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Robot-assisted anatrophic nephrolithotomy for complete staghorn stone

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Abstract

To assess the efficacy and safety of robot-assisted anatrophic nephrolithotomy (RANL) as a choice of minimally invasive treatment for patients with complete staghorn stone.

In a single-tertiary referral center retrospective study, 10 consecutive patients underwent RANL for complete staghorn stone. After dissection to the renal hilum and clamping of the renal vessels, an incision was made along the Brodel line and exposed the collecting system to extract the stone. Then, the collecting system and parenchyma were closed in layers. The outcomes included reduction of the stone burden, short- and long-term postoperative kidney function, and pain score.

The average age of patients was 54.6 years and body mass index was 27.58 kg/m^2. Mean warm ischemia time was 28.40 minutes, mean robotic console time was 137 minutes, and mean estimated blood loss was 83 mL. The mean length of stay was 5.4 days and there were no severe perioperative complications. Eight of 10 patients had >90% reduction in stone burden and 5 (50%) patients were completely stone-free. There was no significant decrease in postoperative estimated glomerular filtration rate compared with preoperative values after 1 month and 1 year.

Our experience with RANL demonstrated efficacy and safety in the minimally invasive treatment of complete staghorn stone in short- and long-term follow-up periods.

Abbreviations: CT = computed tomography, eGFR = estimated glomerular filtration rate, LANL = laparoscopic anatrophic nephrolithotomy, LOS = length of stay, OANL = open anatrophic nephrolithotomy, PCNL = percutaneous nephrolithotomy, RANL = robot-assisted anatrophic nephrolithotomy, SWL = Extracorporeal Shock Wave Lithotripsy, VAS = visual analog scale, WIT = warm ischemia time

Keywords: anatrophic nephrolithotomy, renal stone, robotic surgery

1. Introduction

Since the modality of percutaneous nephrolithotomy (PCNL) is currently considered the gold standard management for complete staghorn stone, its imperfect stone-free rate, multiple punctures, and times of further procedures are criticized.[1] The goal of decreasing the frequency of treatment for complete staghorn stone and preserved renal function is important. PCNL may cause fluid overload due to normal saline irrigation and may cause uncontrollable bleeding while performing the operation.[2] Open or laparoscopic anatrophic nephrolithotomy (LANL) will prevent such complications, but are not well established due to more time-consuming, more invasion, and equal stone-free rate as PCNL.[3] Robotic surgery is replacing open surgery for cosmetics and postoperative pain and replacing the laparoscopic approach for easier operation.[4] Recently, series of robotic-assist pyelolithotomy and nephrolithotomy for complicated renal stones have been reported.[5,6] However, no study discusses specifically about complete staghorn stone. This study is the first series study to use robot-assisted anatrophic nephrolithotomy (RANL) as an approach for complete staghorn stone.

2. Materials and Methods

2.1. Patient collection

In this single-center retrospective study, between May 2014 and October 2017, 10 consecutive patients with ipsilateral complete staghorn calculi underwent RANL by a single surgeon (C.-P.H.). Before surgery, all patients had an intravenous urography or abdominal computed tomography (CT) to evaluate stone burden and delineate calculi location in the affected kidney. They also underwent Tc-99m-MAG3 renal scintigraphy to assess preoperative renal function. All patients in the study signed informed consents and all data and information included in this article were anonymous.

Indications for RANL include complete staghorn stone and no active acute pyelonephritis. Before performing this new technique, the console surgeon had experienced >100 cases of robotic partial nephrectomy. Additionally, all patients who underwent RANL were informed about the advantages and risks of this procedure before the procedure.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Preoperative characters of patients included age, sex, body mass index, stone laterality, preoperative creatinine, and preoperative estimated glomerular filtration rate (eGFR) calculated by the Cockroft–Gault formula.[7] Operative and postoperative variables included warm ischemia time (WIT), robotic console time including docking time, operative time including anesthesia time, estimated blood loss, conversion rate to open or laparoscopic surgery, perioperative complications, visual analog scale for postoperative pain, length of stay (LOS), percentage of residual stone burden, postoperative 1-month creatinine and postoperative 1-month eGFR value, postoperative 1-year creatinine level, and postoperative 1-year eGFR value.

Plain abdominal radiographs were followed on postoperative day 2 and we calculated residual stone percentage according to the comparison of preoperative and postoperative area of radiopaque lesions. One year after RANL, patients underwent unenhanced CT to evaluate residual stone burden.

