机器人外科学杂志
CJRS
Chinese Journal of Robotic Surgery
Vol. 2 No. 6 Dec. 2021
DOI: 10.12180/j.issn.2096-7721.2021.06.006

论著 · Article

机器人与胸腔镜在早期肺癌肺段切除术中短期疗效的对比研究

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摘　要　目的：分析机器人与胸腔镜手术在早期肺癌肺段切除中的临床疗效。方法：回顾性分析 2019 年 1 月 ~2020 年 12 月在甘肃省人民医院接受达芬奇机器人和胸腔镜行肺段切除手术的 106 例早期肺癌患者的临床资料。其中接受 RATS 肺段切除术 49 例（男 19 例，女 30 例），年龄（59.13 ± 9.38）岁；接受 VATS 57 例（男 21 例，女 36 例），年龄（60.36 ± 10.06）岁，比较两组的临床疗效。结果：两组患者基线资料差异无统计学意义。RATS 组与 VATS 组相比，手术时间（126.42min Vs 110.23min，P=0.007）；术中失血量（40.46ml Vs 62.23ml，P=0.016）；淋巴结清扫站数总数（6.32 Vs 5.21，P<0.001）；淋巴结清扫总数（13.29 Vs 10.81，P=0.023）；术后引流时间（4.29d Vs 5.66d，P=0.005）；总引流量（772.53ml Vs 995.34ml，P=0.011）；术后第 1d 疼痛评分（1.67 Vs 2.59，P=0.031）、第 2d（2.74 Vs 3.71，P=0.025）、第 3d（1.02 Vs 1.92，P=0.006）；术后住院时间（4.45d Vs 6.39d，P=0.008）；住院费用（90 463.37 元 Vs 69 872.21 元，P<0.001），差异有统计学意义。而中转开胸手术、术后咳嗽、术后并发症、术后 30d 再入院率差异无统计学意义（P>0.05）。结论：机器人手术系统在早期肺癌肺段切除术中，术中出血量少，住院时间短，淋巴结清扫优势大，术后疼痛感轻，操作安全有效且创伤小，可作为早期肺癌手术治疗的有效方法。

关键词　肺癌；胸腔镜；手术机器人；肺段切除术；短期疗效
中图分类号　R655.3　R734.2　**文献标识码**　A　**文章编号**　2096-7721（2021）06-0451-12

收稿日期：2021-01-20　**录用日期**：2021-03-21
Received Date: 2021-01-20　Accepted Date: 2021-03-21
基金项目：甘肃省卫生行业科研计划项目（GSWSKY2020-50）
Foundation Item: Health Industry Scientific Research Project of GanSu Province (GSWSKY2020-50)
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引用格式：王兵，刘露，杨宁，等 . 机器人和胸腔镜在早期肺癌肺段切除术中短期疗效的对比研究 [J]. 机器人外科学杂志（中英文），2021，2（6）：451-462.
Citation: WANG B, LIU L, YANG N, et al. Comparative study on short-term outcomes of robot-assisted and video-assisted thoracoscopic surgery in lung segmentectomy [J]. Chinese Journal of Robotic Surgery, 2021, 2 (6): 451-462.
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Comparative study on short-term outcomes of robot-assisted and video-assisted thoracoscopic surgery in lung segmentectomy

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Abstract Objective: To compare the short-term clinical efficacy of robot-assisted thoracoscopic surgery (RATS) and video-assisted thoracoscopic surgery (VATS) in segmental resection for early lung cancer. Methods: Clinical data of 106 patients with lung cancer who underwent RATS and VATS in Gansu Provincial Hospital from January 2019 to December 2020 were retrospectively analyzed. RATS group has 49 patients, including 19 males and 30 females, with a median age of (59.13 ± 9.38) years. 57 patients in VATS group, including 21 males and 36 females, with a median age of (60.36 ± 10.06) years. The clinical efficacy of the two groups was compared. Results: No statistically significant difference in terms of baseline data between the two groups was found. Compared to the VATS group, the RATS group had a longer operative time (126.42min Vs 110.23min, P=0.007), less intraoperative blood loss (40.46 ml Vs 62.23 ml, P=0.016), more groups of lymph node dissection (6.32 Vs 5.21, P<0.001) and total number of lymph node dissection (13.29 Vs 10.81, P=0.023). The RATS group also had a shorter duration of chest drainage (4.29d Vs 5.66d, P=0.005) and less total thoracic drainage volume (772.53ml Vs 995.34ml, P=0.011). The postoperative pain scores 1 day after surgery of RATS group and VATS group were(1.67 Vs 2.59, P=0.031), 2 days after surgery were (2.74 Vs 3.71, P=0.025) and 3 days after surgery were (1.02 Vs 1.92, P=0.006) respectively. RATS group had a shorter postoperative hospitalization than VATS group (4.45 days Vs 6.39 days, P=0.008) but more hospital expenses (90 463.37 CNY Vs 69 872.21 CNY, P<0.001), the difference was statistically significant. However, there was no significant difference on conversion rate to thoracotomy, postoperative chronic cough, postoperative complications and readmission 30 days after surgery (P>0.05). Conclusion: Robotic surgery system has a lower intraoperative blood loss, shorter hospital stay, more lymph node dissection, less postoperative pain and smaller incisions, it is safe and effective in the segmental resection for early stage of lung cancer .

