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Comparison of posterior retroperitoneal and transabdominal lateral approaches in robotic adrenalectomy: an analysis of 200 cases

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Abstract
Background Although numerous studies have been published on robotic adrenalectomy (RA) in the literature, none has done a comparison of posterior retroperitoneal (PR) and transabdominal lateral (TL) approaches. The aim of this study was to compare the outcomes of robotic PR and TL adrenalectomy.
Methods This is a retrospective analysis of a prospectively maintained database. Between September 2008 and January 2017, perioperative outcomes of patients undergoing RA through PR and TL approaches were recorded into an IRB-approved database. Clinical and perioperative parameters were compared using Student's *t* test, Wilcoxon rank-sum test, and χ^2 test. Multivariate regression analysis was performed to determine factors associated with total operative time.
Results 188 patients underwent 200 RAs. 110 patients were operated through TL and 78 patients through PR approach. Overall, conversion rate to open was 2.5% and 90-day morbidity 4.8%. The perioperative outcomes of TL and PR approaches were similar regarding estimated blood loss, rate of conversion to open, length of hospital stay, and 90-day morbidity. PR approach resulted in a shorter mean ± SD total operative time (136.3 ± 38.7 vs. 154.6 ± 48.4 min; $p = 0.005$) and lower visual analog scale pain score on postoperative day #1 (4.3 ± 2.5 vs. 5.4 ± 2.4; $p = 0.001$). After excluding tumors larger than 6 cm operated through TL approach, the difference in operative times persisted (136.3 ± 38.7 vs. 153.7 ± 45.7 min; $p = 0.009$). On multivariate regression analysis, increasing BMI and TL approaches were associated with longer total operative time.
Conclusion This study shows that robotic PR and TL approaches are equally safe and efficacious. With experience, shorter operative time and less postoperative pain can be achieved with PR technique. This supports the preferential utilization of PR approach in high-volume centers with enough experience.

Keywords Robotic adrenalectomy · Transabdominal lateral approach · Posterior retroperitoneal approach

Over the last decade, an advanced technology that operates articulated instruments through a surgeon–computer interface has been applied to many surgical procedures and has challenged laparoscopic surgery. Although not the perfect definition, this technology is widely referred to as "robotic surgery." Robotic surgery was first applied to adrenalectomy in 1999 [1]. Since then, many studies have suggested the safety of robotic adrenalectomy (RA) with complication rates ranging between 2.4 and 20% [2–7]. Nevertheless, most of the experience in the literature is with the transabdominal lateral (TL) approach [3, 6–9], with no study presenting a comparison to the posterior retroperitoneal (PR) technique using the robotic technology.

A robotic endocrine surgery program was started at our institution in 2008, and outcomes of RA were recorded prospectively. Over time, both PR and TL techniques were developed and matured within this program [10].

The differences between the TL and PR techniques regarding patient selection and perioperative outcomes were discussed extensively for laparoscopic adrenalectomy [11, 12]. With growing interest, there is a need to compare the outcomes of PR and TL robotic adrenalectomy. This study

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aims to address this issue by analyzing the perioperative outcomes from a large prospective experience with both approaches.

Materials and methods

Study design

This is a retrospective analysis of a prospectively maintained database. The study was approved by the Institutional Review Board (IRB) at the Cleveland Clinic. Between September 2008 and January 2017, all patients requiring adrenalectomy by a single surgeon (EB) were approached primarily robotically, except when limited by availability of equipment or scheduling.

Selection of posterior retroperitoneal versus transabdominal lateral approach

All tumors larger than 6 cm were operated through TL approach. PR approach was used when the tumor was smaller than 6 cm and one or more of the following was true: (1) Patient was predicted to have abdominal adhesions that would preclude TL approach; (2) Tumor was away from the renal hilum; and (3) Measured distance between the skin and Gerota's fascia was shorter than 7 cm on preoperative CT scans. Our selection of TL versus PR approach in RA was similar to our previously reported selection algorithm for laparoscopic adrenalectomy [12].

