as of endourological procedures like PNL for renal calculi and ureteroscopic lithotripsy for ureteral calculi.

No case was excluded on the basis of pyelocaliceal anatomy, stone burden or previous operations on the kidney. Data was analyzed to determine the indications, procedures performed, operating time, blood loss, hospital stay, stone clearance rate, postoperative complications and ancillary procedures.

The operative technique

A standard preoperative workup was done for each case. The da Vinci-S four armed robot was used for the robot assisted laparoscopic procedures. The port positions used were as described earlier for robotic kidney and pelvic surgery.[7-9]

We describe our technique of robotic extended pyelolithotomy (REP), which is based on standard principles of open stone surgery. The patient was placed in a modified (45 degrees to 60 degrees) lateral decubitus position with minimal flexion of the operating table and kidney rest elevation. After establishing pneumoperitoneum by placing the Veress needle in the ipsilateral hypochondrium/iliac fossa, the rest of the ports were placed. The sites for port placements were mapped out after the pneumoperitoneum was established, Figure 1.[7]

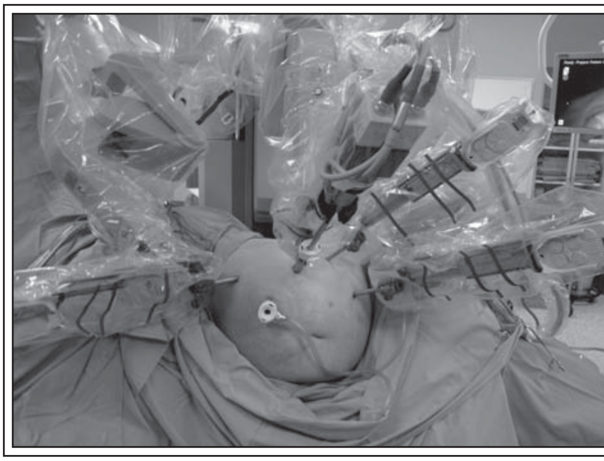

Figure 1. Picture depicting the docked da Vinci-S 4-arm robot. The camera port is a 12 mm port. Three 8 mm metal ports have been placed for the robotic instruments. The port with the pneumoinsufflation tube is for the patient-side assistant.

For left sided procedures, a limited mobilization of the colon overlying the kidney and renal pelvis was performed by incising along the line of Toldt. For right sided procedures an additional 5 mm port, placed below the xiphoid, was sometimes required to retract and elevate the right lobe of the liver and provide a better view of the renal hilum and pelvis. The hepatic flexure, ascending colon and duodenum were mobilized to provide access to the renal hilar area. Entire mobilization of the kidney (especially the lateral attachments) was avoided to prevent it from flopping medially. The ureter was then identified and followed cranially to identify the renal pelvis which was dissected free from its surrounding peripelvic fat. This was followed, if required, by correctly developing the Gil-Vernet's plane which allowed exposure of the infundibula of major calices, especially in cases with intra-renal pelves. The renal vessels (the renal vein in particular) usually lie abutting the cranial edge of the renal pelvis and this tends to limit the extension of the pyelotomy into the superior infundibulum.

Once the pelvis was adequately dissected a V-shaped pyelotomy was made with or without extension into the inferior and/or superior infundibula as per requirement. The pelvic mucosa was dissected off the stone to mobilize it using the tip of the cold scissors. The stone was maneuvered into such a position that its smallest diameter aligned with the pyelotomy. This helped deliver out one end of the stone first. This was followed by manipulation of the stone in a see-saw manner to deliver the rest of it. The camera was then moved into the pyelotomy incision and any secondary caliceal calculi were retrieved under vision by the patient side assistant using a laparoscopic blunt tip fenestrated grasper or by the surgeon using an EndoWrist ProGrasp forceps (Intuitive Surgical Inc., Sunnyvale, CA). Flushing and irrigation were also used to retrieve small caliceal calculi. In a few cases we used a flexible nephroscope or a flexible ureteroscope to inspect the pelvicaliceal system and retrieved the stones using nitinol baskets. All the stones were removed intact without any intrarenal fragmentation and placed in the ipsilateral paracolic gutter for later retrieval.

Once the stones were removed, an antegrade double pigtail ureteral stent was placed over a guide wire introduced through the 5 mm assistant laparoscopic port and the stent could easily be manipulated into the ureter with the robotic instruments thereby avoiding the need for cystoscopy and prior placement of a stent. The proximal end of the stent was then placed within the renal pelvis prior to closure.

