Original Article

Comparison of the perioperative outcomes between robotic-assisted thoracic surgery and video-assisted thoracic surgery in non-small cell lung cancer patients with different body mass index ranges

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Background: Non-small cell lung cancer (NSCLC) is the most common malignancy and one of the most common causes of cancer-related death worldwide. Robotic-assisted thoracic surgery (RATS) has gradually become a prevalent surgical method for patients with NSCLC. Previous studies have found that body mass index (BMI) is associated with postoperative outcomes. This study aimed to investigate the effectiveness of RATS compared to video-assisted thoracic surgery (VATS) in the treatment of NSCLC with different BMI, in terms of perioperative outcomes.

Methods: The baseline and perioperative data, including BMI, of 849 NSCLC patients who underwent minimally invasive anatomic lung resections from August 2020 to April 2021 were retrospectively collected and analyzed. Propensity score matching analysis was applied to minimize potential bias between the two groups (VATS and RATS), and the perioperative outcomes were compared. Subgroup analysis was subsequently performed.

Results: Compared to VATS, RATS had more lymph nodes dissected {9 [inter-quartile range (IQR), 6–12] *vs.* 7 (IQR, 6–10), P<0.001}, a lower estimated bleeding volume [40 (IQR, 30–50) *vs.* 50 (IQR, 40–60) mL, P<0.001], and other better postoperative outcomes, but a higher cost of hospitalization [¥83,626 (IQR, 77,211–92,686) *vs.* ¥75,804 (IQR, 66,184–83,693), P<0.001]. Multivariable logistic regression analysis indicated that RATS (P=0.027) and increasing BMI (P=0.030) were associated with a statistically significant reduction in the risk of postoperative complications. Subgroup analysis indicated that the advantages of RATS may be more obvious in patients with a BMI of 24–28 kg/m^2, in which the RATS group had more lymph nodes dissected [9 (IQR, 6–12) *vs.* 7 (IQR, 5–10), P<0.001] and a decreased risk of total postoperative complications [odds ratio (OR), 0.443; 95% confidence interval (CI), 0.212–0.924; P=0.030] compared to the VATS group.

Conclusions: Both, RATS and VATS can be safely applied for patients with NSCLC. Perioperative outcome parameters indicate advantages for RATS, however at a higher cost of hospitalization. The advantages of RATS might be more obvious in patients with a BMI of 24–28 kg/m^2.

Keywords: Non-small cell lung cancer (NSCLC); robotic-assisted thoracic surgery (RATS); video-assisted thoracic surgery (VATS); body mass index (BMI)

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Introduction

Non-small cell lung cancer (NSCLC), which accounts for the majority of lung cancers, is one of the most common cancer types and the most common cause of cancer-related death worldwide (1,2). At present, radical surgical resection is the mainstay of local treatment in curative stages of NSCLC (1) and in selected cases of oligometastatic disease. As the predominant minimally invasive surgical approach in lung cancer surgery, video-assisted thoracic surgery (VATS) can significantly shorten postoperative hospital stay, and reduce postoperative pain and complications compared to open thoracic surgery, and has a comparable long-term oncologic efficacy to thoracotomy (3). In recent years robotic-assisted thoracic surgery (RATS) has gradually become a common surgical approach for patients with NSCLC due to its advantages in ergonomics, three-dimensional (3D) imaging, and deep regional anatomy.

The Da Vinci robotic surgical system was first approved by United States Food and Drug Administration for laparoscopic surgery in 2000. This system offers advantages including precision, safety, and comfort (4,5). At present, many scholars have conducted application studies on Da Vinci robotic surgery from various aspects, including efficacy, safety, and cost effectiveness. However, the conclusions remain controversial. In 2020, Zhou *et al.* analyzed stage IA NSCLC patients undergoing segmentectomy, and found that patients undergoing RATS compared with VATS had reduced surgery times, decreased hospital stays, and less blood loss (6). A recently published study (7,8) showed that RATS has obvious advantages over VATS in lymph node dissection in clinical stages T1–T2, N0–N1 NSCLC patients. A randomized trial indicated comparable safety and radicality of surgery of RATS and VATS in cN2 NSCLC (9). In addition, other studies have indicated that RATS is similar to VATS both in terms of perioperative outcomes (10,11) and long-term oncologic data (12,13). Several other robotic assisted systems have recently become commercially available.

