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ORIGINAL ARTICLE

Robotic retroperitoneoscopic adrenalectomy: useful modifications of the described posterior approach

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Abstract Herein we describe a technique modification of the robotic posterior retroperitoneoscopic adrenalectomy (RPRA). Three patients presented to our clinic with adrenal lesions. The average BMI and tumor size was 29.3 kg/m^2 and 4.6 cm, respectively. All had prior major abdominal procedures. Long robotic trocars were used. A 5-mm assistant port was added and the number of robotic instrument use was minimized. The average total operation time was 136 min, average docking time was 14.7 min and the average console time was 108.7 min. Blood loss was minimal and there were no complications. In patients with prior history of extensive abdominal procedures, RPRA is safe and effective when performed by surgeons with PRA and robotic experience. Long robotic trocars effectively minimized external robotic arm collisions. Adding a 5-mm assistant trocar maximized the first assistant and console surgeon abilities. Limiting the number of robotic instruments and energy devices contained cost.

Keywords da Vinci robotic system · Posterior retroperitoneoscopic adrenalectomy · Long robotic trocars

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Introduction

Since 1992, laparoscopic adrenalectomy by the transperitoneal (TA) approach has been the standard in many institutions caring for patients with benign adrenal tumors [1, 2]. Most recently, the posterior retroperitoneoscopic (PRA) technique to adrenalectomy has been used with great success as an alternative to laparoscopic TA [3, 4].

The first robotic TA (RTA) adrenalectomy was reported in 2001 by Horgan and Vanuno [5]. Given the advantages of the robotic approach, it gained popularity as an alternative to laparoscopic TA. The first robotic posterior retroperitoneoscopic adrenalectomy (RPRA) was reported by Berber et al. in 2010 [4] and served as the preferred approach for patients with prior extensive abdominal procedures. However, PRA has been plagued with many limitations mentioned in the literature [6–8]. Such limitations include the following: small working space caused by the close positioning of trocars, lack of angular movement of laparoscopic instruments, presence of extensive retroperitoneal fat, morphometric characteristics of the patient [4] and surgeon unfamiliarity with the anatomy.

The advantages of using the robot for the PRA procedure include 3-D vision, freedom of movement of Endowrist instruments and surgical precision. The wrist-like movements of the robotic instruments allow the surgeon to dissect anatomical structures with more ease in tight places. Despite the advantages afforded by the robot, there is still a relatively steep learning curve before one can be proficient in performing robotic adrenalectomy, even for experienced laparoscopic adrenal surgeons [9].

Since our group has extensive experience performing laparoscopic TA, PRA and robotic TA and given the circumstances that the patients presented with, it was the most suitable time to attempt RPRAs [10]. Herein we describe some useful modification of the described RPRA technique.

Patients

Case 1

69-year-old male, with a BMI of 30 was found to have a left renal mass in early 2015. He underwent a left radical nephrectomy for a renal cell carcinoma. In retrospect, there was a small metastastatic nodule in the right adrenal gland. Follow-up CT scan revealed two growing masses in the right adrenal one 1.5 cm and another 2.5 cm. The nodules responded to oral treatment with Votrient by decreasing in size in June 2016, but the patient could not tolerate the drug and lost 40lbs. His medical oncologist referred him for a right adrenalectomy. His surgical history consisted of an appendectomy, open cholecystectomy and radical left nephrectomy. Our plan was to avoid the TA approach due to abdominal adhesions and he was offered a RPRA.

Case 2

A 68-year-old male who underwent an attempted Whipple procedure for pancreatitis in 2010. He ultimately had a choledochojejunostomy and gastrojejunostomy. He presented to VA hospital in 2016 with abdominal swelling. A CT scan revealed a heterogeneous enhancing right adrenal mass that was present in 2010 and had grown from 5.4 to 6.1 cm. A biopsy was ordered by his primary care physician and was consistent with cortical tissue. Because his plasma metanephrines were moderately elevated and the adrenal mass had grown he was placed on an alpha blocker and offered a right adrenalectomy. Given his extensive prior abdominal procedures we offered him the RPRA approach.

Case 3

A 42-year-old female who was involved in a motor vehicle trauma underwent exploratory laparotomy, splenectomy and repair of liver lacerations. She also developed bilateral adrenal hemorrhage. Six years later she was found to have a 5.2 cm left adrenal mass with atypical imaging characteristics and mild elevation of her catecholamines. Because she had extensive adhesions in the abdomen, we chose to offer her the RPRA approach.