The infundibular and pyelotomy incisions were sutured in a running fashion using 5-0 poliglecaprone on an RB-1 needle. The peripelvic fat was also approximated to isolate the repaired pyelotomy. The Gerota's fascia was approximated to close off the perinephric space from the peritoneal cavity. The stones were retrieved from the paracolic gutter using a plastic pouch like the Endo Catch (Covidien AG, Germany) after closure of the collecting system. With care it was possible to retrieve all the stones without losing any of them. An intraperitoneal 10 or15 F Jackson-Pratt drain was placed through the 5 mm assistant's port.

The robotic instruments and camera were then removed and the robot undocked. A 5 mm, 30 degree laparoscope lens was placed through the 5 mm assistant port to provide laparoscopic vision. The specimen bag was then retrieved through the 12 mm camera port by marginally enlarging the port site, thus avoiding another incision to remove the bag from the peritoneal cavity. One can also crush the stone within the plastic bag using a Kelly's clamp or break it into small pieces using any of the stone breaking devices, to facilitate extraction of the bag without unduly enlarging the port site.[10] In this manner, only three robotic ports (one 12 mm and two 8 mm) and an additional 5 mm assistant port were required in most cases. Alternatively if a 12 mm assistant port is placed instead of a 5 mm port, it can also serve as a site for specimen bag insertion and retrieval.

For other robotic assisted surgical procedures on the kidney or upper ureter for stone disease the port positions and other basic steps were similar to that described for REP. The renal artery was controlled with a bull dog clamp for procedures involving incision on the renal parenchyma (partial nephrectomy and nephrolithotomy).

Postoperative management

Postoperatively the patients were initially given clear liquids and advanced to a regular diet on the first postoperative day. Pain was usually well controlled with scheduled ketorolac 15 mg IV or PO every 8 hours for 2 days and prn narcotics for breakthrough pain. We routinely used anticholinergics for stent colic. Ambulation was encouraged as soon as tolerated. The surgical drain was kept off suction, and then removed when there was less than 30 mL drainage over 24 hours; this was usually on the first postoperative day. The urethral catheter was removed on the day following drain removal just prior to discharge. With this regimen most patients were ready to go home in 24 to 48 hours. The double pigtail ureteral stent, placed intraoperatively in every reconstructive procedure, was removed after 2 to 4 weeks as an office procedure. Follow up x-ray KUB or CT stone study was performed to confirm stone clearance.

Results

Overall 50 cases had undergone RALS for upper urinary tract urolithiasis at these two institutions from July 2006 to June 2009. All the cases had a normal serum creatinine.

The procedures performed have been classified into three groups: Group A (36 cases) - Stone extractions in cases associated with reconstructive procedures such as pyeloplasty or ureteral reimplantation, Group B (8 cases) - Procedures like pyelolithotomy, extended pyelolithotomy or nephrolithotomy performed primarily for removal of large volume stones and Group C (6 cases) - Consisting of ablative procedures. The details of the various procedures performed are given in Table 1.

In the first group the average duration of surgery including robotic time for the 29 cases of pyeloplasty was 105 min (86 min to 135 min) including stone extraction time. Ureteral reimplantation (5 cases) with tailoring and stone extraction required an average of 140 min (115 min to 195 min) of operating time while the lower pole partial nephrectomy took 136 min. The estimated blood loss (EBL) was in the range of 50 mL to 100 mL (mean 80 mL) in all cases except for the lower pole partial nephrectomy (250 mL). Anastomotic patency was documented with dynamic renal scan at 6 months postoperatively in all cases of pyeloplasty

TABLE 1. **Details of robotic procedures performed in upper urinary tract urolithiasis**

Group	Indications	Details of procedure employed	No. of cases
Group A - Major reconstructive procedures with stone extraction	Ureteropelvic junction obstruction with secondary stone	Pyeloplasty with pyelolithotomy	29
	Non-functioning lower pole with inferior caliceal calculi	Lower pole partial nephrectomy with stone extraction	1
	Megaureter with stones	Ureteric tailoring and reimplantation combined with stone extraction	5
	Ureteric calculus with ureteral stricture	Ureterolithotomy with resection and anastomosis of ureter with omental wrap	1
Group B - Procedures primarily for stone removal	Partial staghorn renal calculus	Extended pyelolithotomy	5
	Inferior caliceal calculus with narrow infundibulum and thin overlying parenchyma	Nephrolithotomy	1
	Calculus in right to left crossed ectopic kidney-failed case of SWL	Robotic pyelolithotomy	1
	Large mid-ureteric calculus	Ureterolithotomy	1
Group C - Ablative procedures	Non-functioning kidney with renal stone disease	Nephrectomy	4
	Non-functioning hydroureteronephrotic kidney with ureteral calculus	Nephroureterectomy with stone removal	2
Total			**50**

except one. Symptomatic efficacy rate was 97% with one case of pyeloplasty having persistent pain.

