Utilizing da Vinci® surgical system to treat challenging urinary stones

Basmah Al Tinawi, Morris Jessop, Mohamad W. Salkini

Department of Urology, West Virginia University, Morgantown, WV 26505, USA

Abstract

Introduction: A worldwide mounting in the incidence and prevalence of urolithiasis has been observed. The standard treatment of urologic stone disease (USD) has changed from open surgery to extracorporeal shock wave lithotripsy, percutaneous nephrolithotomy (PCNL), or ureteroscopy depending on the size and location of the stone. We are sharing our experience in utilizing Da Vinci® robotic surgical system to treat patient with urolithiasis instead of open surgical approach.

Patients and Methods: We reviewed prospectively collected data of 19 patients who underwent robotic-assisted stone surgery (RSS) between January 2010 and March 2018 at our institute for USD involving 22 nephroureteral units.

Results: A total number of 22 RSS were accomplished with no conversion to open. Three patients had bilateral stone and needed to have RSS on each side separately. Eleven RSS were performed on the right. The indications for RSS included as follows: morbid obesity ($n = 8$, mean body mass index 56.4 kg/m^2), need for concurrent renal surgery ($n = 3$) severe contractures limiting positioning for retrograde endoscopic surgery or PCNL ($n = 2$), symptomatic calyceal diverticular stone with failed endoscopic approach ($n = 4$), and after failed PCNL ($n = 2$). Twenty nephrouretral unit (91%) were rendered stone free on the first attempt with complication occurring after four cases (18%).

Conclusion: RSS is viable options in the treatment of challenging urologic stone with high success rate and low risk of complication. The need for open stone surgery was eliminated by RSS at our center.

Keywords: Challenging urinary stone, open stone surgery, robotic stone surgery, stone-free rate

Address for correspondence: Dr. Mohamad W. Salkini, Department of Urology, West Virginia University, One Medical Center Dr. Morgantown, WV 26505, USA.
E-mail: mhdsalkini@gmail.com
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INTRODUCTION

Human urolithiasis is an ancient disease known since more than 6000 years ago, and the first open stone surgery was documented in prehistoric era during the Indian, Chinese, and Greek civilizations.[1] It is estimated that 12% of the world's population will be afflicted by urinary stone at one stage in their lifetime.[2] Kidney stones develop in both genders of all races and at all ages.[3,4] However, male population within the age of 20–49 years was observed to be affected more frequently.[5] The American Urological Association and European Association of Urologists have been observing the worldwide mounting in the incidence and prevalence of urolithiasis.[4-8] One in 11 US citizen is expected to develop urologic stone in his lifetime and the incidence is even increasing.[9] In fact, with estimated cost

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of $2 billion, urolithiasis is considered the second-most expensive urological disease to treat proceeded only by urinary tract infection. Urinary stone disease (USD) really imposes major healthcare and economic burden with the loss of working days and cost of treatment.[10,11]

The treatment of urolithiasis depends on the size, location, and symptom. The presence of infection, obstruction, and deteriorated renal function should be considered in the management of the USD. Although only 10%–20% of urologic stone will require surgical intervention.[11-14] The end of the twentieth century witnessed major developments in the treatment of urolithiasis lead mainly by the advancing technology.[13] The currently considered standard treatments for USD are ureteroscopy, extracorporeal shock wave lithotripsy (ESWL), and percutaneous nephrolithotomy (PCNL). The role of open surgery for USD, on the other hand, is continuously declining.[12-14] In fact, open stone surgery is reserved for stone that failed the above-mentioned less invasive intervention.[14]

In 1999, Intuitive Surgical Inc., (Sunnyvale, CA, USA) introduced its first robotic surgical system, da Vinci™. Since then robotic-assisted surgery is gradually replacing open surgery in the field of urology as it has faster recovery, lower estimated blood loss (EBL) and shorter hospital length of stay (LOS).[15] Our initial encounter with robotically assisted stone surgery (RSS) started when UDS was found in the renal unit that needs robotic surgical intervention using the Da Vinci® robotic surgical system such as ureteropelvic junction obstruction, renal mass, and ureteral stricture disease. In other words, RSS stated as part of robotic pyeloplasty, robotic partial nephrectomy, and robotic ureteral reconstruction. Later, we utilized the Da Vinci® robotic surgical system instead of open surgery to remove the challenging urologic stone (CUS). In this paper, we are sharing our experience in utilizing Da Vinci® robotic surgical system to treat patient with CUS.

