Original Article

Comparison of perioperative outcomes of robotic-assisted versus video-assisted thoracoscopic right upper lobectomy in non-small cell lung cancer

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Background: Robotic-assisted thoracic surgery (RATS) has been widely used in the treatment of lung cancer. The perioperative outcomes of right upper lobectomy (RUL) using RATS and video-assisted thoracic surgery (VATS) were retrospectively investigated and compared. We aimed to summarize a single-center experience of RATS and 4-port unidirectional VATS in RUL, and to discuss the safety and the essentials of the surgery.

Methods: We retrospectively analyzed the 685 with non-small cell lung cancer (NSCLC) patients who underwent minimally invasive RUL in our center by the same surgical group from January 2015 to December 2019. Both RATS and VATS were performed with three ports with utility incision. The 685 participants were divided into RATS (335 cases) and VATS (350 cases) groups according to surgical method. Baseline characteristics and perioperative outcomes including dissected lymph nodes, postoperative duration of drainage, postoperative hospital stay, and incidence of postoperative complications were compared between the groups.

Results: In the 685 patients enrolled, the baseline characteristics were comparable, and no postoperative 30-day mortality or intraoperative blood transfusion were observed. Compared with VATS, RATS had less surgical duration (90.22±12.16 *vs.* 92.68±12.26 min, P<0.001), less length of stay (4.71±1.37 *vs.* 5.26±1.56 days, P<0.001), and decreased postoperative duration of drainage (3.49±1.15 *vs.* 4.09±1.57 days, P<0.001). No significant difference was observed in the lymph nodes dissection, blood loss, conversion rate and morbidities. The cost of RATS was much higher than VATS (85,329.41±12,893.44 *vs.* 68,733.43±14,781.32 CNY, P<0.001).

Conclusions: Robot assisted RUL had similar perioperative outcomes compared to VATS RUL lobectomy using similar three port with utility incision technique. The advantages of RATS included finer dissection of lymph node, relatively less operation time, earlier chest tube removal and discharge.

Keywords: Lobectomy; non-small cell lung cancer (NSCLC); robotic; video-assisted thoracic surgery (VATS)

Submitted Sep 22, 2021. Accepted for publication Dec 16, 2021.
doi: 10.21037/tlcr-21-960
View this article at: https://dx.doi.org/10.21037/tlcr-21-960

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Introduction

Lung cancer is one of the most common malignancies worldwide, with the highest rate of morbidity and mortality (1). Currently, lobectomy with lymph node dissection remains the cornerstone of radical treatment for resectable lung cancer (2). Due to the use of low-dose computed tomography (CT) scans, an increasing number of patients are being diagnosed at the early-stage (3), for whom the traumatic open thoracotomy may not be the optimal intervention. Recently, video-assisted thoracic surgery (VATS), as a more minimally invasive surgical method, has been developed and implemented more widely in treating patients with early-stage lung cancer (4).

Robotic-assisted thoracic surgery (RATS) has an emerged as an alternative to VATS and thoracotomy and has attracted the interest of thoracic surgeons since it was first performed in 2002. Compared with conventional VATS, RATS offers the advantages of 3-dimensional (3D) visualization, increased degree of motion and rotational freedom, and small-wristed instruments (5). In previous researches, RATS was reported to have the advantage of smaller incisions, decreased postoperative pain, more effective lymph node (LN) dissection, and faster recovery, but no significant survival benefit compared to VATS and thoracotomy (6-8). The equivalence of the oncologic benefit and functional outcomes between RATS and VATS is still controversial (9,10).

We systematically introduced the experience of right upper lobectomy through robotic-assisted or video-assisted method in our center and demonstrated the postoperative outcomes of the two methods, by using a large consecutive cohort which was never reported. Furthermore, we aimed to offer guidance on right upper lobectomy in clinical practice and expand the application of robotic-assisted surgery. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/tlcr-21-960).

Methods

Study cohort and data collection

The Institutional Review Board of Shanghai Lung Tumor Clinical Medical Center, Shanghai Chest Hospital, Shanghai Jiao Tong University approved this retrospective study (KS1735). Informed consent was obtained from all patients for this research and publication of associated results. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013).