This study was approved by the Institutional Review Board of China Medical University Hospital for a retrospective study (CMUH109-REC1-079), and personal identifiers were completely removed and data were analyzed anonymously.

2.2. Surgical technique

Da Vinci Si 4-arm system was adopted consistently with the transperitoneal approach for all cases. Patients were positioned in the lateral decubitus position with the affected side up. A 12 mm camera port was inserted in the periumbilical area. Three 8 mm robotic working ports and 2 assistant ports (5 and 11mm) were then inserted in the ipsilateral upper quadrant, lower quadrant, and lateral abdomen (Fig. 1). The peritoneum was incised along the avascular white line of Toldt. After reflection of the colon and incising through the anterior lamina of Gerota fascia, the renal hilum was dissected to loop major renal vessels. The intraoperative ultrasound was applied to locate the stone burden first (Fig. 2). After all the suture and hemostasis materials were well prepared, the renal artery and vein were clamped separately by using the endo-bulldog vascular clamps.

Then, a longitudinal incision through the Brodel line was made by monopolar scissors. After incising the kidney, the staghorn stone was dislodged by robotic forceps with several big fragments and removed (Fig. 3). After removing the stones, the collecting system was closed with a 3-0 V-Loc™ (Covidien, Mansfield, MA) continuously and then repaired parenchyma with 1-0 Vicryl interruptedly. Next, the clamps of the renal vessels were opened. Hemostatic agents, such as Floseal™ (Baxter Healthcare Corporation, Deerfield, IL) and Surgicel™ (Ethicon, Somerville, NJ) were used to assist in hemostasis at the nephrolithotomy site. Then, place the stone fragments into the Endo Catch bag™ (Covidien, Mansfield, MA) and remove them from the umbilical wound. One Jackson-Pratt drain was put over the affected side of the renal fossa for observing in case of any postoperative bleeding. Foley catheter was kept for recording urine output and monitoring massive hematuria.

Postoperatively, patients were offered a liquid diet the next day after surgery and no dietary restriction thereafter if patients could be tolerable. Oral painkillers such as acetaminophen were given 4 times per day postoperatively for pain control. Discharge criteria included tolerance of general meals without nausea or vomiting, absence of abdominal distention, passages of flatus, and successful urination after Foley catheter removal.

3. Results

The mean age was 54.60-year-old. Six patients were females and 4 were males. The mean body mass index was 27.58 kg/m^2. The mean preoperative creatinine level was 0.96 mg/dL and preoperative eGFR was 83.80 mL/min/1.73 m^2 (Table 1).

All 10 procedures were performed as planned. There were no intraoperative complications including blood transfusion and no conversion to open surgery. The mean WIT was 28.40 minutes, the mean robotic console time was 137.00 minutes, the mean operation time was 205.00 minutes, and the mean estimated blood loss was 83.00 mL. The mean LOS was 5.40 days. There were no postoperative hospital readmissions within 1 month.

