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Original Research

Robotic versus open resection of benign nonadrenal retroperitoneal tumors: A propensity score-matched study

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ABSTRACT

Background: Robotic resection of benign nonadrenal retroperitoneal tumors (BNRTs) is considered safety and feasibility. However, whether robotic BNRT resection (RBR) is superior to open BNRT resection (OBR) has not been reported. The comparative study was designed to analyze the short outcomes of RBR versus OBR on patients with BNRTs.

Methods: Demographics and perioperative outcomes among patients who underwent RBR (n = 30) versus OBR (n = 30) for BNRTs between January 2015 and September 2018 were reviewed. A 1:1 propensity score matched analysis was performed between both groups.

Results: There were no significant differences in the operative time, blood transfusion rate, and morbidity rate between the RBR and OBR groups. No patients underwent RBR required conversion to laparotomy. Robotic approach reduced estimated blood loss (EBL) (50 vs. 100 ml, $p = 0.00$) and postoperative hospital stay (PHS) significantly (4.6 vs. 7.9 d, $p = 0.00$) when compared with OBR. In patients with tumors adherent to major vessels, RBR also reduced EBL and PHS significantly (50 vs. 250 ml, $p = 0.02$; 4.4 vs. 9.3 d, $p = 0.00$), which were similar to the results of the patients with tumors larger than 5 cm (50 vs. 200 ml, $p = 0.00$; 4.9 vs. 7.5 d, $p = 0.01$).

Conclusions: When compared with OBR, RBR was associated with less EBL, and shorter PHS in selected patients even for tumors which are large or adherent to major vessels.

1. Introduction

Benign nonadrenal retroperitoneal tumors (BNRTs) are characterized by deep location, narrow operating space, and adherence to major vessels, which make it challenging to apply laparoscopic techniques for BNRTs [1–5]. The majority of BNRTs are removed by laparotomy, which results in more postoperative pain, slower recovery, and longer postoperative hospital stay (PHS) [6]. Although the development of robotic techniques can overcome the inherent limitations of laparoscopic surgery, there have been few reports of robotic resection of BNRTs in the available literature, and most of them are case reports [7–11]. In our previous study, we demonstrated the safety and feasibility of robotic resection of BNRTs, even when tumors are large or adjacent to major vessels [12]. However, whether robotic BNRT resection (RBR) is superior to open BNRT resection (OBR) has not been reported. In this 1:1 propensity score-matched study, we performed a retrospective analysis of short-term outcomes of robotic and open resection of BNRTs in a high-volume robotic center in China.

2. Patients and methods

Between January 2015 and September 2018, 36 patients with BNRTs underwent robotic resection, and 52 patients with BNRTs underwent open resection in our department.

Indications for resection of BNRTs include the presence of symptoms, tumors larger than 5 cm, and inability to definitely diagnosis in this study. For those who had BNRTs smaller than 5 cm and were asymptomatic, we explained to them that they could choose follow-up or surgery and informed them about the advantages and disadvantages of each option. Patients made the decision and signed informed consent. All these patients were preoperatively evaluated by a highly experienced surgeon (Dr. Rong Liu) and were eligible for both robotic and

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open operation. After the patients were informed of the advantages and disadvantages of the two procedures, they decided which operation to choose and gave written informed consent for this study. Thirty patients who underwent robotic surgery and 30 patients who underwent open surgery were matched in a case–control approach with 1:1 propensity score analysis according to age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, tumor size, and whether the tumor was adjacent to major vessels. This study was approved by the Institutional Review Board of the *** Hospital. The study was registered with ResearchRegitry.com and the work has been reported in line with the STROCSS criteria [13].