However, the majority of previous studies are small cohorts, and most of the studies focused on the comparison between VATS and RATS for lobectomy and sublobar resection, as well as for different clinical stages. Previous studies have found that body mass index (BMI) is associated with postoperative outcomes. But the results are still conflicting (14,15). Interestingly, we observed dissimilar perioperative outcomes and complications between VATS and RATS in NSCLC patients with different BMI ranges, which has not yet been studied in previous study.

The diagnosis and treatment of diseases should follow the principle of "individualization". Considering the high economic cost of RATS, our study aimed to provide high-quality evidence for patients, identify NSCLC patients who are more suitable for RATS treatment, and explore how to maximize the advantages of RATS, performing a subgroup analysis based on BMI. We present the following article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-137/rc).

Methods

Patient selection

This retrospective study was approved by the institutional review board of the Qilu Hospital of Shandong University (No. KYLL-202008-023-1) and was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All patients provided informed consent for the use of their clinical information. A prospectively maintained departmental database in our hospital was retrieved for patients who underwent lobectomy or anatomical sublobar resection for NSCLC between August 2020 and April 2021. All cases had undergone preoperative enhanced computed tomography (CT)/positron emission tomography/body bone scan to defined clinical stage. Pathological staging was determined according to the tumor-node-metastasis (TNM) staging system (16). Patients with missing information on key variables or relevant data were excluded in these regression analyses. We excluded patients who received preoperative neoadjuvant radiotherapy and chemotherapy, previous pulmonary resection or extended resection, and patients staged cM+. Finally, 849 NSCLC patients (477 VATS cases and 372 RATS cases) were included into this cohort study for subsequent analysis.

Data collection and variable definitions

The following data were extracted from the Qilu Hospital database: characteristics of patients, BMI, resection range (lobectomy or sublobar resection), operative duration, conversion to thoracotomy, estimated bleeding volume, total number of dissected lymph nodes, postoperative drainage volume, duration of drainage, postoperative numerical rating scale (NRS) pain score, postoperative complications, postoperative length of stay (LOS), and total cost of hospitalization. Postoperative complications included persistent air leakage (>5 consecutive days), arrhythmias, pleural effusions, chylothorax, severe postoperative bleeding, and other surgical complications. We graded the severity of postoperative complications based on the Accordion Severity Grading System (17): mild complication, moderate complication, and severe complication.

Conversion to thoracotomy was defined as conversion to open surgery for various reasons, such as uncontrolled bleeding and severe adhesions. The NRS pain score was evaluated by the ward nurse at 24, 48, and 72 hours after surgery, and was defined as the postoperative day (POD) 1, 2, and 3 NRS score. All patients with a postoperative hospitalization for more than 8 days had were considered as "postoperative delayed recovery". Subgroup analysis was then performed to analyze how to maximize the advantages of RATS. Patients were divided into three groups according to BMI: under and normal weight group (BMI ≤24 kg/m^2); overweight group (24 kg/m^2 < BMI <28 kg/m^2); and obesity group (BMI ≥28 kg/m^2).

Surgical methods and postoperative management

The choice of surgical approach was principally made by the patients based on a household's ability to pay. All of the procedures were performed by three qualified surgeons. VATS was performed using standard thoracoscopic techniques with a conventional two-incision operation. Systematic hilar and mediastinal lymph node dissection were routinely performed according to the National Comprehensive Cancer Network guidelines, and the station and number of dissected lymph nodes were marked. The 4^{th} generation Da Vinci surgical system was applied in RATS, which involved three robotic arms with an assistant for intraoperative surgical assistance.