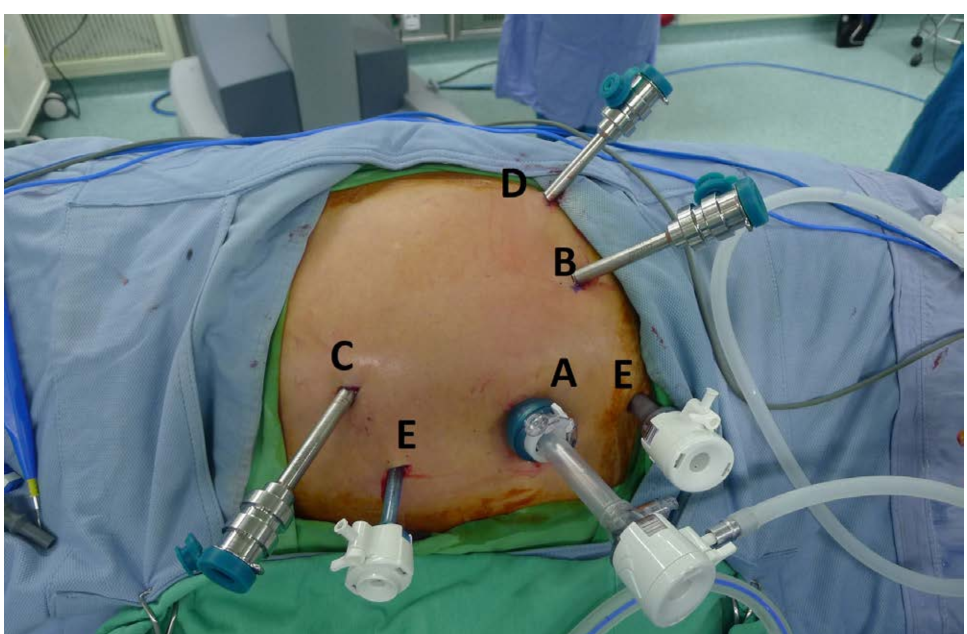

Figure 1. Port placements of robot-assisted anatrophic nephrolithotomy: (A) 12 mm camera port, (B–D) 8 mm working ports for Monopolar Curved Scissors, Maryland Bipolar Forceps and Prograsp, and (E) 5 and 11 mm assistant port.

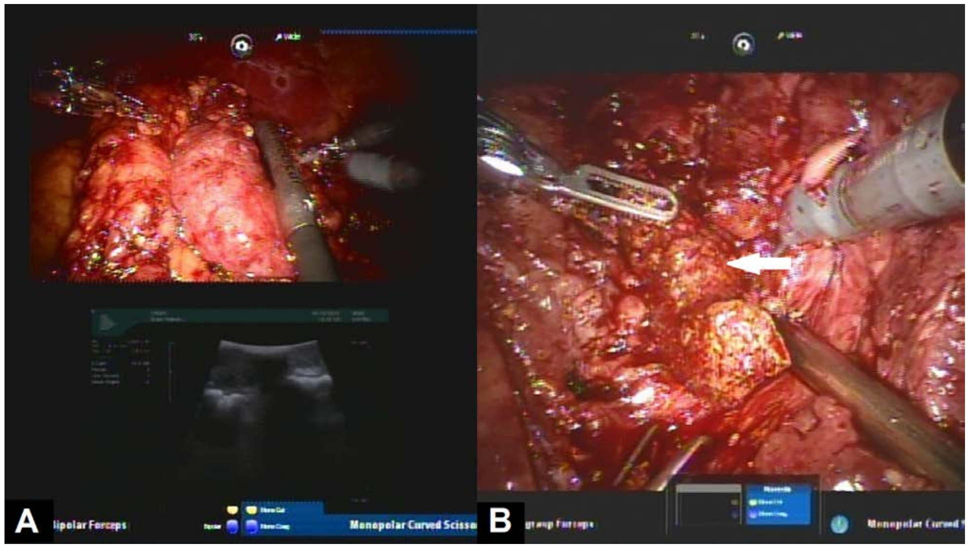

Figure 2. (A) Using intraoperative ultrasound in robotic system to evaluate stone location and (B) intraoperative complete staghorn stone extraction. White arrow = staghorn renal stone.

Figure 3. Stone burden of the patient.

On postoperative abdominal radiography, the first patient had 20% residual stone, which was evaluated by postoperative plain abdominal X-ray. One year later, CT showed that residual calculi were extrarenal spilled stones. Therefore, we performed another laparoscopic surgery to remove all calculi in the retroperitoneal space after well discussing with the patient. In fact, the residual stone under CT of the first patient was <3%. The second patient had a 10% residual stone burden due to 1 polar calyx stone being missed. The third case had a huge stone but the texture was fragile and it was difficult to be removed by robotic forceps quickly and effectively. After the robotic console, we changed the position of this patient from lateral decubitus to lithotomy for double-J insertion (Fig. 4). The 4th and 5th patients had tiny fragments of residual stone (representing <5% of total stone burden) and some were proved as spilled stones in retroperitoneal space after assessing by CT (Figs. 5 and 6). The 6th to 10th patients were rendered stone-free. Among patients with 10% residual stones, the second patient elected to have extracorporeal shock wave lithotripsy (SWL) 1 month after RANL and the third patient who had soft stone received PCNL 1 year later. The patients with <5% residual stone did not want to seek further treatment and some stone fragments spontaneously passed out in the follow-up period. The mean postoperative 1-month creatinine level and eGFR was 0.96 mg/dL and 82.70 mL/min/1.73 m^2, respectively. The mean postoperative 12-month creatinine level and eGFR were 0.95 mg/dL and 84.20 mL/min/1.73 m^2, respectively. Renal function (eGFR) decreased 1 month after the surgery in 1st, 5th, 7th, 8th, and 9th patients but gradually improved in 1 year.