2.1. Preoperative evaluation

We used contrast-enhanced computed tomography (CT) scanning or magnetic resonance imaging (MRI) to diagnose and evaluate the resectability of BNRTs. CT angiography (CTA) or a three-dimensional reconstruction technique was performed in patients whose tumors were adherent to major vessels for preoperative assessment and surgical planning. In the study, tumor adherence to major vessels was defined as tumor contact with major vessels of ≤180°without vessels contour irregularity. Major vessels include aorta, IVC, portal vein, renal artery and vein, splenic artery and vein, and superior mesenteric artery and vein. On the basis of the circumferential contact of the tumor with major vessels, a three-point scale was devised: grade 0. no contact of the tumor with major vessels; grade 1, tumor contact with major vessels of ≤90°; grade 2, tumor contact with major vessels of > 90°, and ≤180°.

2.2. Selection of the procedure

The inclusion criteria were (1) age 18–70 years; (2) presence of a resectable benign, nonadrenal retroperitoneal tumor; and (3) no general medical conditions that contraindicated anesthesia and surgery. The exclusion criteria were (1) tumors larger than 10 cm, (2) tumors with features of malignancy, and 3) the presence of associated serious cardiopulmonary or hepatorenal insufficiency. Tumors adherent to major vessels was not considered a contraindication to surgery.

2.3. Perioperative data

Baseline demographics as well as perioperative and pathology data were obtained from the electronic medical records. Operation time, estimated blood loss (EBL), blood transfusion, rate of conversion to open surgery, postoperative complications, and PHS were analyzed retrospectively. Readmission rates within 90 days and 30-day mortality rates were also examined. The data on tumor location [1], tumor number, tumor histopathology, tumor size and major vessel adhesion were also obtained from the pathology records. Postoperative complications were graded using the Clavien–Dindo classification [14].

2.4. Surgical technique and follow-up

All RBRs were performed using the *Da Vinci Si* Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) by an experienced surgical team that had already performed more than 1500 robotic surgeries.

The surgical procedures of RBRs have been described previously [12]. After docking, the adjacent retroperitoneal structures were identified depending on the tumor location. Mobilization and dissection of tumors were performed using an ultrasonic scalpel or coagulation hook (Harmonic®, Ethicon Endo-Surgery, Cincinnati, OH, USA). The tumor vessels were dissected off and clipped by Hem-o-lok® clips (TFX Medical Ltd, RTP Durham, NC, USA) or ligated with Mersilk® sutures (Ethicon, Sommerville, NJ, USA) and divided.

After laparotomy, the open surgical procedure was similar to that of the robotic approach. All robotic and open operations were performed by the same surgical team in the study. All patients were followed up once every 3 months in the first year and then at 6-month intervals thereafter.

2.5. Statistical analysis

Continuous data are presented as the mean ± SD or median and interquartile range (IQR) according to their distributions. Student's *t*-test was used to compare normally distributed variables, whereas the Mann–Whitney *U* test was used for nonnormally distributed variables. Categorical data were compared using the chi-square test.

To minimize the effect of potential confounders and selection bias, propensity score analysis was used to compensate for the differences in baseline patient characteristics between both groups. A propensity score was calculated by logistic regression, and covariates such as age, sex, BMI, ASA score, tumor size, and tumor adjacent to major vessels were matched. A 1:1 nearest neighbor matching approach was used to select the participants in both groups. All statistical analyses were performed using SPSS v22.0 (SPSS Inc., Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

3. Results

3.1. Patient characteristics

A total of 88 patients (36 RBRs and 52 OBRs) underwent BNRTs resections during the study period. Before matching, patients in the OBR group had lower BMI values (23.2 ± 3.3 vs. 24.9 ± 3.9, $p < 0.05$) and had a larger tumor size (7.2 ± 5.6 cm vs. 5.0 ± 2.1 cm, $p < 0.05$) than those in the RBR group. This propensity score matching study included 30 patients who underwent RBRs and 30 patients who underwent OBRs. After matching, there were no significant differences between the two groups in demographic characteristics (Table 1).

3.2. Pathological outcome

All the tumors were benign on final histopathological examination (Table 1). Both groups were similar in the pathology of BNRTs ($p = 0.37$). The leading indication for RBR was lymphangioma (n = 8), followed by schwannoma (n = 6) and lymphatic cysts (n = 5). Paraganglioma was the most common indication in the OBR group (n = 7), followed by lymphangioma (n = 6) and schwannoma (n = 6).