For robotic pyelolithotomy and extended pyelolithotomy the average operating time was 106 min (88 min-174min) with an EBL of less than 50 mL in all the cases. The average stone size was 3.5 cm. One case, where nephrolithotomy had been performed, had a blood loss of 200 mL. This patient also needed conversion to an open procedure due to non-localization of stone with robotic visualization. Complete stone clearance was achieved in five out of six cases of robotic pyelolithotomy and extended pyelolithotomy.

Nephrectomy and nephroureterectomy cases had a mean operating time of 80 min and 110 min respectively while the EBL was 50 mL to 100 mL (mean 79 mL). The specimen was retrieved intact by extending one of the port sites. All cases withstood the procedure well with no intraoperative complications.

Complete clearance of stones was achieved in 41/44 (93.1%) cases in groups A and B. Thirty-one cases had a single stone and 30 (96.7%) of them achieved complete clearance. The remaining 13 had multiple calculi and 11 (84.6%) of them had complete stone clearance. An additional procedure in the form of SWL was performed in two of the three cases with residual calculi to achieve complete stone clearance. The third case is under follow up and is symptom free. One case of REP had prolonged hematuria in the postoperative period and required selective angioembolization for control of bleeding. The average hospital stay for the entire study population was 2.7 days (range 1-4 days). One case of robotic assisted pyelolithotomy/

pyeloplasty had febrile urinary tract infection 2 weeks postsurgery and was managed conservatively with antibiotics. One case of pyeloplasty, performed on a giant hydronephrotic kidney, failed and the patient underwent a simple nephrectomy.

Discussion

In the quest for minimally invasive option for management of urolithiasis RALS is the most recent entrant. Although more than 95% of upper urinary tract urolithiasis can be managed by endourological techniques there is still a place for open surgery. This is most clearly seen in the management of urolithiasis associated with anatomical abnormalities like ureteropelvic junction obstruction and primary obstructive megaureter. It also has a role, albeit small, in the management of large staghorn calculi especially in those patients with unfavorable collecting system anatomy or morbid obesity as has been accepted by the American Urological Association Nephrolithiasis Guideline Panel.[11] RALS has already established itself as a viable minimally invasive alternative for a number of complex renal ablative and reconstructive procedures such as pyeloplasty and partial nephrectomy and substantial data has already been published from different centers.[8,9] These studies have shown that RALS has better results than open procedures and at least equivalent results to corresponding laparoscopic procedures in terms of morbidity. The present study indicates that RALS can be effectively adopted for upper urinary tract lithotomy thus opening up newer minimally invasive options in the management of urolithiasis of the upper urinary tract.

Our study corroborates the findings of other published series that stone clearance in RAL pyeloplasty is routinely feasible, efficient and efficacious.[12] The additional maneuvers for stone clearance (which are detailed below) did not significantly add to the operating times. We did not find the need to use a flexible nephroscope routinely in every case for stone extraction. Routine use of flexible nephroscopy would have significantly increased operating times.[12] A similar observation has been made by Stein et al in their review of stone retrieval in laparoscopic pyeloplasty.[13]

The use of robotic technology for surgical treatment of primary upper urinary tract lithiasis has only recently been explored. The first case series of REP was published in 2006.[2] However, experience with the use of robotic assisted surgery for upper urinary tract lithiasis remains limited with only a few reports being published so far. To the best of our knowledge, the present series is the largest in literature reviewing RALS in stone disease for various pathologies and indications. Robotic assistance greatly facilitated the tailoring and reimplantation in ureteral surgery and similarly, it helped in robotic pyelocaliceal reconstruction after pyelolithotomy. In the case of reconstructive procedures like pyeloplasty or ureteral reimplantation the presence of stone did not add significantly to the operating time when compared with the average operating times for similar procedures performed on patients without calculus as published in literature.