Description of RPRA procedure with modifications

After appropriate consent was obtained, the patient was brought to the major operating suite, placed in a supine position and general endotracheal anesthesia was established. The patient was repositioned in prone over a Wilson frame in jackknife. All at risk areas were padded. The patient's back was then prepped and draped in the usual sterile manner.

Figure 1 displays our trocar placement slightly modified from the original description by Walz [3]. We entered the retroperitoneal space by making a 12-mm transverse incision just below the tip of the 12th rib. The retroperitoneal space was entered sharply with mayo scissors and developed bluntly with a finger. Two 8 mm long robotic trocars were then placed one lateral to the camera port site and one medial in the subcostal location about 3 cm below the junction of the 12th rib and the medial muscle. Regular length (11 cm) robotic trocars (Fig. 2) were initially utilized but we quickly switched to longer obesity (16 cm) robotic trocars (Fig. 2) to avoid external robotic arm collisions during the procedure. A 5-mm assistant port was then added and placed lateral and inferior to the camera port (Fig. 1). A 12-mm blunt balloon trocar (AutoSuture/Covidien, Mansfield, MA, USA) was placed in the middle/camera access site. Pneumoretroperitoneum was established with CO_2 insufflation and was maintained at 20 mmHg throughout the procedure. The non-robotic laparoscope 30-degree camera was introduced looking up and Gerota's retroperitoneal fascia was then taken down with care not to injure surrounding structures or to violate the peritoneal layer laterally (over liver or spleen) by using a blunt laparoscopic Grasper.

Once the "triangulating" view of the medial muscle and the blue layer of peritoneum was obtained (Fig. 3) the da Vinci robot was docked (Intuitive Surgical, Sunnyvale, CA, USA) (Fig. 4). The robot was docked and brought in from the patient head. The 8-mm robotic cardiere forceps were used on the left side and the 8-mm robotic cautery hook was used in the right side port. With the 30-degree camera looking down, dissection began from lateral to medial detaching the tissue above the kidney. The assistant vigorously retracted the kidney caudad. We dissected the adrenal gland and the tissue surrounding it from the superior aspect of the kidney. The right adrenal vein was identified medially extending from the adrenal gland to the vena cava (Fig. 5). The adrenal vein was clipped with 5 mm Hem-o-lok clips (Teleflex Medical, Morrisville, NC, USA) (Fig. 6) and then divided by the first assistant through the 5-mm assistant port. The adrenal gland was then removed from the retroperitoneal attachments. It was then placed in an Endopouch Retriever (Ethicon Endo-surgery, Cincinnati, OH, USA) and removed via the l2-mm middle port by extending that port site incision at the skin and fascia as necessary.

After desufflation and then re-insufflation there was no evidence of bleeding. All CO_2 was removed and the camera port site was closed at the fascia level and all other port sites at the skin level. The patient was then placed

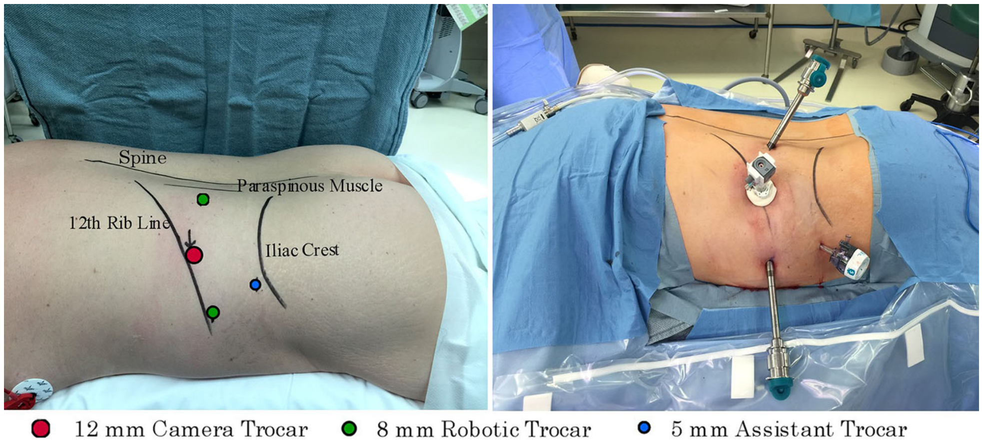

Fig. 1 Trocar placement for robotic retroperitoneoscopic adrenalectomy (*left*)