Two cases suffered from postoperative fever and recovered 2 days after the operation. No sepsis, no postoperative bleeding, no ileus, nor hollow organ perforation was reported. All patients successfully removed the Foley catheter and Jackson-Pratt drain before discharge.

4. Discussion

The definition of complete staghorn stone was >80% stones in the collecting system. In other words, complete staghorn stone included renal pelvic stone extending into all major calyxes.[1] American Urological Association Guideline for the management of staghorn stone estimated stone-free rate following treatment is highest for PCNL (78%).[1] PCNL should be the first treatment utilized for most patients. The Clinical Research Office of the Endourological Society has reported the efficacy of PCNL for the treatment of 1466 patients with staghorn stones compared with 3869 patients without staghorn stones.[8] They found that 16.9% of patients with staghorn stones underwent multiple punctures and had low complete stone-free rates (56.9%). The 299 patients analyzed in the United Kingdom study group reported PCNL for staghorn calculi demonstrating the stone-free rate was about 59%.[9] These studies consisted of patients undergoing multiple procedures. Patients with previous PCNL or SWL were not excluded. The stone clearance rate may be the result of staged surgeries. Besides, the estimated stone-free rate for open surgery in monotherapy is about 71%.[1] Keshavamurthy et al reported a case series of open anatrophic

Table 1

Patient characteristics and perioperative variables.

Patient	1	2	3	4	5	6	7	8	9	10	Mean
OP year	2014	2014	2014	2015	2015	2015	2016	2016	2017	2017	
Age, yr	42	57	66	58	57	47	56	48	55	60	54.60
Sex	F	M	F	M	F	M	F	F	M	F	
BMI, kg/m^2	25.86	26.56	28.99	24.90	37.11	27.82	26.71	25.23	28.12	24.45	27.58
Laterality	Left	Left	Right	Left	Right	Left	Right	Left	Right	Left	
WIT, min	36	20	25	34	26	31	30	28	28	26	28.40
Console time, min	160	120	100	170	130	195	185	100	110	100	137
OP time, min	230	180	150	240	190	280	260	180	180	160	205
EBL, mL	50	100	50	200	200	50	50	80	30	20	83
LOS, days	6	5	4	7	6	5	5	5	6	5	5.4
Post-op 1 day residual stone, %	20	10	10	5	5	0	5	0	5	0	6
Post-op 1-yr residual stone, %	3	10	10	3	3	0	0	0	0	0	2.9
Pre-op Cr, mg/dL	0.65	0.79	0.78	1.26	0.66	0.87	1.35	0.98	1.21	1.07	0.96
Pre-op eGFR mL/min/1.73 m^2	101	102	74	59	92	94	76	88	69	83	83.80
Post-op Cr, mg/dL	0.66	0.68	0.78	1.21	0.77	0.77	1.36	1.02	1.33	1.02	0.96
Post-op eGFR mL/min/1.73 m^2	99	121	74	62	77	100	69	80	58	87	82.70
Post-op 1-yr Cr, mg/dL	0.65	0.77	0.75	1.23	0.68	0.89	1.22	0.97	1.26	1.10	0.95
Post-op 1-yr eGFR mL/min/1.73 m^2	101	103	78	61	90	91	78	88	70	82	84.20
Post-op VAS score	3	3	2	3	3	2	3	3	2	2	2.60

BMI = body mass index, Cr = creatinine, EBL = estimated blood loss, eGFR = estimated glomerular filtration rate, F = female, LOS = length of stay, M = male, mins = minutes, OP = operation, VAS = visual analog scale, WIT = warm ischemia time.