The specific surgical method applied was the same as that of VATS. One or two chest tubes were placed postoperatively. All of the patients received postoperative analgesia using an analgesic pump. The chest tube could be removed if there was no pneumonia, subcutaneous emphysema, or pneumothorax with daily drainage less than 200 mL for 3 days. Chest tube suction was applied in cases of persistent air leak or poor lung re-expansion. A continuous negative pressure suction device with a negative pressure range of 6–10 cm water column was used for patients with persistent air leakage. All patients in this study were managed using enhanced postoperative recovery.

Statistical analysis

Binary and categorical variables were compared using the chi-squared test, and continuous data were compared using Student's *t*-test. For non-normal distributions, continuous variables were expressed as the median [inter-quartile range (IQR)], and the Wilcoxon rank-sum test was used to compare groups. The baseline data of patients in the two groups were analyzed to identify bias factors. A 1:1 propensity score matching (PSM) analysis was applied to minimize the potential bias between the two groups of patients. A nearest-neighbor matching method was adopted, and the caliper size was selected as 0.01. The variables used to determine PSM were age, gender, BMI, smoking history, surgical methods (lobectomy or sublobar resection), and lymph node metastasis.

Univariable and multivariable regression analyses were performed to determine the association between surgical approach and postoperative complications, excluding the interference of confounding factors arising from statistically significant differences in the incidence of postoperative complications between patients with different BMI ranges. Interaction of BMI and Surgical approach was assessed through the incorporation of an interaction term into regression models. Where no interaction effects occurred, the interaction effect was removed from the regression model. A two-sided P<0.05 was considered statistically significant. R software, v4.1.1 (The R Foundation for Statistical Computing, Vienna, Austria) was used for PSM, and SPSS software, v26.0 (SPSS Inc., Chicago, IL, USA) was used for further data analysis.

Results

The patient characteristics before and after PSM are shown in *Table 1*. Before matching, there was a significant difference in age and BMI between the two groups (P<0.05). There were no significant differences in gender, smoking

Table 1 Baseline characteristics of NSCLC patients before and after PSM

Variables	Before PSM			After PSM		
	VATS (n=477)	RATS (n=372)	P value	VATS (n=316)	RATS (n=316)	P value
Age (years), mean ± SEM	60.43±0.54	57.62±0.52	<0.001	57.93±0.62	58.48±0.54	0.502
Sex, n (%)			0.721			0.170
Female	270 (56.7)	206 (55.5)		193 (61.1)	176 (55.7)	
Male	207 (43.3)	166 (44.5)		123 (38.9)	140 (44.3)	
BMI (kg/m^2), n (%)			0.007			0.723
≤24	198 (41.5)	163 (43.8)		140 (44.3)	130 (41.1)	
24–28	228 (47.8)	146 (39.2)		133 (42.1)	141 (44.6)	
≥28	51 (10.7)	63 (16.9)		43 (13.6)	45 (14.2)	
Smoking status, n (%)			0.743			0.356
Non-smoker	351 (73.6)	270 (72.6)		243 (76.9)	233 (73.7)	
Smoker	126 (26.4)	102 (27.4)		73 (23.1)	83 (26.3)	
Resection range, n (%)			0.228			0.241
Lobectomy	309 (64.8)	226 (60.8)		214 (67.7)	200 (63.3)	
Sublobectomy	168 (35.2)	146 (39.2)		102 (32.3)	116 (36.7)	
Tumor size (cm), mean ± SEM	2.08±0.007	1.58±0.05	<0.001	1.66±0.06	1.62±0.06	0.613
Lymph metastasis, n (%)			0.115			0.776
N0	423 (88.7)	342 (91.9)		306 (92.2)	304 (91.6)	
N1/2	54 (11.3)	30 (8.1)		26 (7.8)	28 (8.4)	

NSCLC, non-small cell lung cancer; PSM, propensity score matching; SEM, standard error of the mean; BMI, body mass index; VATS, video-assisted thoracic surgery; RATS, robotic-assisted thoracic surgery.

history, surgical methods, and N stage. After PSM there were no significant differences in all variables.