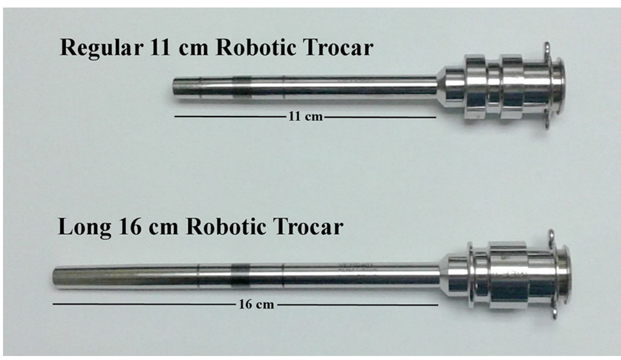

Fig. 2 8 mm robotic regular and long trocars

supine, extubated and taken to the recovery room in stable condition.

Results

The total operation times were 148 min for case 1, 170 min for case 2 and 91 min for case 3 (average 136 min); docking times (from skin incision to docking complete) were 14 min for case 1, 16 min for case 2 and 14 min for case 3 (average 14.7); surgeon console times for case 1,2 and 3 were 117, 142 and 67 min, respectively (average 108.7). All three patients had minimal blood loss and were discharged from the hospital on postoperative day 1 or 2. There were no complications. Final pathology for case 1 was a metastatic 3.4 cm clear renal cell carcinoma of 37.49 g; for case 2, a completely resected 6.3 cm right adrenal cortical carcinoma of 96 g and for case 3, a 6-cm myelolipoma with hemorrhage weighing 73.23 g.

Discussion

PRA is a safe and effective minimally invasive technique that avoids the abdominal cavity in patients who have had extensive abdominal procedures. Robotic technology can potentially improve the limitations of the posterior retroperitoneoscopic approach for adrenalectomy. Robotic advantages include: 3D vision which allows the surgeon to inspect and dissect the adrenal gland and the surrounding structures with greater detail and ability and superior

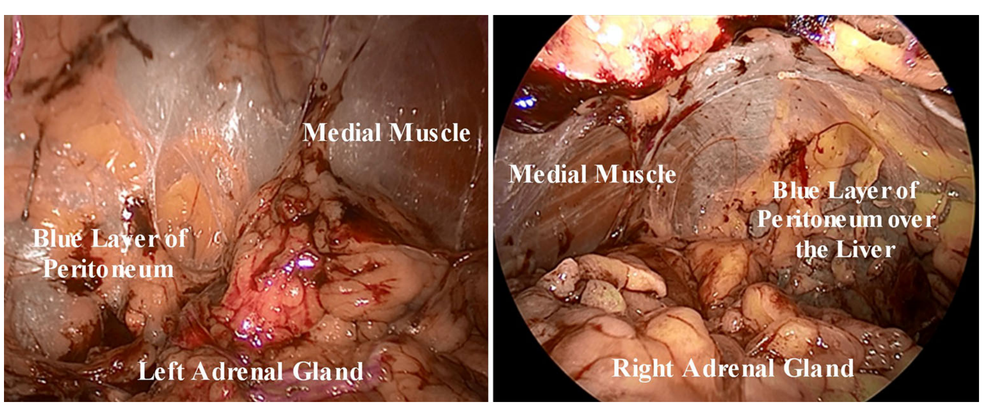

Fig. 3 The "triangulating" view of the medial muscle and the *blue layer* of peritoneum (over liver on the *right side* and spleen on the *left side*)

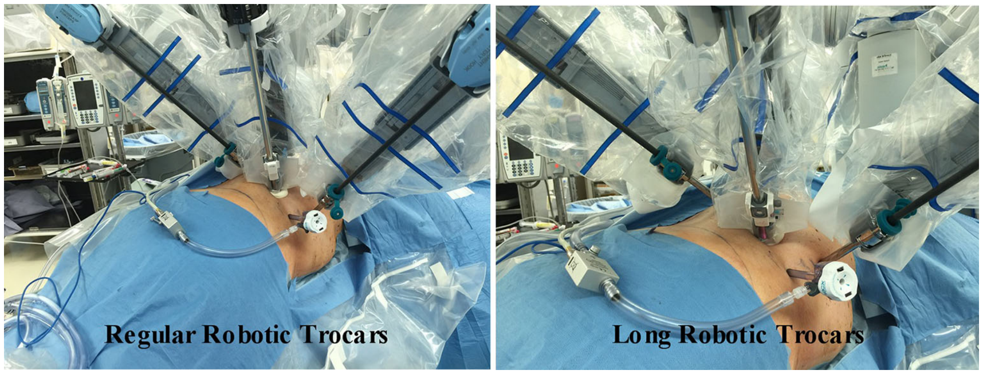

Fig. 4 Robot docking with regular (*left*) and with long robotic trocars (*right*)