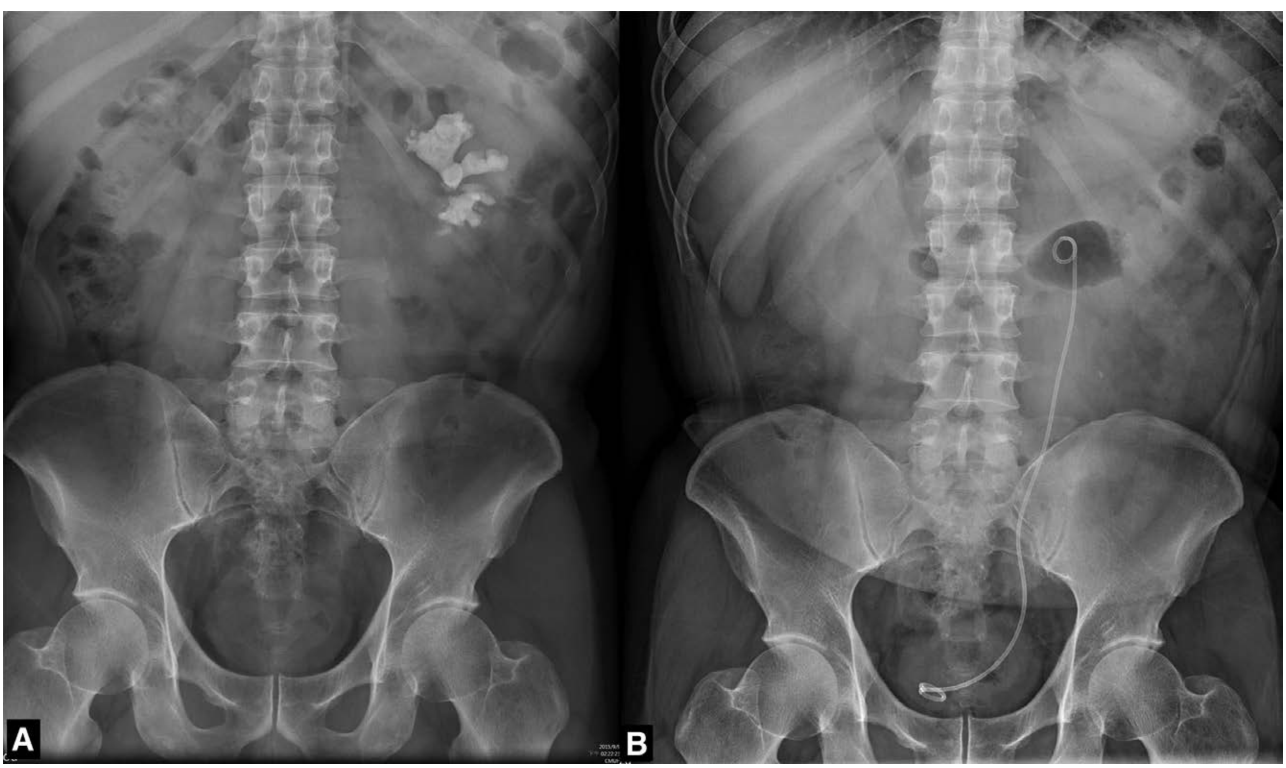

Figure 4. Decrease of stone burden after RANL. (A) Preoperative abdominal radiograph showed left staghorn renal stones. (B) Nearly stone-free was noted after the RANL. RANL = robot-assisted anatrophic nephrolithotomy.

nephrolithotomy (OANL) between 2008 and 2015, including 14 renal units. The median clearance rate is 95% and the stone-free rate is 28.6%.[10]

However, another minimally invasive laparoscopic technique has previously been applied to anatrophic nephrolithotomy in an attempt to recreate the stone-free rates of open surgery with less morbidity. Initial reports of laparoscopic anatrophic nephrolithotomy (LANL) were promising. Giedelman et al,[11] Simforoosh et al,[12] and Zhou et al[13] achieved results of 50% to 90% stone-free rate. However, the laparoscopic suture was more difficult to perform and complication of urine leakage was reported in a high proportion (50%).[10]

Encouraged by the successful experience of LANL, King et al[14] reported that RANL for the management of staghorn calculi was able to accomplish a 29% stone-free rate. These stone-free rates, however, are similar to those of Ghani and associates (33%).[15] In our experience, RANL achieved the 50% complete stone-free rate. Although the stone-free rate seems lower in the earlier patients, this may be explained by an early learning curve for RANL. After 5 cases of RANL in our series, we could

Figure 5. Pre- and postoperative plain abdominal radiographs. White arrow = extrarenal stone.