PATIENTS AND METHODS

We reviewed prospectively collected data of 19 patients who underwent RSS between January 2010 and March 2018 at our institute for USD in 22 nephroureteral units. All patients were evaluated with computed tomography (CT) urogram as the standard evaluation test. CT abdomen and pelvis without contrast infusion was used in patients with chronic kidney disease III or higher (glomerular filtration rate ≤ 45 mL/min). The robotic da Vinci® surgical system was initially utilized to treat CUS at our institute as a part of other robotic procedure initially then as *de novo* procedure. CUS is defined as a stone that affect urinary tract that is not accessible to or have failed the traditional minimally invasive approach of treatment such as ESWL, ureteroscopy, or/and PCNL. The failure was due to anatomic location of the stone, patient anatomy, or both. An example of difficult anatomic location is the stone in noncommunicating calyceal diverticulum [Figure 1], or stone in the presence of anatomic stricture of the urinary tract that prevent applying traditional endoscopic access.

Morbidly, obese patients with large stone [Figures 2-5] can preclude the patient from having PCNL, ESWL, and ureteroscopy, due to the lack of the appropriate instrumentation. We added the cases that needed intervention such as robotic partial nephrectomy, pyeloplasty, and reconstruction of the ureter. All the 19 cases of CUS were the kidney and upper ureteral stone.

Surgical technique

No special preoperative preparation was adopted for RSS. As in all robotic surgeries at our institute, patient was given 300 mL of magnesium citrate about 18 h before the planned surgery and was asked to stay on liquid diet till 8 h before the procedure. Of great importance is to make sure that the urine is sterile before the RSS. Perioperative antibiotics should be selected based on recent culture data, or, empiric broad-spectrum coverage against the typical skin and urinary flora if the urine culture was negative. We, routinely, adopt the standard methods used at our institute to prevent deep venous thrombosis. These include preoperative 5000 unit of subcutaneous heparin and sequential compression devices. An orogastric tube and an indwelling Foley catheter were always inserted. The transperitoneal approach was adopted in all patients with modified lateral decubitus position with minimal flexion of the operating table as it is shown in Figure 5.

We utilized three robotic arms, one for the camera and two for the instruments. The robotic trocars were placed in the upper quadrant with triangulation when using the Si robotic system like in Figure 6. The exact location of the robotic trocars depends on the anatomy of the kidney, stone

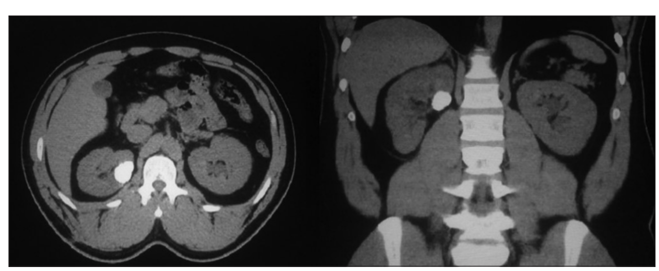

Figure 1: Computed tomography urography scan showing renal calculi in a closed diverticulum

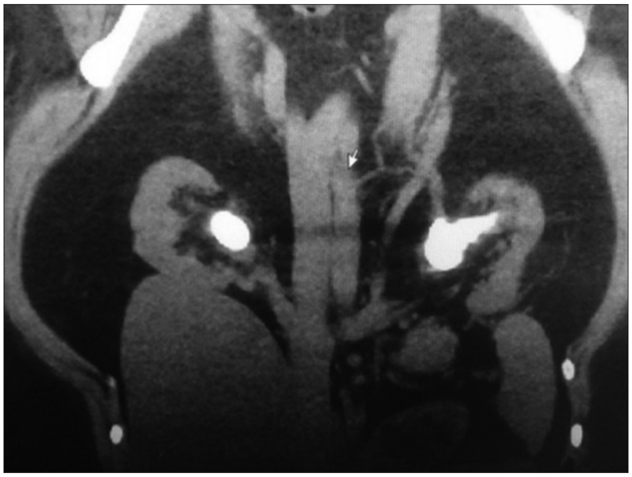

Figure 2: Morbidly obese patient. With large bilateral kidney stones

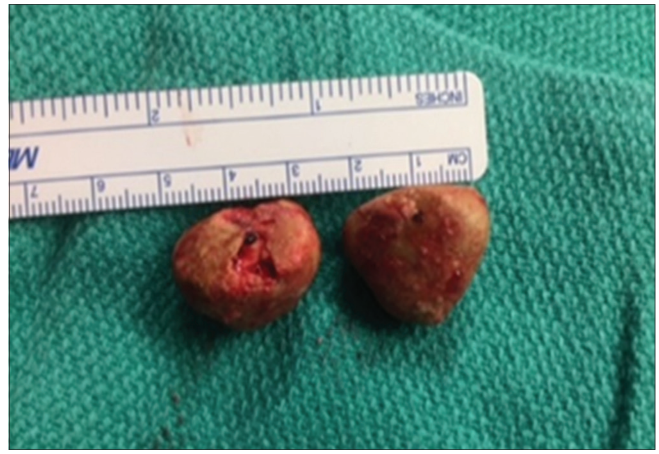

Figure 3: The right kidney stone after removal

Figure 4: The left kidney stone after removal

Figure 5: Patient positioning

location, and patient habitus and can be shifted medially versus laterally and caudally versus cephalad accordingly. One assistant trocar was used for most cases, and that was placed at or around the umbilicus. The second assistant trocar was utilized in two patients and was introduced cephalad to the first assistant trocar.