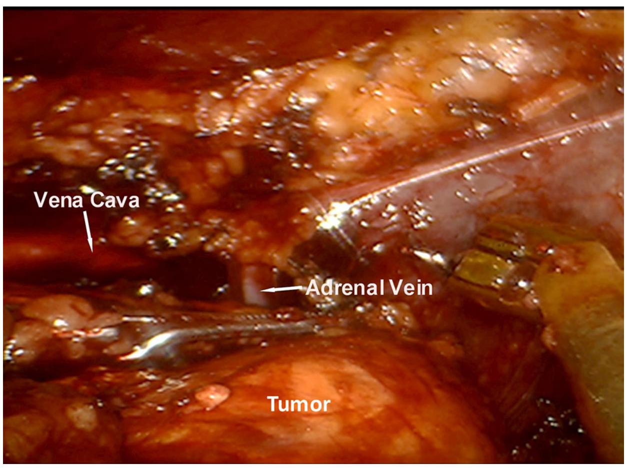

Fig. 5 Identification of the vena cava and adrenal vein

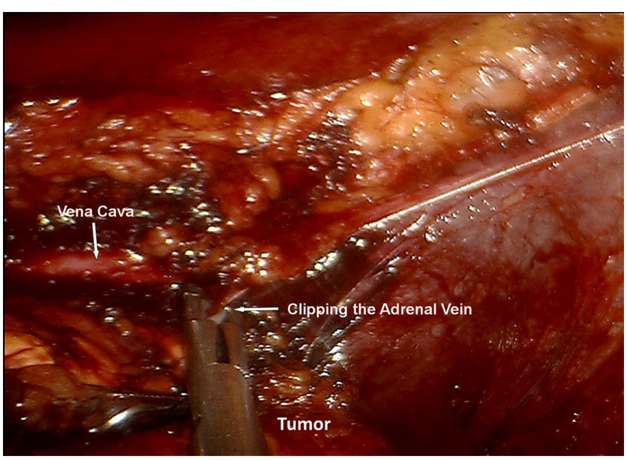

Fig. 6 Clipping of the *right* adrenal vein during a robotic *right* retroperitoneoscopic adrenalectomy

dexterity from the freedom and precision provided by the EndoWrist instruments (as compared to the stiff 2D laparoscopic instruments) which allows the surgeon to reach tucked-in spaces in the retroperitoneum.

Since 2009, our group has acquired experience with more than 202 endoscopic adrenalectomies, including 45 PRAs [10] and 30 RTA adrenalectomies. Berber et al. [4] attempted a robotic PR approach to adrenalectomy after having already performed 100 laparoscopic PRA cases. With experience in such cases, our robotic team was ready to attempt the RPRA approach with excellent results on the first three presented patients. The average total OR time for these first three modified cases was comparable to larger series reported in the literature (Table 1). After their initial study, Berber and his team reported a follow-up study of 31 RPRAs (only 6 had prior abdominal surgery). They demonstrated significant improvement in their average total OR time from 209.6 min [4] (the first ten cases) to 139.1 min [11] (the last 21 cases). The average docking time in our first three patients was below average when compared the docking times reported by Berber, Dickson and Agcaoglu (Table 1) even after the learning curve was established in some of those series [4, 6, 11]. We attribute our favorable initial OR and docking times to the combined laparoscopic and robotic experience acquired by our dedicated surgical team over the past 7 years (First Assistant, Scrub Technologist and Circulator).

Many studies utilize three trocar sites for robotic PRA [4, 7, 8]: a camera trocar and two 5-mm robotic trocars. If the surgeon needs a first assistant to apply suction or to clip the adrenal vein, he has to remove one of the robotic instruments and allow the first assistant to insert their instrument through the robotic trocar to perform those actions. Other studies utilize four port sites consisting of two 10–12 mm, one 8 mm robotic and one 5 mm assistant trocar [6]. Our study utilized four ports, one 10–12 camera port, two 8 mm robot ports and one 5 mm assistant port. On the first case the first assistant used a 17-cm laparoscopic suction tip placed 4 cm lateral and 3 cm inferior to the camera port. However, in the case the first assistant ran into some issues colliding with the camera head while suctioning, retracting, irrigating and clipping. To rectify this issue, in the next case the first assistant used a 13-cm