3.3. Perioperative outcome

The perioperative outcomes for both groups are presented in Table 2. The robotic group experienced a shorter mean operative time (125.0 vs. 152.7 min, $p = 0.21$) compared to the open group and a lower overall morbidity rate (13.3% vs. 30.0%, $p = 0.15$); however, these differences were not statistically significant. Postoperative major complication (Clavien ≥ 3) occurred in one patient in robotic group. The patient had intra-abdominal hemorrhage from splenic artery and was treated by interventional radiology. Both groups had similar frequencies of blood transfusion (0% vs. 3.3%, $p = 0.31$), whereas the robotic group had lower median estimated blood loss (EBL) (50 (20 85) ml vs. 100 (50 550) ml, $p = 0.00$) and shorter PHS after operation (4.6 vs. 7.9 days, $p = 0.00$) when compared with the open group. The BNRTs were successfully removed robotically in all patients without conversion to laparotomy. No patients required reoperation, had 90-day hospital readmission or died within 90 days of the operations in the two groups.

3.4. Clinical outcomes according to adherence to major vessels

For the patients with tumors adherent to major vessels, the demographic and perioperative outcomes are summarized in Table 3. There

Table 1
Comparison of robotic group and open group: demographic outcomes.

Characteristics	Before propensity score matching			After propensity score matching		
	Open (N = 52)	Robotic (N = 36)	P value	Open (N = 30)	Robotic (N = 30)	P value
Age, yrs	47.8 ± 15.7	50.8 ± 15.1	0.35	50.9 ± 13.6	50.5 ± 15.1	0.91
Male, N (%)	26 (50.0)	17 (47.2)	0.87	15 (50.0)	15 (50.0)	1.00
BMI, N (%)	23.2 ± 3.3	24.9 ± 3.9	**0.04**	24.5 ± 2.7	24.1 ± 3.8	0.69
ASA score, N (%)			0.42			0.45
1	43 (82.7)	32 (88.9)		25 (83.3)	27 (90.0)	
2	9 (17.3)	4 (11.1)		5 (16.7)	3 (10.0)	
3	0 (0)	0 (0)		0 (0)	0 (0)	
4	0 (0)	0 (0)		0 (0)	0 (0)	
Tumor location			0.76			0.97
Right upper area	11 (21.2)	10 (27.8)		7 (23.3)	8 (26.7)	
Left upper area	24 (46.2)	15 (41.7)		13 (43.3)	12 (40.0)	
Right lower area	6 (11.5)	6 (16.7)		4 (13.3)	5 (16.7)	
Left lower area	7 (13.5)	4 (11.1)		4 (13.3)	4 (13.3)	
Posterior to the IVC	4 (7.7)	1 (2.8)		2 (6.7)	1 (3.3)	
Tumor number	1.0 ± 0.0	1.0 ± 0.0	N/A	1.0 ± 0.0	1.0 ± 0.0	N/A
Largest tumor size, cm	7.2 ± 5.6	5.0 ± 2.1	**0.02**	5.8 ± 2.2	5.3 ± 2.1	0.43
Adhesion to major vessel	33 (63.5)	19 (52.8)	0.32	14 (46.7)	14 (46.7)	1.00
Pathology, N(%)			0.50			0.37
Lymphangioma	12 (23.1)	8 (22.2)		6 (20.0)	8 (26.7)	
Schwannoma	9 (17.3)	7 (19.4)		6 (20.0)	6 (20.0)	
Bronchogenic cyst	0 (0)	3 (8.3)		0 (0)	2 (6.7)	
Mucinous cystadenoma	1 (1.9)	2 (5.6)		1 (3.3)	2 (6.7)	
Lymphatic cyst	7 (13.5)	7 (19.4)		2 (6.7)	5 (16.7)	
Neurofibroma	2 (3.8)	1 (2.8)		1 (3.3)	1 (3.3)	
Paraganglioma	11 (21.2)	4 (11.1)		7 (23.3)	3 (10.0)	
Castleman disease	3 (5.8)	2 (5.6)		1 (3.3)	2 (6.7)	
Teratoma	2 (3.8)	0 (0)		2 (6.7)	0 (0)	
Ganglioneuroma	1(1.9)	1 (2.8)		1 (3.3)	1 (3.3)	
Neuroendocrine tumor	4 (7.7)	1 (2.8)		3 (10.0)	0 (0)	

Values represent mean ± SD, or N (%). Boldface represents statistically value. IVC inferior vena cava.