Flexible ureteroscopy and/or flexible cystoscopy were utilized during the procedure and introduced through the assistant trocar to examine the renal pelvis, calyces, and ureter and to accomplish stone removal when needed. Ultrasound was used occasionally to locate the stone [Figure 7].

The ascending colon or descending colon in the right or left stone, respectively, was deflected medially. The ureter was isolated, and the stone location was identified. His renal pelvis or the ureter was opened based on the stone location. The kidney was exposed over the diverticulum for diverticular stone. The stone was delivered and the cavity where the stone was located was inspected, using the robotic scope, flexible ureteroscopy or flexible cystoscopy to insure no fragment was left behind and the incision was closed over ureteral double pigtail stent in cases of stone in the renal pelvis, calysis, or ureter. The divertucular cavity was ablated and closed in case of diverticular stone. 15 F Jackson Pratt drain was always left at the endo of the procedure. Postoperatively, the drainage fluid was checked for urine leak by checking its creatinine.

RESULTS

A total number of 19 patients underwent RSS on 22 renal unit at our institute all accomplished robotically with no conversion to open. Patient demographics and preoperative data are shown in Table 1. The mean age of the patients was 53 years (range 19–75) years. Nine patients were female (47%). Three patients had bilateral stone and needed to have RSS of both sides. Eleven RSS were performed on the right. Eight patients presented initially with sepsis due to pyelonephritis, 13 presented with

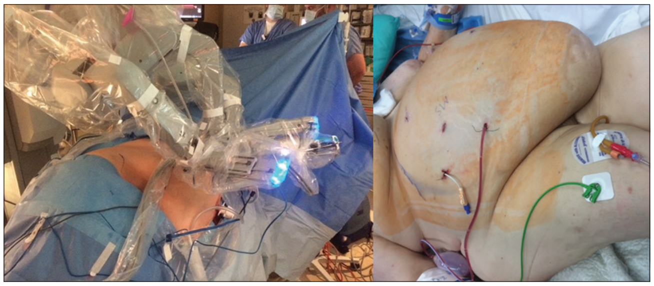

Figure 6: Trocar placement in robotic assisted stone surgery

pain, and 7 patients were found to have the stone during hematuria workup. Three stones were found incidentally during workup for another medial problem. The indications for RSS included the following: morbid obesity (*n* = 8, mean body mass index [BMI] 56.4 kg/m^2), need for concurrent renal surgery (*n* = 3) severe contractures limiting positioning for retrograde endoscopic or PCNL (*n* = 2), symptomatic calyceal diverticular stone with failed endoscopic approach (*n* = 4), and after failed PCNL (*n* = 2). The mean BMI in all patients was 39.5 kg/m^2 (17.7–61.4 kg/m^2). Our patients had a mean of 2.3[1-7] stones and total stone volume of 16.5 cm^3 (0.7–75 cm^3) per kidney. Surgical outcome is displayed in Table 2. The mean of EBL was 57.8 mL (10–400). The average operating time was 180 min (90–300 min). The average LOS was 3.5 days (1–12). Average follow-up was 54 days (30–90 days) showed that 20 renal unit were rendered stone free in the first attempt, stone-free rate (SFR 91%). A total of four complications were observed. One patient needed intensive care unit admission due to candida induced sepsis. Two patients developed trocar site infection treated with antibiotic. One patent needed prolonged stenting and bladder drainage due to urine leak. Postoperative pain was minimal, and most patients were ambulating and tolerating regular diet on the first postoperative day. Stone was set for chemical analysis after surgery and the composition of the stone is displayed in Table 3.

DISCUSSION

The evolving endourology era is refining minimally invasive surgeries for USD to decrease morbidity and augment the SFR. Yet, in some cases, these procedures are limited and not applicable.[16] Open approach, utilizing the traditional surgical incision, to treat urologic stones is fading due to the significant postoperative complications, pain, and prolonged recovery period. Open stone surgery is being replaced with minimally invasive procedure such as ESWL, PNL, laparoscopic, and recently robotic surgery.[17] The role of retroperitoneal laparoscopy and pyelolithotomy was explored by Gaur *et al*., in 1994.[18] The goal of adopting such approach was to minimize the warm ischemia time,

Figure 7: Utilizing the ultrasound intraoperatively to locate the challenging urologic stone