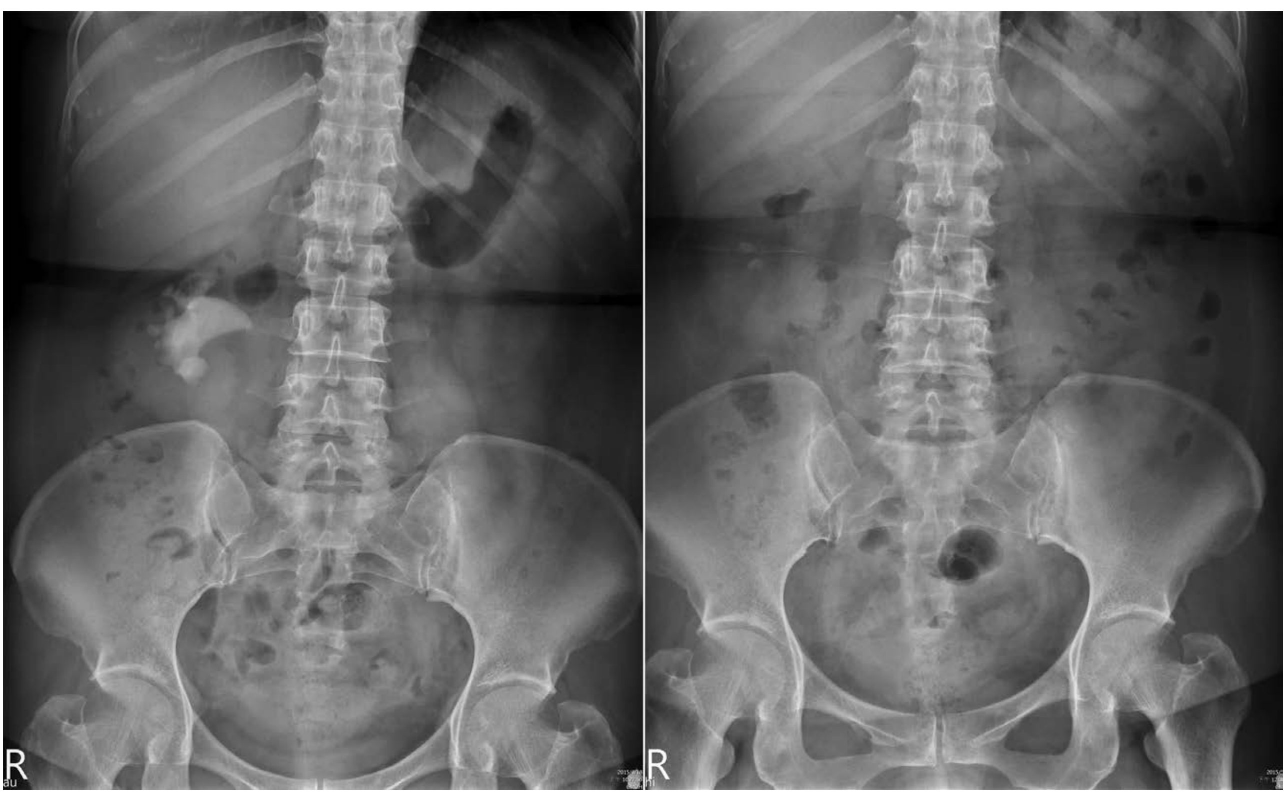

Figure 6. Pre- and postoperative plain abdominal radiographs.

achieve complete stone-free. To the best of our knowledge, this is the second study with the most patients reporting short- and long-term outcomes of RANL. We demonstrated that this procedure may achieve an impressive stone-free rate with a single procedure with minimal operative blood loss and morbidity after the maturity of the surgeon's technique. The good points of RANL include the 3-dimensional image, instruments without fulcrum effect, increased dexterity, more dedicated suture technique, and decreased surgeon fatigue.[16] Intraoperative ultrasonography may be feasible for kidney surgery and locating stone fragments during extraction.[17]

The renal function of our patients seemed minimal changes after RANL in 1 month and gradually better in 1 year. In King et al and Ghani et al's study, postoperative creatinine and eGFR

Table 2

Comparison with other anatrophic nephrolithotomy series.