We retrospectively identified patients with single lesions in the right upper lobe who had been surgically treated between 1 January 2015 and 31 December 2019. All included patients were pathologically diagnosed with non-small cell lung cancer (NSCLC). Preoperative examinations like echocardiography and pulmonary function testing were conducted to ensure participant tolerance of the operation. Distant metastasis was excluded through positron emission tomography-CT (PET/CT), bone scintigraphy, and cranial enhanced magnetic resonance imaging (MRI).

A total of 685 patients were enrolled and divided into the RATS group and VATS group. Participants' clinicopathological characteristics [age, gender, body mass index (BMI), preoperative pulmonary function (FEV1%), tumor stage, histological type and subtype] and perioperative outcomes (operation time, number of dissected LNs, blood loss, conversion rate to open surgery, duration of chest tube drainage and postoperative hospitalization, postoperative complications and death) were retrieved from medical records. All cases were staged based on the 8th edition of the tumor-node-metastasis (TNM) classifications of the International Association for the Study of Lung Cancer.

Surgical procedure

After general anesthesia was initiated, patients were placed in the lateral decubitus position and intubated with a double-lumen endotracheal tube for contralateral single-lung ventilation. In the RATS group, the camera port was usually made at the 8th intercostal space (ICS) mid-axillary line according to the thoracic percussion. At a nearly same horizontal line (mostly ventral 7th ICS and dorsal 9th ICS), the other 2 ports for arms were set on both sides of the camera port 4 fingers wide (8 to 9 cm). The utility incision was made at the 4th ICS anterior axillary line. A stereoscopic camera was inserted at a downwards angle of 30 degrees through the camera port to explore the thoracic cavity. Cadiere forceps and a cautery hook were manipulated by the left and right arm respectively. The utility incision was used by the bedside assistant for retracting the lung, exposing the operating fields, and cutting tissue through a linear stapler. In the VATS group, the camera port was selected at the 7th ICS middle axillary line. The utility incision was at the 4th ICS anterior axillary line, while the 2 auxiliary ports were made at the 7th ICS of

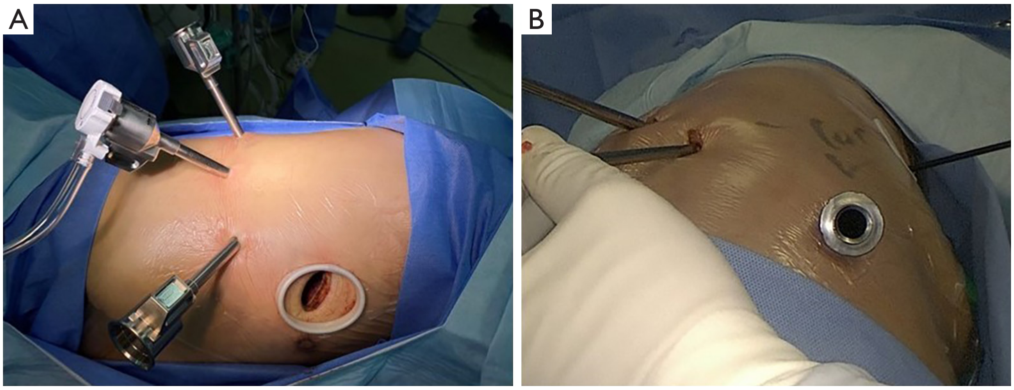

Figure 1 The incisions and ports placement of RATS (A) and VATS (B). RATS, robot assisted thoracic surgery; VATS, video assisted thoracic surgery.

the posterior axillary line (port 1) and scapular line (port 2). The incisions and port placements of RATS and VATS are shown in *Figure 1*.