Laparoscopic pyelolithotomy is also a feasible and well reported minimally invasive stone treatment modality but its role is limited to patients who have a non-staghorn renal calculus and a relatively capacious extra-renal pelvis.[14] Furthermore, laparoscopic reconstructive procedures are technically more demanding and, as is seen from the experience with radical prostatectomy, not uniformly reproducible in most centers. But with the advent of robotic assistance with its wristed instruments, 3D imaging and ergonomic comfort RALS is easier than pure laparoscopy not only to make an adequate pyelotomy with caliceal extensions if needed for stone extraction but also for accurate resuturing of the pyelotomy. With RALS intact removal of renal stones can be extended to patients with more complex pelvicaliceal anatomy as shown in our study. We have experience in both laparoscopy and robotic surgery in the management of stone disease and we strongly feel that clearance is better and reconstruction of pelvicaliceal anatomy more accurate with robotic assistance than with pure laparoscopy. The two recently published series of robot assisted laparoscopic extended pyelolithotomy reporting excellent results also testify to the same.[2,3]

The stones extracted from the renal pelves in the pyelolithotomies, though large, were sufficiently small to be delivered intact through the pyelotomy. However, stone fragmentation may be required in some cases such as a patient with a complete staghorn calculus. Although not used in our cases we feel there should be no difficulty in using any of the commonly used intracorporeal lithotripters, i.e. pneumatic, ultrasonic or Holmium laser lithotripter, for stone fragmentation. These can be introduced through the patient-side assistant's port. Intraoperative stone localization in robotic assisted surgery is still in its infancy. We used a combination of robotic visual cues and tactile cues through "sounding" by the patient-side assistant's laparoscopic grasping forceps. For stones located in the calices we found that extension of the infundibulo-pyelotomy is a useful maneuver that helped visualize the interiors of the calices.

Clearance of stones was aided by the suction-irrigation device, as copious irrigation of the pelvicaliceal system helped in clearing the secondary and free floating stones. In a few cases a flexible cystoscope or a ureteroscope, connected to a different endoscopic vision cart, and introduced into the abdomen through the cranial 8 mm robotic or the midline assistant 12 mm ports, was used and the stones were retrieved using nitinol baskets. To inspect and access different calices, pressure irrigation is required, which helps in intrarenal inspection and identification of caliceal stones. A technique of intraoperative flexible ureteroscopy has been described which can be adapted to stone localization.[15] Although we did not use intraoperative ultrasonography we feel it can be an additional aid in stone localization. However, fluoroscopy and intraoperative radiography are cumbersome as these would involve undocking and docking of the robot. Stone localization techniques in robotic surgery are still imperfect and thus we had to convert one such procedure in our series. There remains much scope for innovations in this area.

Robotic assisted extended pyelolithotomy for staghorn calculi or complex pelvic stones with secondary calculi have some limitations. The lack of haptic feedback through the robotic instruments makes it essential for the main surgeon to see rather than "feel" the stone. Recurrence of stones is also a concern, especially in metabolically active stone disease since these cases may require multiple procedures in their lifetime. Robotic assisted surgery is minimally invasive but the scar and fibrosis over the pelvis from previous renal surgery or SWL may make robotic reoperation more difficult. That said, acceptable results have been reported with robotic pyeloplasty in patients with previous failed open pyeloplasty.[16] Another drawback is that the space required for robotic arms, at present, limits its use only through the transperitoneal route approaching the pelvis from its anterior surface. Due to this anterior approach, the renal vessels present a major limiting factor in making an adequate superior infundibulotomy. Presence of anomalous vessels if any further hinders access into the interiors of the pelvicaliceal system. The inherent position of the patient and the robot precludes the satisfactory use of intra-operative fluoroscopy to assess residual calculi. Also there is a theoretical possibility of a visceral injury or leakage of urine into the general peritoneal cavity. Nevertheless, the risk of urine leak is much less than in open surgery as the reconstruction is very accurate in RALS. We did not encounter any such complication in our experience. Although we have performed retroperitoneoscopic robotic pyelolithotomy, it's not feasible to do this routinely in every case due to the limitations imposed by the patient's body habitus and stature. In contrast, in conventional laparoscopy retroperitoneoscopic approach is a viable alternative. The high cost of robotic surgery, as reported in literature, is also a major drawback[17] and although the cost would be less in high volume centers a significantly higher cost may be expected in the case of RALS for urolithiasis as compared to pure laparoscopic surgery.