	Patient number	Surgery	Ischemia time, min	Blood loss, mL	Length of stay, d
Current study	10	RANL	Warm IT 28.4	83	5.4
Giedelman et al[11]	8	LANL	Warm IT 20.8	315	3.5
Zhou et al[13]	11	LANL	Warm IT 31	<150	
Simforoosh et al[12]	5	LANL	Warm IT 32	<100	5.4
Keshavamurthy et al[10]	13 (14 renal units)	OANL	Cold IT 47.6	130	15.44

IT = ischemia time, LANL = laparoscopic anatrophic nephrolithotomy, OANL = open anatrophic nephrolithotomy, RANL = robotic-assisted anatrophic nephrolithotomy.

levels were comparable to their preoperative renal function in all patients.[13,14] Two patients suffered from postoperative fever and recovered 2 days after RANL. The complications of PCNL such as acute loss of a kidney, colon injury, hydrothorax, pneumothorax, prolonged urine leak, and vascular injury were not reported in our patients[18] because complications may be decreased by high-definition, magnified 3-dimensional view, and dedicated robotic suturing.

Our patients could tolerate pain and only needed oral painkillers. Compared with PCNL, patients usually needed double-J stents after PCNL for preventing stone fragments obstruction in the ureter.[19] The patients might suffer from lower urinary tract symptoms and flank pain caused by double-J stents.[20] In this case series, only 1 patient needed the double-J stent because of soft consistency of the stones to avoid ureteral obstruction by stone fragments. We might utilize the Hounsfield units of the stones on preoperative CT to predict the stone component.[21]

In our study, RANL was performed clamping the renal hilar vessels as WIT as King et al' study.[13] By comparison, the cold ischemia method which needed a large incision wound for inserting a hand port for placing ice slush around the kidney was used by Ghani et al.[14] Although there were 4 of 10 patients who had a slightly prolonged WIT of >30 minutes in our series, postoperative 1-month and 1-year creatinine and eGFR levels were comparable to their preoperative renal function in all patients.

There are some advantages to our series. First, we performed RANL with less WIT because the stones could be extracted soon. The reasons were that we had a good plan with preoperative CT and intraoperative sonography for precise stone location. Second, no ice water would be drained into the peritoneal cavity to minimize complications such as postoperative ileus, disseminated infection due to struvite stone or intra-abdominal fluid accumulation because we did not place ice slush. Third, no patients needed narcotic agents for pain control because their incision wound was small. Besides, only 1 patient needed the double-J stent because of the stone texture which cause many tiny stone fragments after RANL and the other 9 patients were double-J stent free to avoid postoperative double-J symptoms.[22] Last but not least, the blood loss of RANL in our study is less than in the previous series of LANL and OANL. The LOS of patients undergoing RANL is much shorter than patients receiving OANL[10–13] (Table 2).

The drawbacks of RANL for complete staghorn stone include, first, the low incidence resulting in difficulty to accumulate enough cases for a prospective, randomized study in a single center. Second, it is hard to use fluoroscopy to check stone-free status intraoperatively because of the robotic arms occupying the space and the need of minimizing the WIT. Besides, WIT, postoperative bleeding, or urine leakage remains a great concern for doing RANL. Spilled stones in RANL could be reduced by checking the surrounding area of the kidney meticulously after releasing the vessel clamps as well as bleeding control.

There are some limitations in the present study. It is a retrospective single-arm case series. There is no control group such as OANL, LANL, or PCNL. We did not compare the perioperative outcomes and the stone-free rate between the different surgical modalities directly. Besides, the case number is few and the outcomes are from a single surgeon's experience. Although RANL is a safe and efficacious method for complete staghorn stone, the procedure is technique-dependent and needs an experienced robotic surgery expert. Last, we only used serum creatinine to check the perioperative change in renal function. Although the patients underwent preoperative Tc-99m-MAG3 renal scintigraphy, most patients did not follow renal scintigraphy after the surgery. Therefore, it is difficult to evaluate the pre- and postoperative changes of the affected kidney.

5. Conclusions

Our experience with RANL demonstrated its feasibility for complete staghorn stone. We noted no severe complications, no difference of short-term measures of convalescence, and no significant differences in pre- and postoperative renal function. The stone-free rate is impressive after the procedure. With refinement and improvement of the technique, the utility of robotic surgery for the treatment of complete staghorn stone could be a safe and efficacious method.

Author contributions

P-JH is responsible for data collection and manuscript writing. J-KF and H-CC revised the manuscript. C-PH is involved in surgery, project development and supervision.

Data curation: Po-Jen Hsiao.
Project administration: Chi-Ping Huang.
Supervision: Chi-Ping Huang.
Writing – original draft: Po-Jen Hsiao.
Writing – review & editing: Hung-Chieh Chiu, Jen-Kai Fang, Po-Jen Hsiao.

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