Operative technique

The steps of the surgical procedures were described in detail before [13]. For the PR approach, the patients were placed prone on a Wilson frame. The initial entry to the Gerota's space was performed through a 12-mm incision using an optical trocar. The space was further developed using a balloon trocar and insufflated to a pressure of 15 mm Hg. Two to three additional, 5- or 8-mm trocars were also inserted into this space. Laparoscopic ultrasound was used to identify the tumor and establish its relationship with the liver, spleen, kidney, and vascular structures. Then, the robot was docked (Fig. 1). The procedures were performed using a 30-degree down-looking camera, a robotic grasper, a robotic vessel sealer, and a suction–irrigator operated by the first assistant as needed. For the TL approach, the patient was placed in lateral decubitus position on a bean bag and the table flexed at the flank. The procedure was performed using the same robotic instruments as in the PR approach. In obese patients undergoing left TL adrenalectomy, a 4-robotic arm technique was used. In this technique, an extra robotic grasper was inserted from the 4th robotic arm to provide adequate retraction (Fig. 2).

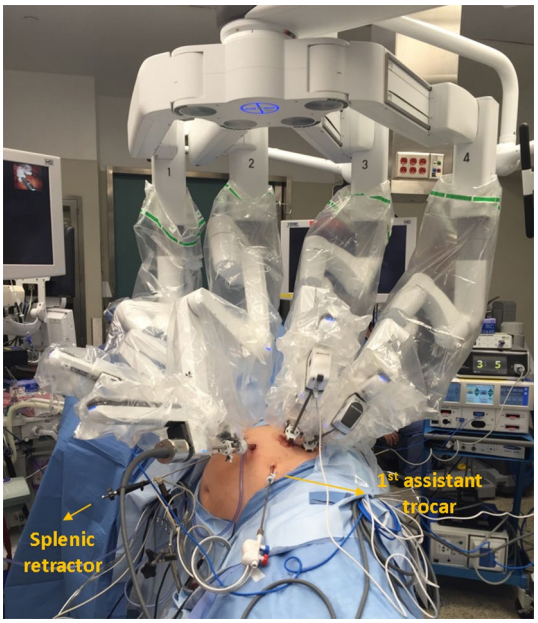

Fig. 2 Intraoperative photo demonstrating the 4-arm robotic transabdominal lateral left adrenalectomy technique in an obese patient. In addition to four robotic arms, a splenic retractor and a 1st assistant trocar are introduced. Robotic arms 1 and 4 operate the graspers, arm 2 holds the camera, and arm 3 operates the vessel sealer

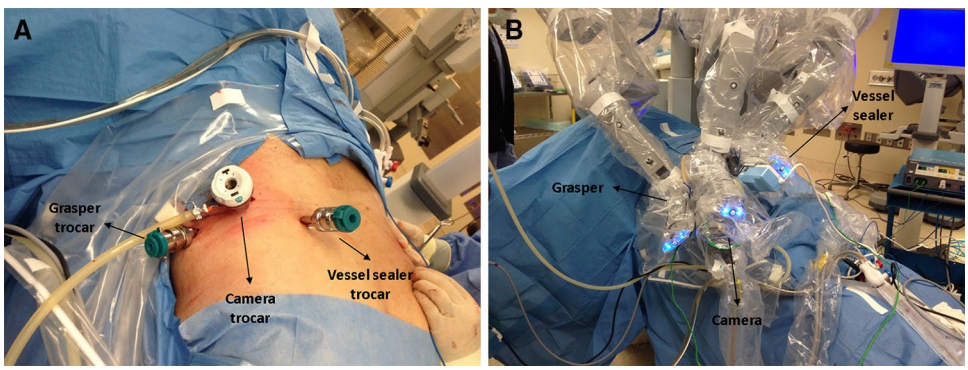

Fig. 1 Intraoperative photos demonstrating the 3-arm robotic posterior retroperitoneal left adrenalectomy technique. **A** Trocar placement. **B** Position of robotic arms after docking

Postoperative care

The patients were started on a clear liquid diet after surgery and advanced to regular as tolerated. Postoperative analgesia included intravenous ketorolac and oral acetaminophen. Patients were discharged home on postoperative day #1 if they were tolerating diet, ambulating, and pain level was acceptable.