Perioperative outcomes

The perioperative outcomes of patients who underwent VATS or RATS after PSM are shown in *Table 2*. The number of lymph nodes dissected that we focused on were statistically different between the two groups. Compared to VATS, the RATS group had more lymph nodes dissected [9 (IQR, 6–12) *vs.* 7 (IQR, 6–10), P<0.001]. In terms of the other short-term postoperative outcomes, RATS had a lower bleeding volume [40 (IQR, 30–50) *vs.* 50 (IQR, 40–60) mL, P<0.001], shorter duration of drainage [4 (IQR, 3–6) *vs.* 5 (IQR, 4–6) days, P<0.001] and postoperative LOS [6 (IQR, 5–8) *vs.* 7 (IQR, 6–9) days, P<0.001], lower rate of postoperative delayed recovery (19.3% *vs.* 26.6%, P=0.003), higher cost of hospitalization [¥83,626 (IQR, 77,211–92,686) *vs.* ¥75,804 (IQR, 66,184–83,693), P<0.001], higher NRS pain score on POD1 [3 (IQR, 3–4) *vs.* 2 (IQR, 2–3), P<0.001], lower NRS pain score on POD2 [3 (IQR, 3–4) *vs.* 4 (IQR, 4–4), P<0.001], and fewer postoperative complications (16.8% *vs.* 23.7%, P=0.027) compared to VATS. However, there were no significant differences in the operative duration [100 (IQR, 80–115) *vs.* 100 (IQR, 75–120), P=0.823], average drainage volume in the first 3 days after surgery [196.67 (IQR, 142.08–253.33) *vs.* 190 (IQR, 121.67–266.67) mL, P=0.426], NRS pain score on POD3 [2 (IQR, 2–3) *vs.* 3 (IQR, 3–3), P=0.018], conversion to thoracotomy (0.3% *vs.* 1.9%, P=0.057), mild postoperative complications (10.1% *vs.* 13.6%, P=0.176), and severe postoperative complications (0 *vs.* 1.3%, P=0.124).

Postoperative complications

The occurrence of these postoperative complications was

Table 2 Comparison of the perioperative outcomes of VATS and RATS in NSCLC patients after PSM

Variables	VATS (n=316)	RATS (n=316)	P value
Number of dissected lymph nodes, median [IQR]	7 [6–10]	9 [6–12]	<0.001
Bleeding volume (mL), median [IQR]	50 [40–60]	40 [30–50]	<0.001
Operative duration (min), median [IQR]	100 [80–115]	100 [75–120]	0.823
Duration of drainage (days), median [IQR]	5 [4–6]	4 [3–6]	<0.001
LOS (days), median [IQR]	7 [6–9]	6 [5–8]	<0.001
Postoperative delayed recovery, n (%)	84 (26.6)	61 (19.3)	0.030
Hospitalization cost (¥), median [IQR]	75,804 [66,184–83,693]	83,626 [77,211–92,686]	<0.001
Average drainage volume in the first 3 days (mL), median [IQR]	190 [121.67–266.67]	196.67 [142.08–253.33]	0.426
NRS score on POD1, median [IQR]	2 [2–3]	3 [3–4]	<0.001
NRS score on POD2, median [IQR]	4 [4–4]	3 [3–4]	<0.001
NRS score on POD3, median [IQR]	3 [3–3]	2 [2–3]	0.018
Mild complication, n (%)	43 (13.6)	32 (10.1)	0.176
Moderate complication, n (%)	43 (13.6)	23 (7.3)	0.009
Severe complication, n (%)	4 (1.3)	0 (0.0)	0.124
Total complications*, n (%)	75 (23.7)	53 (16.8)	0.029
Conversion to thoracotomy, n (%)	6 (1.9)	1 (0.3)	0.057

*, some cases showed complications of different severity during the hospital stay. VATS, video-assisted thoracic surgery; RATS, robotic-assisted thoracic surgery; NSCLC, non-small cell lung cancer; PSM, propensity score matching; IQR, inter-quartile range; LOS, length of stay; NRS, numerical rating scale; POD, postoperative day.