Table 2
Comparison of robotic group and open group: perioperative outcomes.

Characteristics	Open (N = 30)	Robotic (N = 30)	P value
Operative time, mean (SD), min	152.7 ± 72.4	125.0 ± 50.3	0.21
Estimated blood loss, median (IQR), ml	100 (50 550)	50 (20 85)	**0.00**
Blood transfusion, N (%)	1 (3.3)	0 (0)	0.31
Conversion rate, N (%)	N/A	0 (0)	N/A
Morbidity, N (%)	9 (30.0)	4 (13.3)	0.15
Clavien 1–2	9 (30.0)	3 (10.0)	
Clavien ≥3	0 (0)	1 (3.3)	
Postoperative hospital stay (PHS), days	7.9 ± 4.1	4.6 ± 1.7	**0.00**
90-day readmission	0 (0)	0 (0)	N/A
90-day mortality	0 (0)	0 (0)	N/A
Reoperation, N (%)	0 (0)	0 (0)	N/A

Values represent mean ± SD, or N (%); median (25th, 75th percentile) as IQR. Boldface represents statistically value.
N/A: not applicable.

Table 3
Comparison of robotic versus open resection of tumor adherent to major vessels: demographic and perioperative outcomes.

Characteristics	Open (N = 14)	Robotic (N = 14)	*P* value
Age, mean (SD),yrs	54.6 ± 11.0	58.4 ± 11.8	0.39
Male, N (%)	7 (50.0)	6 (42.9)	0.71
BMI, kg/m^2	24.7 ± 2.7	23.7 ± 3.0	0.38
ASA score (3/4)	0 (0)	0 (0)	N/A
Operative time, min	175.4 ± 73.1	136.8 ± 59.6	0.14
Estimated blood loss, median (IQR), ml	250 (50 800)	50 (20 100)	**0.02**
Blood transfusion, N (%)	1 (7.1)	0 (0)	0.31
Largest tumor size, cm	5.8 ± 2.7	5.2 ± 2.1	0.46
Morbidity, N (%)	5 (35.7)	4 (28.6)	0.84
Clavien 1-2	5 (35.7)	3 (21.4)	
Clavien ≥ 3	0 (0)	1 (7.1)	
Postoperative hospital stay (PHS), days	9.3 ± 5.6	4.4 ± 1.5	**0.00**
90-day readmission	0 (0)	0 (0)	N/A
90-day mortality	0 (0)	0 (0)	N/A
Reoperation	0 (0)	0 (0)	N/A

Values represent mean ± SD, or N (%); median (25th, 75th percentile) as IQR.

were no significant differences between the RBR and OBR groups with respect to age, sex, BMI, and largest tumor size. The two groups had similar blood transfusion rates and morbidity rates ($p > 0.05$). However, EBL and PHS were significantly reduced in the robotic group when compared with the open group (50 (20 100) vs. 250 (50 800) ml, $p = 0.02$; 4.4 vs. 9.3 days, $p = 0.00$). The operation time was shorter in the RBR group than in the OBR group; however, there was no statistically significant difference between the two groups.

3.5. Clinical outcomes according to large tumor size

When clinical outcomes were compared between the RBR and OBR groups of patients with tumors that required major tumor resection (tumor size > 5 cm), the demographic outcomes, operation times, blood transfusion rates, and morbidity rates were not significantly different (Table 4, $p > 0.05$). Robotic surgery reduced EBL and PHS significantly when compared with the open group (50 (20 100) vs. 200 (50 500) ml, $p = 0.00$; 4.9 vs. 7.5 days, $p = 0.01$).