Study variables

All data were acquired prospectively. Intraoperative surgical and perioperative clinical parameters were collected into data forms, which were recorded into a prospective IRB-approved database. Intraoperative study variables included conversion to open, estimated blood loss, and the detailed operative times including total operative, exposure, docking, console, and hemostasis and closure times. Postoperative study variables included length of hospital stay, visual analog scale pain scores on postoperative day #1 and at first follow-up visit, and 90-day morbidity.

Statistical analysis

Demographic, clinical, and perioperative parameters were compared using Student's *t* test, Wilcoxon rank-sum test, and χ^2 test. Association of clinical factors with total operative time was analyzed using a multivariate generalized linear model. A *p* value of less than 0.05 was considered statistically significant. Continuous data are presented as mean plus or minus standard deviation unless otherwise specified.

Results

Between 2008 and 2017, 200 robotic adrenalectomies were performed in 188 patients. Eighty-one patients had right-sided tumors, while 95 had left-sided, and 12 had bilateral tumors. 110 patients were operated through TL and 78 were operated through PR approach.

In the whole series, mean age was 51.7 ± 14.5 years and body mass index (BMI) 31.0 ± 7.2 kg/m^2. Final pathology included pheochromocytoma ($n = 40$), Cushing's ($n = 39$), primary hyperaldosteronism ($n = 34$), non-secreting adrenocortical adenoma ($n = 35$), malignancy ($n = 14$), and others ($n = 26$). Of 39 patients with Cushing's, 28 had adrenocortical adenomas, 5 Cushing's disease, and 6 ACTH-independent macronodular hyperplasia. (Table 1).

The TL and PR groups were similar regarding age and sex, but BMI was higher in the TL group (32.3 ± 8.1 vs. 29.2 ± 4.7 kg/m^2, $p < 0.001$). The two groups did not differ in pathology, side and/or laterality of tumor, or history of previous upper abdominal surgery. The tumor size was greater in the TL compared with the PR group (4.2 ± 2.5 vs. 3.3 ± 2.0 cm, $p = 0.01$).

Total operative time was shorter in the PR than the TL group (136.3 ± 38.7 vs. 154.6 ± 48.4 min; $p = 0.005$). This difference seemed to arise from the shorter exposure time in the PR approach (32.8 ± 17.3 vs. 43.3 ± 14.9 min; $p < 0.001$) (Fig. 3). To ensure that the difference was not a result of larger tumor size in the TL group, the analyses were repeated after excluding patients with tumors larger than 6 cm operated through TL approach. In this subgroup analyses as well, the PR approach was associated with shorter total operative (136.3 ± 38.7 vs. 153.7 ± 45.7 min; $p = 0.009$) and exposure (32.8 ± 17.3 vs. 40.0 ± 15.1 min; $p = 0.007$) times. On multivariate regression analysis, increasing body mass index ($p = 0.005$) and TL approach ($p = 0.04$) were associated with longer total operative time. Notably, history of prior abdominal surgery, tumor side, and tumor size did not show association with total operative time (Table 2).

There was no difference in estimated blood loss or conversion to open rate between TL and PR approaches (Table 3). The overall rate of conversion to open was 2.5% (5 of 200 adrenalectomies) and reasons for conversion involved inability to identify a safe dissection plane ($n = 3$) and tumoral involvement of the inferior vena cava ($n = 2$). Ninety-day morbidity was 4.8% (9 of 188 patients) with no mortality. Complications included urinary tract infection ($n = 3$), abscess at surgical site ($n = 1$), postoperative ileus ($n = 1$), pancreatic leak ($n = 1$), pneumonia ($n = 1$), congestive heart failure ($n = 1$), and axillary neuropathy ($n = 1$) Complication rates were similar between TL and PR groups (6 of 110 [5.5%] vs. 3 of 78 [3.8%] patients; $p = 0.61$).