closely related to the quality of life of NSCLC patients (18). Therefore, after discovering the relationship between the incidence of postoperative complications and the surgical approach, we performed univariable and multivariable regression analyses of the variables predicting the incidence of postoperative complications. The risk of postoperative complications was statistically significantly decreased in the RATS group compared with VATS group [odds ratio (OR), 0.619; 95% confidence interval (CI): 0.405–0.948; P=0.027]. Meanwhile, increasing BMI was associated with a statistically significant reduction in the risk of postoperative complications (OR, 0.903; 95% CI: 0.845–0.965; P=0.003). In addition, age and tumor size were strong positive predictors of postoperative complications (*Table 3*).

Subgroup analysis of perioperative outcomes

Thus, to investigate how to maximize the advantages of RATS, we performed subgroup analysis according to the BMI. Using 24 and 28 kg/m^2 as cut-off values, we divided all of the patients into three groups. Patients with a BMI ≤24 kg/m^2 were defined as under and normal weight, patients with a BMI of 24 kg/m^2 < BMI <28 kg/m^2 were considered overweight, and those with a BMI ≥28 kg/m^2 were considered obese. The subgroup comparison of perioperative outcomes based on the BMI between the VATS and RATS groups are presented in *Table 4*.

For patients with a BMI ≤24 kg/m^2, there were no significant differences in the operative duration and delayed postoperative recovery between the VATS and RATS groups. However, compared with VATS, the RATS group had more lymph node dissections [8.5 (IQR, 5–12) *vs.* 7 (IQR, 6–10), P=0.044], a lower bleeding volume, shorter duration of drainage, decreased postoperative LOS, and increased hospitalization cost.

For patients with 24 kg/m^2 < BMI <28 kg/m^2, there were no significant differences in the operative duration, duration of drainage, postoperative LOS, and postoperative delayed recovery between the VATS and RATS groups. Same as patients with a BMI ≤24 kg/m^2, the RATS group had more lymph node dissections [9 (IQR, 6–12) *vs.* 7 (IQR, 5–10), P<0.001], a lower bleeding volume, and increased

Table 3 Univariable and multivariable logistic regression analyses of postoperative complications in NSCLC patients

Variables	Univariable logistic regression analysis			Multivariable logistic regression analysis		
	OR	95% CI	P value	OR	95% CI	P value
Age (years)	1.031	1.010–1.052	0.004	1.026	1.004–1.049	0.021
Sex						
Male	Ref.			Ref.		
Female	1.726	1.168–2.550	0.006	0.630	0.377–1.054	0.078
BMI (kg/m^2)	0.913	0.855–0.974	0.006	0.903	0.845–0.965	0.003
Smoking						
No	Ref.			Ref.		
Yes	1.520	0.992–2.331	0.055	0.877	0.492–1.560	0.654
Surgical approach						
VATS	Ref.			Ref.		
RATS	0.648	0.437–0.959	0.030	0.619	0.405–0.948	0.027
Resection range						
Sublobectomy	Ref.			Ref.		
Lobectomy	1.149	0.759–1.737	0.512	0.952	0.608–1.489	0.828
Tumor size (cm)	1.366	1.149–1.625	<0.001	1.246	1.021–1.520	0.030
Lymph node metastasis						
N0	Ref.			Ref.		
N1/2	1.286	0.591–2.798	0.526	0.983	0.408–2.367	0.969
Operation time (min)	1.008	1.002–1.014	0.009	1.008	0.999–1.017	0.099
Bleeding volume (mL)	1.007	1.001–1.013	0.033	0.999	0.989–1.008	0.777

Postoperative complications refer to the occurrence of one or more of the following conditions: persistent air leakage (more than 5 consecutive days), arrhythmias, pleural effusions, chylothorax, severe postoperative bleeding that cannot be treated conservatively, and other surgical complications. NSCLC, non-small cell lung cancer; BMI, body mass index; VATS, video-assisted thoracic surgery; RATS, robotic-assisted thoracic surgery; OR, odds ratio; CI, confidence interval.

hospitalization cost compared to the VATS group for patients with 24 kg/m^2 < BMI <28 kg/m^2.