Table 1: Patient demographics and data

Variable	Value
Number of patients	19
Number of renal units	22
Gender (male/female)	10/9
Mean number of stone	2.3 (1-7)
Age (years)	53 (19-75)
BMI*, kg/m^2	39.5 (17.7-61.4)
Stone size the longest axis (mm)	29 (12-60)
Total stone volume (cc)	16.7 cc (0.7-75 cm^3)
Stone side (right/left)	11/11

BMI: Body mass index, BMI*Unit (kg/m^2)

Table 2: Operative results of the robotic assisted stone surgery

Surgical Outcome	Value
Operative time, min	180 (90-300)
EBL, mL	57.8 (10-400)
Length of hospitalization, days	3.5 (1-12)
Mean follow-up, days	54
Postoperative complications (%)	4/22 (18)
SFR (%)	20/22 (91)

SFR: Stone free rate, EBL: Estimated blood loss

Table 3: Stone composition

Stone composition	Renal unit
Calcium oxalate	7
Calcium phosphate	5
Uric acid	2
Struvite stone	4
More than one component	3

renal impairment, and complication and to increase SFR.[17] However, laparoscopic approach to urologic stone was limited due to the encountered difficulty in reconstructing the urinary tract.[15,19] Bove reported on the first RSS using two robots, AESOP® for the orientation of the laparoscope and PAKY® to perform the percutaneous access.[19] The utilization of the daVinci® robotic surgical system by urologist is increasing and gaining popularity in the treatment of many surgical urological diseases.[20] The main objective of utilizing robotic technology in surgery has always been to provide safer and more consistent outcomes, with fine movement control and drift-free maintenance of the endoscope and instrument and also providing better dexterity to the surgeon.[21] Indeed, the robotic approach allows the kidney stones to be removed intact leading to the upsurge in the SFR and complete stone clearance.[21,22] The so-called “zero-fragment nephrolithotomy” was the driving argument for the multi-institutional evaluation of RSS.[22] That evaluation came in favor of adopting robotic pyelolithotomy and robotic nephrolithotomy in the centers of RSS assessment.[22] A recent systemic review of RSS endorsed the utilization of the da Vinci® robotic surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) in pyelolithotomy.[23] Badalato *et al*. published a meta-analysis of four clinical trials with 39 patients that endured robot-assisted stone removal from the kidney with or without pyeloplasty.[24] In fact, the idea of utilizing the da Vinci® robotic surgical system is not new. In 2006, Badani *et al*. accomplished robot-assisted pyelolithotomy in 12 out of 13 patients with kidney stones and with 92% SFR.[25] Mufarrij then Atug reported on the success of utilizing the robotic approach to combine pyelolithotomy and pyeloplasty.[26,27] Lee also published a retrospective case series of five cases of robot-assisted pyelolithotomy completed robotic pyelolithotomy was done to four patients, three were stone-free.[28] However, in one case, it was converted to open surgery because the stone could not be removed by the robotic grasper or fragmented by electrohydraulic lithotripsy. In 2014, King *et al*. also described a reproducible technique for robotic pyelolithotomy.[29] In 2016, Swearingen *et al*. performed retrospective case series from five different surgical centers of 27 patients with an SFR of 96% on imaging without conversion to open surgery. The reported complications rate was 18%.[22]

RSS at our institute was started as part of other procedures initially and then became *de novo* after we found encouraging results. Nevertheless, PCNL remains the first-choice of intervention in large kidney stones.[30] In our series, we utilized RSS to treat CUS that are not amenable to other traditional treatment modality such as PCNL, ESWL, and ureteroscopy. CUS in our series were large kidney stones (>2 cm) in morbidly obese patient (BMI >35), and patients with skeletal deformity that prevent percutaneous access to the kidney or positioning for the access. We considered RSS after PCNL failure in diverticular stone or anatomically inaccessible location. Sometimes, RSS was part of another robotic procedure. Moreover when the robotic system was used for another purpose such as pyeloplasty, partial nephrectomy, ureteral reconstruction on the same nephroureteral unit. RSS allowed us to utilize other endoscopic instruments to achieve high SFR comparable to other procedure used under normal circumstances. The major advantage of RSS is delivering the fragment freestone, with low rate of morbidly and mortality. We encounter no need for conversion as we were able to achieve our goal with the minimally invasive approach. Our finding echo what has been found in the literature.

CONCLUSION

RSS enabled us to achieve minimally invasive approach to treat CUS achieving a high rate of stone clearance and zero fragmentation stone removal. RSS has not replaced the traditional less invasive approach to treat urologic stones and reserved for the CUS that was defined earlier. SFR, complication rate, and LOS were acceptable. RSS eliminated the need for open stone surgery in our challenging patients.

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Conflicts of interest
There are no conflicts of interest.

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