Median (interquartile range) length of stay was similar for TL and PR groups (1 [1–1] vs. 1 [1–1] days; $p = 0.32$). The mean visual analog scale pain score was higher in the TL versus PR group (5.4 ± 2.4 vs. 4.3 ± 2.5, $p = 0.001$) on postoperative day #1, but was similar on day #14.

Discussion

To our knowledge, this is the largest experience of RA performed through both PR and TL approaches. In this analysis of 200 cases, the procedures were completed with low rates of morbidity and conversion to open, once again underscoring the safety and efficacy of RA. In addition, it is the first study comparing the two approaches on the robotic platform.

As in laparoscopic adrenalectomy [12], the same criteria were used to select patients into PR and TL approaches robotically. With the utilization of this algorithm, those undergoing PR adrenalectomy ended up being patients who had smaller tumors and lower BMI, similar to our laparoscopic experience [11]. Overall, the intraoperative parameters of both approaches were similar, except for a

Table 1 Demographic and clinical characteristics of patients operated through transabdominal lateral (TL) and posterior retroperitoneal (PR) approaches

Parameter	TL group ($n=110$)	PR group ($n=78$)	p value
Age, mean (SD), years	50.9 (14.8)	52.7 (14.1)	0.42
Body mass index	32.3 (8.1)	29.2 (4.7)	<0.001
Sex, no. (%) of patients			
Female	76 (69.1)	55 (70.5)	0.83
Male	34 (30.9)	23 (29.5)	
Pathology, no. of patients			
Pheochromocytoma	27	13	0.75
Cushing's syndrome	21	18	
Adrenocortical adenoma	14	14	
Cushing's disease	4	1	
ACTH-independent macronodular hyperplasia	3	3	
Non-secreting adrenocortical adenoma	19	16	
Primary hyperaldosteronism	18	16	
Malignancy[a]	9	5	
Other[b]	16	10	
Side, no. (%) of patients			
Right	48 (43.6)	33 (42.3)	0.82
Left	56 (50.9)	39 (50.0)	
Bilateral	6 (5.5)	6 (7.7)	
Tumor size, (SD) [range], cm	4.2 (2.5) [0.5–12.5]	3.3 (2.0) [0.9-6.0]	0.01
Previous upper abdominal surgery, no. (%) of patients	21 (19.1)	22 (28.2)	0.14

[a]Includes adrenocortical carcinoma ($n=3$) and metastases from colorectal cancer ($n=1$), hepatocellular carcinoma ($n=2$), Merkel cell carcinoma ($n=1$), and lung cancer ($n=2$) in the TL group and metastases from colorectal cancer ($n=1$), gastric cancer ($n=1$), hepatocellular carcinoma ($n=1$), poorly differentiated thyroid cancer ($n=1$), and lung cancer ($n=1$) in the PR group

[b]Includes benign cyst ($n=9$), myelolipoma ($n=3$), Schwannoma ($n=2$), benign adenomatoid tumor ($n=1$), and chronic granulomatous infection ($n=1$) in the TL group and benign cyst ($n=7$), lymphatic malformation ($n=2$), and Schwannoma ($n=1$) in the PR group