4. Discussion

Because BNRTs are located deep and proximal to major vessels, it is difficult to apply laparoscopic techniques to BNRT resection, and only a few cases of laparoscopic BNRT resection have been reported [1–5]. Robotic surgery has been developed to overcome the inherent limitations of laparoscopic surgery and has become widely applied in many

Table 4
Comparison of robotic versus open large tumor (> 5 cm) resection: demographic and perioperative outcomes.

Characteristics	Open (N = 20)	Robotic (N = 15)	*P* value
Age, mean (SD),yrs	48.5 ± 15.2	52.8 ± 13.9	0.40
Male, N (%)	10 (50)	8 (53.3)	0.85
BMI, kg/m^2	24.5 ± 2.8	25.0 ± 4.2	0.67
ASA score (3/4), N (%)	0 (0)	0 (0)	N/A
Operative time, min	156.6 ± 65.8	153.5 ± 43.6	0.88
Estimated blood loss, median (IQR), ml	200(50 500)	50(20 100)	**0.00**
Blood transfusion, N (%)	1 (5.0)	0 (0)	0.38
Adhesion to major vessel	2 (10.0)	3 (20.0)	0.40
Morbidity, N (%)	8 (35.0)	3 (20.0)	0.33
Clavien 1-2	8 (35.0)	3 (20.0)	
Clavien ≥ 3	0 (0)	0 (0)	
Postoperative hospital stay (PHS), days	7.5 ± 2.9	4.9 ± 2.1	**0.01**
90-day readmission	0 (0)	0 (0)	N/A
90-day mortality	0 (0)	0 (0)	N/A
Reoperation	0 (0)	0 (0)	N/A

Values represent mean ± SD, or N (%); median (25th, 75th percentile) as IQR. Bold numbers represent statistically significant values.

retroperitoneal operations, such as pancreatic and adrenal tumor resection [15–20].

Our previous study demonstrated that robotic resection of BNRTs is safe and feasible. Even large tumors or tumors adherent to major vessels can be resected without any significant adverse effects on the perioperative outcomes [12]. However, a comparative study of robotic BNRT resection has not been reported. In the present study, a propensity score-matched comparison between robotic and open resection of BNRTs was performed, which involved the largest RBR sample size in the world. The robotic approach demonstrated the advantages of reducing EBL and decreasing PHS in patients with BNRTs compared with open surgery, even when tumors are larger than 5 cm or adherent to major vessels.

All enrolled patients were eligible for both robotic and open surgery and made their decision after they were informed of the advantages and disadvantages of both surgeries. Patients in the OBR group had a larger tumor size compared with the RBR group, which is due to selection bias. In the present study, we applied propensity score matching to reduce selection bias. After matching, there were no significant differences in demographic parameters between the robotic and open groups.

It is still controversial whether the minimally invasive approach should be used for malignant lesions. Recently, a randomized controlled study demonstrated that minimally invasive radical hysterectomy was associated with lower rates of disease-free survival and overall survival than open operation in patients with early-stage cervical cancer [21]. A retrospective cohort study confirmed the above result, although it was impossible to explain why minimally invasive surgery was associated with shorter overall survival [22]. Considering the lack of long-term survival data for patients with malignant NRTs treated with robotic surgery, we included patients with benign NRTs in this study. Each patient underwent preoperative radiologic examinations to identify benign and malignant tumors, and all resected tumors were confirmed to be benign on postoperative histopathological examination.

Previous studies have confirmed that the robotic technique could effectively improve the ability to control bleeding [23,24]. In this study, median blood loss in the RBR group was significantly less than that in the OBR group. The improved manipulation and visualization of the robot facilitated vessel dissection, suturing and knotting [25–27], which ultimately reduced EBL during the operation. The reasons for conversion to laparotomy include uncontrolled bleeding and poor visualization [28]. In this study, all RBRs were completed using the totally robotic approach without conversion to open surgery, which might be attributed to the advantages of robotic surgery in precise manipulation, improved visualization, and fast bleeding control.