However, patients with BMI ≥28 kg/m^2 showed different results. The number of lymph nodes dissected did not differ statistically between the VATS and RATS groups. Similarly, the hospitalization cost of patients in the RATS group was higher than that of patients in the VATS group.

Subgroup analysis of perioperative complications

In order to further determine the cost-performance ratio of RATS and VATS among the different BMI groups, we conducted a multivariable logistic regression analysis of the postoperative complications in the three BMI groups, respectively, and the detailed outcomes are presented in *Table 5*. Adjustments included surgical approach, age, sex, smoking, resection range, tumor size, lymph node metastasis, operation time, and bleeding volume.

After adjusting for age, sex, smoking, resection range, tumor size, lymph node metastasis, operation time, and bleeding volume, surgical approach was still significantly associated with postoperative complications in patients with 24 kg/m^2 < BMI <28 kg/m^2. Compared with patients in the VATS group, the risk of postoperative complications was markedly decreased in the RATS group (OR, 0.443; 95% CI: 0.212–0.924; P=0.030). However, no statistical relationship

Table 4 Comparison of the perioperative outcomes of VATS and RATS in normal-weight and obese patients

Variables	For patients of BMI ≤24 kg/m^2 (n=270)			For patients of 24 kg/m^2 < BMI <28 kg/m^2 (n=274)			For patients of BMI ≥28 kg/m^2 (n=88)		
	VATS (n=140)	RATS (n=130)	P value	VATS (n=133)	RATS (n=141)	P value	VATS (n=43)	RATS (n=45)	P value
Number of dissected lymph nodes, median [IQR]	7 [6–10]	8.5 [5–12]	0.044	7 [5–10]	9 [6–12]	<0.001	8 [7–10]	9 [7–12]	0.454
Bleeding volume (mL), median [IQR]	50 [40–60]	30 [30–50]	<0.001	50 [40–60]	40 [30–50]	<0.001	60 [40–60]	40 [30–70]	0.038
Operative duration (min), median [IQR]	95 [66.25–118.75]	95 [70–115]	0.899	100 [80–110]	100 [80–120]	0.893	100 [80–120]	110 [77.50–137.50]	0.436
Duration of drainage (days), median [IQR]	5 [4–6.75]	4 [3–6]	<0.001	4 [4–6]	4 [3–6]	0.172	5 [4–7]	4 [3–5]	0.004
LOS (days), median [IQR]	7 [6–9]	6 [5–8]	<0.001	7 [6–8]	6 [5–8]	0.079	7 [6–9]	6 [5–7]	0.005
Postoperative delayed recovery, n (%)	46 (32.9)	31 (23.8)	0.101	27 (20.3)	27 (19.1)	0.811	11 (25.6)	3 (6.7)	0.015
Hospitalization cost (¥), median [IQR]	79,889 [68,903–87,982]	83,447 [76,702–90,986]	0.004	71,485 [65,814–78,281]	83,756 [76,910–95,774]	<0.001	76,829 [58,550–88,202]	84,596 [78,444–92,805]	<0.001

VATS, video-assisted thoracic surgery; RATS, robotic-assisted thoracic surgery; IQR, inter-quartile range; LOS, length of stay; BMI, body mass index.

was observed between the surgical approach and the incidence of postoperative complications among patients with BMI ≤24 kg/m^2 (P=0.403) and BMI ≥28 kg/m^2 (P=0.151).

Discussion

This study retrospectively compared the perioperative safety and short-term efficacy of RATS and VATS in the surgical treatment of NSCLC. The results indicated that compared to VATS, RATS could increase the number of lymph nodes dissected, slightly reduce the intraoperative bleeding volume, shorten the duration of drainage, reduce the postoperative LOS, decrease the rate of postoperative delayed recovery, and minimize postoperative complications. Considering the higher cost of RATS, we conducted a subgroup analysis of patients based on BMI and found that the advantages of RATS might be more cost-effective for patients with 24 kg/m^2 < BMI <28 kg/m^2. This is the first study investigating the advantages and disadvantages of RATS and VATS in NSCLC patients with different BMI ranges.