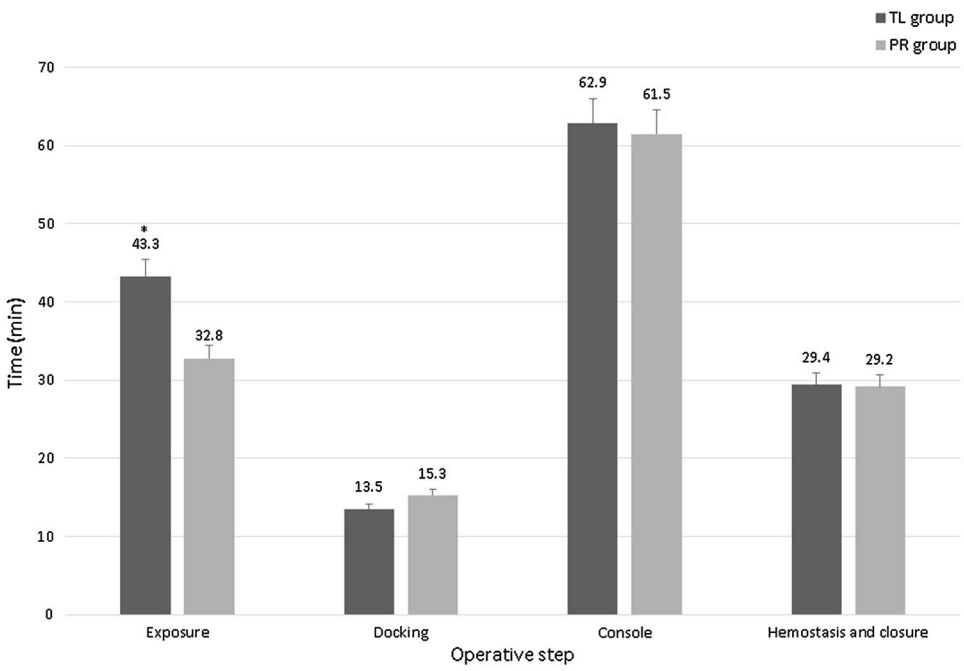

Fig. 3 Bar graph showing the mean ± standard error of the mean duration of different steps of robotic adrenalectomy for the posterior retroperitoneal and transabdominal lateral approaches. The difference between the groups for the exposure time (*) was statistically significant ($p<0.001$)

Table 2 Multivariate analysis of factors associated with total operative time

Variable	Mean difference, min	95% confidence interval		
		Minimum	Maximum	*p* value
Increasing BMI	1.2	0.4	21	0.005
No prior abdominal surgery	0.3	−13.8	14.5	0.96
Left-sided tumor	7.8	−3.8	19.3	0.19
Increasing tumor size	−0.6	−3.4	2.1	0.65
TL approach	12.5	0.2	24.9	0.04

BMI body mass index, *TL* transabdominal lateral

shorter total operative time in the PR approach. This difference seemed to arise from shorter exposure time with similar docking, console, and hemostasis and closure times. To exclude the effect of larger tumor size on operative time, analyses were repeated after exclusion of tumors larger than 6 cm operated through TL approach. As before, PR approach was found to result in shorter total operative and exposure times. In line with this finding, on multivariate regression analysis, increasing body mass index and TL approach, but not increasing tumor size, were associated with longer total operative time. Another important point is the effect of learning curve on operating times. PR and TL adenalectomy cases in our series were distributed over 9 years in similar fashions. Therefore, an unequal benefiting from the learning curve is unlikely.

The postoperative outcomes of robotic TL versus PR adrenalectomy were similar except for the pain level. Possibly because of fewer trocar use, patients experienced less pain after PR versus TL RA on postoperative day #1. To our knowledge, this is the first study that reports a comparison of postoperative pain scores between PR and TL approaches in RA.

With similar tumor size, morbidity, and rate of conversion to open with previous studies, our study reemphasizes the safety and efficacy of RA. The tumor size in the previous series ranged between 3 and 5.5 cm [3, 4, 6, 8, 9] with the largest tumor size reported to be 10–12 cm. In our experience, the mean tumor size was 3.4 cm in the PR and 4.2 cm in the TL approach, with tumors as large as 12.5 cm successfully removed robotically. Morbidity for RA was reported to range between 2.4 and 20% and mortality 0 and 2.4% [3, 4, 6–9]. 4.8% morbidity and 0% mortality in our experience compared favorably with the previous series. These values were also comparable with the 3.4–6.8% morbidity and 0–0.5% mortality [14, 15] reported for laparoscopic adrenalectomy. The rate of conversion to open has been reported between 0 and 4% [3, 4, 6, 9] for RA and 1.6 and 6.2% [14, 16] for laparoscopic adrenalectomy. The rate of 2.5% in our study again compares favorably with these series.