In our study, the robotic group demonstrated a significantly shorter PHS when compared with the open group. The greater dexterity and precision in manipulation might reduce surgical damage [25,26], and minimally invasive surgery could relieve postoperative pain [29,30], both of which can help the RBR patients recover more rapidly. Our study showed that RBR was associated with a shorter operative time when compared with the OBR group, although the difference was not statistically significant. The two groups of patients in this study also had similar blood transfusion rates and morbidity rates. Considering that docking the robot and exchanging instruments increases the surgery time and the learning curve in the robotic group, we expect that the robotic technique might reduce the operative time and produce better short-term outcomes when compared with open surgery in a future study.

BNRTs are often adherent to major vessels, which increases the risk of injury to adjacent vessels and excessive bleeding [1]. In this study, nearly half of the patients in each group (14/30) had tumors adherent to major vessels. The robotic operation system allows precise dissection around major vessels and good bleeding control; therefore, our study demonstrated that RBR can significantly reduce EBL and PHS when compared with OBR. Although the decrease in operative time in RBR was not significant compared with OBR, the RBR operation times in our study seemed to be much shorter than in our previous study, which might be due to the accumulated robotic surgery experience at our institution.

Because a large retroperitoneal tumor is more likely to invade adjacent organs or vessels, patients with large tumors required a longer operation time, lost more blood, and required a longer postoperative hospital stay [31,32]. We further classified the patients according to tumor size and found that robotic surgery reduced EBL and PHS significantly in patients with tumors larger than 5 cm. These might be attributed to the improved dexterity and visualization of the robotic technique, which benefited tumor dissection, tissue mobilization, and vascular control [25–27]. The postoperative morbidity rates were also not significantly different between RBR and OBR, suggesting that robotic resection of large BNRTs is technically safe and effective.

There are several limitations to this study. First, this study has a relatively small sample size. To our knowledge, resectable BNRTs are rare, and this is the largest study to compare robotic resection with open surgery for patients with BNRTs. Second, the nonrandomized retrospective study design is subject to inherent selection bias. However, all patients were required to be eligible for both surgical approaches, and a 1:1 propensity score matching comparison was performed, all of which were used to minimize selection bias in this retrospective study. Lastly, this retrospective study has inevitable assessor and response bias. All operations were performed by the same surgical team within a short time span, and the surgical techniques and assessment criteria were consistent, which helped to reduce performance and assessor bias. A multicenter randomized controlled trial will be required in future to investigate benefits of RBR.

5. Conclusion

In conclusion, our study demonstrates that RBR has comparable safety and efficacy to OBR in selected patients with BNRTs. With the advantages of the robotic technique, RBR may offer significant benefits over OBR, thus reducing EBL and decreasing PHS in patients even for tumors that are large or adjacent to major vessels.

Ethical approval

The study was approved by the Institutional Review Board of the People's Liberation Army General Hospital (S2016-098-01).

Author contribution

Conception and design: Qu Liu, Rong Liu.
Acquisition of the data: Ruiquan Zhou, Guodong Zhao.
Analysis and interpretation of the data: Qu Liu, Zhiming Zhao, Yuanxing Gao.
Drafting of the article: Qu Liu, Ruiquan Zhou.
Critical revision of the article: Qu Liu, Ruiquan Zhou, Rong Liu.
Final approval of the article: Rong Liu.

Conflicts of interest

No conflicts of interest to declare by any of the authors.

Research registration unique identifying number

The study was registered with ResearchRegistry.com. The Unique Identification Number is researchregistry4545.

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Provenance and peer review

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Research data for this article

Due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared.

Declarations of interest

None.

CRediT authorship contribution statement

Qu Liu: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Ruiquan Zhou:** Data curation, Writing - original draft, Writing - review & editing. **Zhiming Zhao:** Formal analysis. **Yuanxing Gao:** Formal analysis. **Guodong Zhao:** Data curation. **Rong Liu:** Conceptualization, Writing - review & editing.

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Appendix A. Supplementary data

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