The best surgical option for resectable stage II and above NSCLC is still controversial, and studies generally agree that thoracotomy can achieve excellent long-term postoperative outcomes, especially in lymph node dissection (13,19). It has been reported recently that RATS has the same long-term outcomes as thoracotomy and VATS, as well as better short-term results (20-24). The ROMAN study (7) and RVlob Trial (25), which is a perioperative randomized multicentric clinical trial for stage I–II NSCLC, both confirmed that robotic methods can improve lymph node staging and obtain a higher lymph node yield. Also our results demonstrate that RATS can significantly improve the anatomical clarity of non-obese patients with lymph node metastasis, which is helpful for the completion of systematic lymph node dissection, but not in NSCLC patients with a BMI ≥28 kg/m^2. Whether this translates into differences in long term overall or disease-free survival need to be confirmed by prospective clinical trials.

In addition to lymph node dissection, we showed that RATS was not inferior to VATS in terms of other perioperative outcomes, including intraoperative bleeding volume, duration of drainage, LOS, postoperative delayed recovery, etc. This might be attributable to the finely manipulated components of robotic surgery. The naked eye 3D visualization and higher maneuverability of RATS allows the surgeon to distinguish anatomical structures and handle them more easily and properly, thereby reducing

Table 5 Multivariable logistic regression analysis of postoperative complications in NSCLC patients with different BMI ranges

Variables	For patients of BMI ≤24 kg/m^2 (n=270)			For patients of 24 kg/m^2 < BMI <28 kg/m^2 (n=274)			For patients of BMI ≥28 kg/m^2 (n=88)		
	OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Surgical approach									
VATS	Ref.			Ref.			Ref.		
RATS	0.767	0.412–1.428	0.403	0.443	0.212–0.924	0.030	0.346	0.081–1.475	0.151
Age (years)	1.008	0.980–1.036	0.576	1.076	1.026–1.129	0.003	0.978	0.883–1.083	0.669
Sex									
Male	Ref.			Ref.			Ref.		
Female	0.529	0.245–1.142	0.105	0.607	0.254–1.450	0.261	1.052	0.211–5.248	0.951
Smoking									
No	Ref.			Ref.			Ref.		
Yes	0.854	0.328–2.219	0.745	0.936	0.384–2.284	0.885	0.502	0.083–3.026	0.452
Resection range									
Sublobectomy	Ref.			Ref.			Ref.		
Lobectomy	0.951	0.493–1.835	0.882	0.867	0.409–1.839	0.711	1.313	0.168–10.228	0.795
Tumor size (cm)	1.135	0.868–1.483	0.355	1.309	0.917–1.869	0.138	2.745	1.020–7.386	0.046
Lymph node metastasis									
N0	Ref.			Ref.			Ref.		
N1/2	2.763	0.810–9.428	0.105	0.499	0.104–2.389	0.384	0	0	0.999
Operation time (min)	0.998	0.985–1.012	0.807	1.031	1.006–1.056	0.014	1.047	0.992–1.106	0.097
Bleeding volume (mL)	1.014	0.997–1.031	0.098	0.963	0.930–0.998	0.040	0.942	0.870–1.020	0.138

Postoperative complications refer to the occurrence of one or more of the following conditions: persistent air leakage (more than 5 consecutive days), arrhythmias, pleural effusions, chylothorax, severe postoperative bleeding that cannot be treated conservatively, and other surgical complications. NSCLC, non-small cell lung cancer; BMI, body mass index; VATS, video-assisted thoracic surgery; RATS, robotic-assisted thoracic surgery; OR, odds ratio; CI, confidence interval.

unexpected injuries to blood and lymphatic vessels (26,27).