For RATS, the oval clamp was inserted through the utility incision to grip the right upper lobe and tuck it cranially, and a suction was inserted to help further expose the operative fields. The RUL usually started with completing the interlobar fissure and the pleura over the right upper bronchus to expose the arteries and bronchus, then dissecting the interlobar LNs to expose branches of the pulmonary arteries further. Firstly, A3 was dissected free and sectioned using a mechanical stapler. Then the lung was tucked ventrally to dissect and transect the bronchus and A1+2. Next, the lobe was tucked dorsally, and the vein and remaining fissure transected together. All staplers were introduced through the utility incision by the assistant. For VATS, the unidirectional procedure reported by Liu *et al.* and our previous research was adopted (11,12). The pleura behind the phrenic nerve was dissected free from the arch of the azygos vein. The superior lobar vein and the A1+2 were respectively dissected free and sectioned. The remaining superior lobar artery was sectioned together with the interlobar fissure. Finally, the right upper lobe was retracted downward to expose the right upper bronchus which was dissected. According to the recommended surgical principle in National Comprehensive Cancer Network (NCCN) guideline, all participants underwent a systematic lymph node dissection.

Statistical analysis

Categorical data were summarized as numbers and percentages. Continuous data were summarized as means with standard deviations (SDs). Differences between the RATS and VATS groups were explored using Pearson's chi-square test for categoric data and Student's *t*-test or Mann-Whitney U test for continuous variables. Since the distribution of age, gender, smoking status, tumor size, pulmonary function, and clinical stages were comparable between the 2 groups, propensity score matching was not performed in further analysis. A P value of <0.05 was considered to indicate a significant difference. All statistical analyses were performed with the software SPSS 23.0 (IBM Corp., Armonk, NY, USA).

Results

Participants' clinical characteristics

A total of 685 patients were included consecutively from 1 January 2015 to 31 December 2019, of whom 335 underwent RATS and 350 underwent VATS. Compared with the VATS group, there was no significant difference in age (57.90±10.23 *vs.* 58.76±9.08 years), gender (male 45.23% *vs.* 39.86%), BMI (23.84±3.73 *vs.* 24.09±3.50 kg/m^2), tumor size (17.47±9.88 *vs.* 18.12±10.27 mm) and FEV1% (89.61%±8.46% *vs.* 90.40%±8.23%). Participants receiving RATS and VATS had comparable TNM stage, histological classification, and subtype. Participants' clinical characteristics are presented in *Table 1*.

Perioperative outcomes

Participants who underwent RATS were associated with

Table 1 Clinicopathologic characteristics according to the surgical methods

Characteristics	RATS (n=335)		VATS (n=350)		P value
	N	SD or %	N	SD or %	
Age (years)	59.89	10.78	58.78	9.39	0.151
Gender, %					0.38
Male	148	44.18	142	40.57	
Female	187	55.82	208	59.43	
BMI (kg/m^2)	23.86	3.72	24.12	3.60	0.35
FEV1%	92.31	8.91	93.45	8.23	0.082
Tumor size (mm)	20.4	12.06	20.74	12.16	0.718
TNM stage, %					0.266
I	228	68.06	243	69.43	
IIA	24	7.16	29	8.29	
IIB	51	15.22	37	10.57	
IIIA	32	9.55	41	11.71	
Histological classification, %					0.215
Adenocarcinoma	285	85.07	310	104.73	
Others	50	14.93	40	13.51	
Invasive type, %					0.382
AIS	11	3.86	10	3.23	
MIA	34	11.93	27	8.71	
IAC	240	84.21	273	88.06	

RATS, robot assisted thoracic surgery; VATS, video assisted thoracic surgery; BMI, body mass index; FEV1%, preoperative pulmonary function; TNM, tumor-node-metastasis; AIS, adenocarcinoma in situ; MIA, minimally invasive adenocarcinoma; IAC, invasive adenocarcinoma.

shorter surgical duration (90.22±12.16 *vs.* 92.68±12.26 min), time of drainage (3.49±1.15 *vs.* 4.09±1.57 days), and postoperative hospitalization (4.71±1.37 *vs.* 5.26±1.56 days). No significant difference was observed in blood loss, conversion rate, and postoperative complications. The RUL through RATS was demonstrated as a safe approach with accelerated recovery, which could be attributed to its precise operation and less surgical harm. In terms of LN dissection, the number of dissected LNs and stations were comparable in two groups. The RUL through RATS could obtain finer lymph node dissection and minimize the damage. No death within 30 days was observed. Meanwhile, the overall cost was relatively higher in the RATS group (85,329.41±12,893.44 *vs.* 68,733.43±14,781.32 CNY). Participants' perioperative outcomes are presented in *Table 2*.