Although endourology is the mainstay of treatment of large renal calculi, laparoscopic surgery has been shown to be an acceptable minimally invasive alternative. Meria et al compared PNL and laparoscopic transperitoneal pyelolithotomy for pelvic stones > 20 mm and found comparable results (82% versus 88% 3 month stone-free rate) but significantly longer operative time and different postoperative morbidity.[18] While bleeding was the predominant complication in the PNL group; open conversion and urinary leakage were seen in the laparoscopic group. They concluded that though PNL remains the gold standard for most large pelvic stones, specific indications needed to be determined for each of the techniques. Transperitoneal laparoscopic pyelolithotomy was successfully utilized in children with large pelvic renal calculi with failed SWL therapy in whom a percutaneous access failed.[19]

Our study reconfirms published preliminary reports that REP is a feasible and safe technique for renal stone surgery.[2] No doubt bulky renal stones present in a pelvis with an extra-renal configuration allowed an easier procedure; however the advantages of wristed robotic instruments and magnification allowed successful completion of the procedure in a pelvis with an intra-renal configuration also. REP is also suitable for treating a large calculus in a pelvic or an anomalously located kidney that is unsuitable for retrograde intrarenal surgery as well as PNL. Any patient who is deemed to be a candidate for traditional laparoscopy should be able to undergo REP. Despite the transperitoneal access and the inevitable minimal urine spillage no adverse sequelae have been reported. REP attempts to replicate the principles of open stone surgery in a select group of patients- i.e. bulky renal pelvic stones- without transgression of the renal parenchyma, thus obviating its associated inherent complications.[10] The procedure may thus serve as an additional technique, in the armamentarium of the urologist, in treating large renal calculi. Its renal parenchyma-sparing approach may especially prove useful in patients with bulky renal pelvic stone disease and impaired renal function/decreased renal functional reserve and yet allow the benefits of a minimally invasive approach. However, retroperitoneal robotic pyelolithotomy is difficult to perform routinely because of the challenging anatomical configuration of port placement required for docking the robot.

Although a direct comparison of robot assisted laparoscopy with pure laparoscopy was not carried out, based on our previous experience with pure laparoscopy the advantages of robotic assistance were most easily evident in procedures involving complex steps for reconstruction of the urinary tract. It did not seem to provide as significant an advantage while performing ablative surgical procedures like simple nephrectomy or nephroureterectomy for a non-functioning kidney with stone disease. Nevertheless these kidneys with stone disease had significant dense perinephric adhesions possibly due to previous episodes of pyelonephritis. The tedious dissection of these adhesions was made a little easier and more controlled with robotic assistance because of the better maneuverability of the robotic wristed instrument. However, these advantages were offset somewhat by the degree of wide excursions of instruments needed in upper tract procedures as compared to the pelvic procedures. Similarly, although we did perform one case, we feel that laparoscopic ureterolithotomy can be quite easily performed without robotic assistance, unless an associated reconstructive procedure like tailoring or reimplantation is needed. It is possible that robotic assistance in such procedures may just add to the cost of these procedures as robotic surgery has been shown to be more expensive than laparoscopic surgery.[17]

Overall, the availability of robotic assistance has added a new dimension to the minimally invasive management of upper urinary tract stones and merits more studies to define its status. Currently, its use is limited mostly to stone extraction during a reconstructive procedure like pyeloplasty or ureteral reimplantation. For cases where stone extraction is the primary aim the benefits of a minimally invasive procedure may be obtained in carefully selected patients using REP. At centers where the robot is available, it may provide a good minimally invasive alternative to other conventional techniques in these patients.

The role of RALS for upper urinary tract stone disease is being explored. Our study shows that RALS for stone surgery in the upper urinary tract is not just feasible but also safe with good efficacy. It is an excellent modality in patients who require concurrent reconstructive procedure in addition to stone removal such as pyeloplasty or correction of a ureteral stricture. Despite limitations, it is a reasonable alternative for a solitary partial staghorn or a large pelvic stone removal and this technique can be used in cases of urolithiasis where the kidney is located in a pelvic or an anomalous position and in patients on anticoagulants. Further investigations are needed to define the specific indications of REP. It may not be appropriate to use such an expensive technology for the extraction of an isolated ureteral stone removal or for performing ablative procedures on the kidney, which we feel can be done with pure laparoscopy. At this point in time, cost is a major impediment. □

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