Over the years, we have made some modifications to our RA technique. For the PR approach, the main modification was the incorporation of the articulating instead of the non-articulating vessel sealer with the development of newer generation robotic systems. Otherwise, the usage of the 3-robotic arm technique has remained consistent. For the TL approach, the most important change over time was the modification of the approach in obese patients. In addition to using the articulating vessel sealer, we switched to a 4-robotic arm technique for the removal of left-sided tumors in this patient population. The abundant retroperitoneal fat and more challenging anatomy hinder exposure in obese patients and adequate retraction becomes critical. This is where the 4th robotic arm comes in handy. For right-sided tumors in obese patients, we continue to use the 3-robotic arm technique, with the additional use of a self-retaining laparoscopic liver retractor through a laparoscopic 5-mm trocar.

A comparison of robotic versus laparoscopic adrenalectomy is beyond the scope of this manuscript. Nevertheless,

Table 3 Perioperative characteristics of patients operated through transabdominal lateral (TL) and posterior retroperitoneal (PR) approaches

Parameter	TL group ($n=110$)	PR group ($n=78$)	*p* value
Total operative time, mean (SD), min	154.6 (48.4)	136.4 (38.7)	0.005
Exposure, mean (SD), min	43.3 (14.9)	32.8 (17.3)	<0.001
Docking, mean (SD), min	13.5 (10.3)	15.3 (7.6)	0.21
Console, mean (SD), min	62.9 (19.2)	61.5 (23.0)	0.68
Hemostasis and closure, mean (SD), min	29.4 (15.9)	29.2 (12.9)	0.93
Estimated blood loss, mL	15.1 (15.5)	12.2 (16.6)	0.24
Conversion to open, No. (%) of patients	4 (3.6)	1 (1.3)	0.32
Length of hospital stay, median (IQR) [range], d	1 (1–1) [1–6]	1 (1–1) [1–7]	0.32
Pain score, mean (SD)			
Postoperative day #1	5.4 (2.4)	4.3 (2.5)	0.001
First follow-up visit	1.7 (2.6)	1.3 (2.2)	0.21
90-Day morbidity, no. (%) of patients	6 (5.5)	3 (3.8)	0.61

the benefits of the robotic technique in our experience were the stable surgical platform that minimized instrument collision and camera smearing, and the ability to dissect in multidirectional planes. The stable camera platform was useful in the limited working space with the PR approach and the multidirectional dissection was useful in obese patients and with large tumors.

The cost of robotic surgery is not discussed in this manuscript. In an earlier study, we reported that RA added about $900 extra cost compared to laparoscopic adrenalectomy [2]. In order to reduce this additional cost, we minimize the use of disposables, such as clip appliers and drapes. Decreased operative times compared to laparoscopic technique also help offset the additional costs.

In conclusion, to the best of our knowledge, this study represents the largest RA experience with both PR and TL approaches reported to date in the literature. Our results indicate that when certain selection criteria and technical steps are followed, both approaches result in excellent postoperative outcomes. With enough surgical experience, PR robotic adrenalectomy can result in shorter operative time and less postoperative pain compared to TL approach. This supports the preferential utilization of PR technique in eligible patients who are operated at high-volume, experienced centers.

Compliance with ethical standards

Disclosures Eren Berber is a consultant to Ethicon Inc. and Aesculap Inc. His activities involve consultation on product development for open and laparoscopic liver procedures and has received honoraria from both companies. Bora Kahramangil declared no conflict of interest.

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