Invasive LN dissection

Although the results of dissected LNs and stations were similar between groups, we observed a different distribution of LN dissection in the 160 participants with involved LNs. The number of LNs (14.87±2.05 *vs.* 12.42±3.8) and LN stations (6.19±1.01 *vs.* 5.86±0.983) were both relatively higher in the patients with invasive lymph node in RATS group. Meanwhile, the time of drainage (3.23±0.83 *vs.* 4.14±1.8) and postoperative hospitalization (4.87±1.17 *vs.* 5.42±1.62 days) were shorter in LN-positive patients undergoing RATS, while the operation duration not significantly different. The above results suggested that RATS might better facilitate a radical LN dissection with shorter recovery time and no increase in surgical time. Perioperative outcomes in LN-positive patients are presented in *Table 3*.

Table 2 Perioperative outcomes according to surgical methods

Perioperative outcomes	RATS (n=335)		VATS (n=350)		P value
	N	SD or %	N	SD or %	
Surgical duration (min)	90.22	12.16	92.68	12.26	<0.001
Dissected LN stations	5.3	1.24	5.19	1.29	0.267
Dissected LNs	10.08	3.66	9.72	3.23	0.174
Blood loss (mL), %					0.593
≤100	315	94.03	325	92.86	
101–400	15	4.48	16	4.86	
>400	5	1.49	9	2.57	
Conversion rate, %	4	1.19	7	2.36	0.547
Time of drain	3.49	1.15	4.09	1.57	<0.001
Length of stay (days)	4.71	1.37	5.26	1.56	<0.001
Postoperative complication, %	36	10.75	42	10.00	0.692
Death with 30 days	0	0	0	0	1.000
Cost (CNY)	85,329.41	12,893.44	68,733.43	14,781.32	<0.001

RATS, robot assisted thoracic surgery; VATS, video assisted thoracic surgery; LN, lymph node; SD, standard deviation.

Table 3 Partial perioperative outcomes of patients with positive lymph node

Variables	pN+ RATS (n=83)		pN+ VATS (n=77)		P value
	N	SD	N	SD	
Dissected LN stations	6.19	1.01	5.86	0.983	0.035
Dissected LNs	14.87	2.05	12.42	3.8	<0.001
Surgical duration (min)	90.37	12.29	93.2	12.22	0.145
Time of drain	3.23	0.83	4.14	1.8	<0.001
Length of stay (days)	4.87	1.17	5.42	1.62	0.014

RATS, robot assisted thoracic surgery; VATS, video assisted thoracic surgery; LN, lymph node; SD, standard deviation.

Discussion

As a new minimally invasive surgical method, the Da Vinci robotic surgery system has become more widely used because of its advantages over the traditional VATS, such as 3D imaging system, high flexibility of the mechanical arms, and an ergonomic console. In contrast, VATS lobectomy with a lymphadenectomy was first reported as a treatment for early-stage NSCLC in 1994. After more than 20 years of development and practice, its feasibility, safety, and long-term oncological efficacy have been confirmed in many studies (13). The NCCN guidelines also recommend VATS lobectomy as a gold standard treatment for early NSCLC. In 2009, our center completed the first RATS lobectomy in mainland China. At present, our center is one of the medical centers with the largest number of robotic thoracic operations in China. In this study, we summarized the unique method of converse unidirectional RATS RUL. At the same time, through the exploration in the field of traditional VATS, the improved 4-port method of unidirectional VATS right upper lobe resection was outlined. The surgery was performed in a single direction using both methods, without repeatedly flipping the lobes, which greatly shortened the operation time, and reduced the dosage of anesthetics and risk of bleeding (12,14). The single direction approach enhanced operator comfort and surgical fluency, facilitating biological minimal invasiveness. As the characteristic methods of our center, converse unidirectional RATS and 4-port unidirectional VATS are similar in their inclusion of incision numbers and port location. Comparing the perioperative results of the 2 methods and summarizing the relevant experiences can provide guidance for clinical practice.