Table 1 Comparison of robotic PRA Studies

Author	No.	Average tumor size (cm)	Average BMI (kg/m^2)	Average total OR time (min)	Average robot docking time (min)	Average console time (min)	Trocar sites	Robotic instruments used	Average estimated blood loss (mL)
Berber et al. [4]	8	2.7	NR	214	21.7	97.1	3	Grasper, Harmonic	24
Ludwig et al. [8]	6	2.8	30	143	14	57	3	Grasper, Bipolar, Harmonic	60
Dickson et al. [6]	28	3.8	31.6	154	NR	NR	4	Grasper, Maryland Bipolar, Harmonic	28
Karambulut et al. [7]	18	2.7	30	166	21	NR	3	NR	NR
Agcaoglu et al. [11]	31	3.1	27.5	163.2	19.1	NR	3	Grasper, Harmonic	25.3
Current study	3	4.6	29.3	136.3	14.7	108.7	4	Grasper, Monopolar hooks	15

laparoscopic suction tip placed 7 cm lateral and 6 cm inferior to the camera trocar, thereby avoiding the previous collisions.

Both the laparoscopic and robotic PRA techniques have the same disadvantage of a narrow surgical field and close vicinity and crowding of port sites. Previous studies have tried to address these limitations by [4, 7, 8] utilizing two 5 mm robotic trocars; another study [6] utilized a 10–12 mm obesity trocar in the medial position and one 8 mm standard robotic trocar in the lateral port site. The authors stated that the use of obesity trocars, regardless of patient size, provides a larger external range of movement and eliminates the problems of external collision that Berber et al. encountered [4, 6]. In the three cases presented we utilized two 8 mm long robotic trocars to avoid external collision. The long robotic trocar was designed for robotic procedures in obese patients (BMI > 40) with a thick abdominal wall. Figure 4 illustrates and compares the operating space when using standard size 11-cm vs. longer 16-cm (Fig. 2) obesity 8-mm robotic trocars.

One of the criticisms against robotic use in adrenalectomy is the cost associated with the da Vinci system and its instruments. At our institution there is a standard robotic surgery pack limiting the surgeon's ability to reduce the cost of the operation in that area. However, surgeons are able to limit costs by avoiding the use of additional unnecessary robotic instruments and energy devices. For robotic instruments, previous reports describe the use of 5 or 8 mm Graspers (Prograsp or Cadiere), Bipolar (Maryland or Fenestrated) and Harmonic scalpel [4, 6–8]. From our experience in performing robotic TA, we have been able to use the cardiere forceps and the permanent cautery hook in all cases without the use of energy sealing devices and were able to utilize the same instruments in the RPRAs. After 30 RTAs and now 3 RPRA using only the above robotic instruments there have been no operative or postoperative bleeding complications. The advantage of using the robotic hook as opposed to the Harmonic scalpel in RPRA or RTA is the 7 degrees of freedom, which helps the surgeon to better identify and dissect critical structures such as the vena cava, adrenal vein and renal hilum. Table 2 shows the cost of robotic instruments per operation. The robotic instrument cost in the cases presented was $400 (cardiere forceps and permanent cautery hook). Depending on how many instruments, energy sealing devises and other hemostatic agents are used, the costs can add up significantly for both laparoscopic and robotic procedures.

Table 2 Costs of da Vinci robotic instruments (per time used)

Robotic instruments	Cost (USD)
8 mm Fenestrated Bipolar forceps	270.00
8 mm Maryland Bipolar forceps	270.00
8 mm Prograsp forceps	220.00
8 mm Cardiere forceps	200.00
8 mm Permanent cautery hook	200.00
5 mm Grasper forceps	230.00
8 or 5 mm Insert ACE Harmonic	430.00
8 or 5 mm Harmonic ACE curved shears	55.00

Conclusion

Robotic PRA is safe, effective and an excellent minimally invasive alternative for patients with prohibitive abdominal adhesions. Other authors have attempted to deal with the problem of arm collision in RPRAs. We rectified this issue by using two long robotic trocars. We also added and altered the placement of a 5-mm assistant trocar. The use of the additional assitant trocar maximized the first assistant's ability to retract, suction and handle tissue. Our study also shows that it is possible to decrease the cost of robotic procedures using a limited number of robotic instruments and eliminating energy sealing devises.

Compliance with ethical standards

Conflict of interest Zuliang Feng, Michael Feng, Jessica Levine and Carmen C. Solórzano declare that they have no conflict of interest.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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