With the rapid development of diagnostic and treatment technology, the disease-free survival rate of NSCLC patients after surgery has been further improved. Therefore, paying greater attention to the postoperative quality of life of patients has become an important part of modern medical treatment. It has been reported that VATS and RATS have markedly fewer postoperative complications than open surgery (28), improving the quality of life of those patients. After adjusting for confounding factors such as age, BMI, and tumor size, our study demonstrated that surgical approach was still significantly associated with the incidence of postoperative complications. Also, univariable and multivariable regression analyses showed that all patients with NSCLC in the RATS group had a lower risk of postoperative complications than patients in the VATS group. However, these results varied for patients in different BMI ranges.

Despite NSCLC patients treated with RATS could receive more detailed and thorough systematic lymph node dissection, as well as reduced risk of postoperative complications, this procedure is still very expensive, which prevents its use in many patients (29). Thus, identifying NSCLC patients who are more suitable for RATS treatment, and explore how to maximize the advantages of RATS becomes essential in the clinical practice.

This study is the first to explore the advantages and disadvantages of RATS and VATS in NSCLC patients with different BMI ranges, aiming to maximize the advantages of RATS. In recent years, the number of overweight or obese patients with NSCLC increased significantly (30). Surgeons will encounter greater challenges for VATS or RATS with obese patients due to increased internal fat, limited movements of instruments, and deeper body cavity, as well as their well-known poor outcomes (31). In this study, it was found that for NSCLC patients with 24 kg/m^2 < BMI <28 kg/m^2, RATS may provide better perioperative outcomes, a higher number of lymph nodes dissected and lower perioperative complications. However, for obese patients (BMI ≥28 kg/m^2), RATS did not achieve better outcomes than VATS in terms of the number of lymph nodes dissected and the incidence of postoperative complications. Therefore, it is not cost-effective to select RATS for obese patients (BMI ≥28 kg/m^2). More prospective clinical trials are needed to demonstrate the effectiveness of RATS for obese NSCLC patients.

It is worth noting that the placement of the robotic arm and the increased number of incisions did not significantly increase the operative duration. This may due to the fact that during RATS anatomic lung resections, surgeons could control the endoscopic field of vision to ensure the stability of the operation.

Finally, it is not yet fully clear whether RATS can reduce short-term postoperative pain compared to VATS. In this study, the NRS pain score was used to compare the short-term postoperative pain of the two groups of patients. In contrast to the findings of most previous studies (32,33), we found out that RATS had a higher NRS pain score on POD1, lower NRS pain score on POD2, and a comparable NRS pain score on POD3. The increase in pain on POD1 might be related to the use of four-ports for RATS in our center. However, the NRS pain score is multi-faceted and subjective (34). More efficient clinical indicators must be included to further investigate the effectiveness of RATS in terms of reducing short-term postoperative pain.

Similar with previous studies (10,28), this study showed that the implementation of RATS leads to a higher hospitalization cost, which is currently the biggest disadvantage of RATS. However, our study is an important supplement to the existing literature and competitions by other manufacturers of robotic systems might contribute to a better cost efficiency of RATS.

In summary results observed in this study confirmed that RATS has certain perioperative advantages compared to VATS. We confirmed that RATS had the best cost-performance ratio among patients with 24 kg/m^2 < BMI <28 kg/m^2, which provides a basis for the individualized treatment for NSCLC patients. In addition, although this was a retrospective study, PSM was performed to control the confounding variables between the two groups, so that the comparability between them was guaranteed to a certain extent.

This study has several limitations that should be noted. Firstly, this was a single-center, retrospective analysis. The rate of lymph node upstaging was not captured and no long-term follow-up data were available due to the limited follow-up time. We intend to perform prospective research comparing the long-term follow-up data of VATS and RATS in the future.

Conclusions

RATS is a safe and effective surgical treatment and has perioperative advantages compared to VATS for patients with NSCLC. The advantages of RATS might be more obvious in patients with BMI of 24–28 kg/m^2.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-137/rc

Data Sharing Statement: Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-137/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-137/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013), and was approved by institutional review board of the Qilu Hospital of Shandong University (No. KYLL-202008-023-1). All patients provided informed consent for the use of their clinical information.

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