Converse unidirectional RATS appropriately handles the close proximity of the hilum to the operation port which can complicate management of the right upper lobe vein due to directional problems when using the stapler. With converse-single direction, the ascending branch of the pulmonary artery and the right upper lobe bronchus are dissected and divided first, and the pulmonary vein and lobe fissure are dealt with finally, yielding smooth operation effects. Positioning of the assistant's auxiliary operation port is very important. Selecting the fourth ICS of the anterior axillary line, which is directly aimed at the hilum, can provide an appropriate angle for the assistant to operate the stapler. Establishing an observatory port at the seventh ICS of the mid-axillary line, and the bilateral operation arm ports being almost at the same level are also the key to smooth operation. Other global centers have summarized their own methods in clinical practice (15,16). Xu and Wang (17) believe that moving the auxiliary port down to the 7th ICS of the mid-axillary line is more convenient for the use of a stapler, but there are also issues such as insufficient exposure of lung traction and inconvenience of operation when converting to thoracotomy. Conversely, VATS is more flexible than RATS in the choice of surgical port location. A variety of surgical methods have been developed for VATS, such as the uniportal method, 3-hole method, and 4-hole method. Gao *et al.* showed that that unidirectional VATS group has less thoracic drainage (208.33±50.39 *vs.* 413.78±134.65 and 245.98±45.32 mL, P=0.019) and intraoperative bleeding (78.79±24.23 *vs.* 112.63±64.32 and 153.67±45.21 mL, P=0.009) than the traditional thoracotomy group (18). There was no significant difference in LN dissection and postoperative overall survival time. The 4-hole unidirectional VATS in our center is to open the mediastinal pleura from the rear through the main operative hole between the 4^{th} rib of the axillary front, the lens hole between the 7^{th} rib of the axillary front, and the 2 auxiliary operation holes. The operation is performed in the order of pulmonary vein, pulmonary artery, bronchus, and pulmonary fissure. This operation is more hierarchical, clearer, and the existence of 2 auxiliary operation holes also makes the operation easier. It is easier to expose the pulmonary hilum by multi-angle traction, and the stapler entry angle is more flexible.

In this study, the main perioperative results of the two minimally invasive operative approaches were nearly the same, but in the practical clinical application, the two methods had their own emphasis. Converse unidirectional RATS usually starts with opening the fissure to dissecting the hilum, which requires the pulmonary lobe with preferable fissure. For the patients with dysplasia or incomplete fissure, the incidence of conversion to thoracotomy and continuous air leakage after the operation will increase due to the large wound area caused by the opening of the pulmonary fissure (19,20). Due to the different management order of hilum, the cut and closure of pulmonary fissure tissue was performed last, thus 4-port unidirectional VATS has low requirements for the development of the pulmonary fissure and relatively less postoperative air leakage. Hilar lymph node dissection is another important factor affecting the smooth operation. In the presence of severe LN fusion, calcification, or "doornail lymph node", both RATS and VATS will encounter difficulties in dealing with hilar structures, which is often the cause of intraoperative vascular injury, bleeding, and conversion to thoracotomy (21). In addition, when there are extensive thoracic adhesions, the operation time will be significantly prolonged, which often leads to conversion to thoracotomy. However, robotic surgery has some advantages on account of its flexible hook, especially the latest Da Vinci Xi system. This is due to the new supporting structure of the mechanical arm, which adopts the suspender-type extendable and rotatable design, facilitating movement of the big arm above the target anatomical part, and simplifying operation of the big arm when changing the posture during the operation, enabling easy separation of the adhesion at all corners of the chest.

The LN dissection is an important factor affecting the prognosis of NSCLC. Previous studies have shown that there is no significant difference in the number of LN dissections and the number of groups between RATS, VATS, and open surgery. Some studies have also shown that RATS can dissect more LNs than VATS (22). As an indicator of the rigorousness of LN dissection, pathologic upstaging in research by Wilson *et al.* (23) and Kneuertz *et al.* (24) was shown to be higher in RATS than that in VATS, indicating that LN dissection in RATS was more thorough. A study conducted in our center also suggested that the effect of LN dissection in pathological N2 patients was similar to that of thoracotomy (25). The results of this study showed that there was no significant difference in the number of LN stations and the number of LNs dissected in the right upper lobe resection in NSCLC between converse unidirectional RATS and 4-port unidirectional VATS. There were more dissected LN stations and numbers in RATS pN+ group, suggesting that converse unidirectional RATS may be able to achieve more thorough LN dissection for NSCLC patients in right upper lobe with LN involvement, but whether it can bring survival benefits is not clear. However, existing studies have shown that there is no significant difference in the long-term survival results between RATS and VATS lobectomy in the treatment of early NSCLC, and RATS and thoracotomy also has similar oncological effects in patients of locally advanced NSCLC. In conclusion, whether the advantages of LN dissection of RATS can bring long-term survival benefits is not clear, which needs further investigation.

Converse unidirectional RATS and 4-port unidirectional VATS are advanced minimally invasive surgical methods. With the constant development of minimally invasive surgical techniques, especially with uniport thoracoscopic surgery having been put into clinical practice, the above 2 surgical methods which require 4 surgical ports have encountered difficulties in adapting to the aesthetic demands of patients, and some studies have pointed out that multiple incisions may affect postoperative pain. However, compared with uniport VATS, RATS and 4-port unidirectional VATS lobectomy are more well-rounded surgical methods, with greater safety, operability, and oncological effects. At the same time, we look forward to the further development of uniport thoracoscopic surgery technique, instruments, and robot-assisted system, which will bring the minimally invasive thoracic operations for tumors into a new developmental stage.

In summary, the converse unidirectional RATS and 4-port unidirectional VATS in our center have considerable perioperative outcomes in the resection of right upper lobe NSCLC. In patients with positive pathological LNs, RATS has a more thorough LN dissection, but also makes surgery more expensive. In clinical practice, we should follow the principle of individualization, by evaluating patient condition according to thorough preoperative examinations, such as lobe fissure development and LN calcification, and considering their financial situation, so as to choose the appropriate surgical method. Due to the short follow-up time of the participants in this study, there was no comparison of long-term survival results. We are looking forward to the reports of long-term survival results and other prospective studies or randomized controlled clinical studies, so as to further explore the application of RATS and VATS in the treatment of NSCLC.

Acknowledgments

The authors appreciate the academic support from the AME Thoracic Surgery Collaborative Group.

Funding: This work was supported by Shanghai Hospital Development Center (Grant Number: SHDC12016113), Shanghai Natural Science Foundation (No. 18ZR1435100), National Natural Science Foundation of China (No. 81972176).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://dx.doi.org/10.21037/tlcr-21-960

Data Sharing Statement: Available at https://dx.doi.org/10.21037/tlcr-21-960

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/tlcr-21-960). MPK reports royalty from Medtronic; consulting fee from Medtronic, Intuitive Surgical, Veran/Olympus and AstraZeneca. REM reports that he is a speaker of Intuitive Surgical. The other 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. Informed consent was obtained from all patients for this research and publication of associated results. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The Institutional Review Board of Shanghai Lung Tumor Clinical Medical Center, Shanghai Chest Hospital, Shanghai Jiao Tong University approved this retrospective study (KS1735).

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(English Language Editor: J. Jones)

Cite this article as: Huang J, Tian Y, Zhou QJ, Ning JW, Gu ZN, Lu PJ, Li JT, Lin H, Chen TX, Yang YH, Kim MP, Merritt RE, Ghisalberti M, Jiang L, Luo QQ. Comparison of perioperative outcomes of robotic-assisted versus video-assisted thoracoscopic right upper lobectomy in non-small cell lung cancer. Transl Lung Cancer Res 2021;10(12):4549-4557. doi: 10.21037/tlcr-21-960