Key words Lung cancer; Thoracoscopy; Surgical robot; Segmentectomy; Short-term efficacy

Introduction

Lung cancer is a malignant tumor with the highest morbidity and mortality in the world. About 1.4 million people die of lung cancer every year, among which non-small cell lung cancer (NSCLC) accounts for about 85% of all lung cancer[1]. With the popularization of low-dose spiral CT(LDCT), more and more patients with early lung cancer have been found. The comprehensive treatment based on surgery is still the main method for the treatment of early lung cancer[2]. However, it is difficulty to remove the lesion completely while preserving the lung function as much as possible. Current studies believe that segmental pulmonary resection has more advantages than lobectomy for patients with early NSCLC, especially those with poor cardiopulmonary function, since it can not only provide similar prognostic effects as lobectomy, but also retain more lung tissue, thus effectively preserving lung function and improving quality of life[3]. At present, this surgical approach has been widely used in thoracoscopic radical resection of pulmonary nodules or ground glass opacity[4], however, robotic pulmonary segmental resection has been relatively less reported. Therefore, we retrospectively analyzed the clinical data of patients underwent robot-assisted and video-assisted thoracoscopic pulmonary segmentectomy in our hospital, aiming to explore the clinical efficacy of robot-assisted pulmonary segmentectomy.

1 Materials and methods

1.1 Patients and study design

The clinical data of patients who underwent segmental pulmonary resection with robot-assisted thoracoscopic surgery (RATS) and video-assisted thoracoscopic surgery (VATS) in the single center of Gansu Provincial People's Hospital from January 2019 to December 2020 were retrospectively analyzed. Routine preoperative cranial CT, upper abdominal CT, thyroid, neck color ultrasound and bone scan, or positron emission tomography (PET) computed tomography were performed to exclude preoperative metastasis. Echocardiography and pulmonary function examination were performed to assess patients' cardiopulmonary function and tolerance to pulmonary surgery. The inclusion criteria were (1) patients with single or multiple ground-glass opacity (GGO) in the lung; (2) lesion diameter ≤ 2cm; (3) preoperative clinical staging T1a~bN0M0 by preoperative chest CT; (4) the GGO component of tumor was more than 50% under chest CT; (5) tumor doubling time was more than 400d and lung malignant tumor suggested by postoperative pathology. The exclusion criteria were (1) incomplete case data; (2) pulmonary lobectomy and pulmonary segmentectomy were performed simultaneously; (3) pulmonary segmentectomy and mediastinal tumor or other thoracic surgery were performed simultaneously. Based on the above criteria, 106 patients were eventually selected into this study, including 49 patients in the RATS group and 57 patients in the VATS group. All procedures of the two groups were managed by the same surgeon who had performed more than 1,000 cases of thoracoscopic surgery. Patients and their families decided to take RATS or VATS. This study was approved by the Ethics Committee of Gansu Provincial People's Hospital.

1.2 Surgical methods

All the surgeries were completed by the same group of physicians. In the RATS group, intravenous, inhalation and general anesthesia were taken. Jackknife position on the healthy side was adopted. The surgical hole location was determined before surgery by the lesion location and patient's physical condition. Three-arm method was adopted. 12mm Trocar was placed in the 8th intercostal in the left posterior axillary line as the observation hole. Two 8mm Trocars were placed in the 5th interspace in the anterior axillary line and the 8th intercostal area in the subscapular line as the hole of No. 1 and No. 2 arm respectively. Patient cart was connected from the dorsal shoulder with an angle of 75°. To connect unipolar electrocoagulation hook to the No.1 arm, bipolar forceps to the No. 2 arm. A 12mm Trocar was placed in the 7th intercostal in the midaxillary line as an auxiliary hole. The assistant stood by the ventral side of the affected side to pull the lung lobe to expose the operative field by grabbing the gauze with a normal thoracoscopic forceps. The surgeon and anesthetist paid closely attention to the patient's respiration during the surgery. The hilar tissue was treated by standard lobotomy. Vessels with a diameter < 2mm were treated with ultrasound knife or electrocoagulation, while diameter ⩾ 2mm were cut off with a linear cutter after ligation. The intersegmental plane of lung was determined by inflation-deflation lines and the intersegmental tissue was cut off with a linear cutter and ultrasonic knife. Residual lung tissue was inflated during the surgery to ensure the incision completely closed without leakage. Routine hilar and mediastinal lymph node dissection was performed, and intraoperative tumor sample and lymph node were taken for pathological examination. The incisal margin of lesion shall be over 2cm or larger than the diameter of the tumor, otherwise lobectomy and systemic lymph node dissection shall be performed, especially for lymph node metastasis suggested by intraoperative freezing. Patients in the VATS group were given the conventional thoracoscopy, lateral position on the healthy side was adopted. Intubation was performed with double-lumen catheter for anesthesia. 1cm incisions were made in the 7th intercostal space in the midaxillary line and the 5th intercostal space in the posterior axillary line respectively, meanwhile a 3cm incision were made in the 4th intercostal space in the anterior axillary line, then thoracoscopy, ultrasound knife and other supporting instruments were placed. The following operation is similar with the RATS group. See Table 2 for specific pulmonary segments in surgery.

1.3 Observation indexes

The lung cancer database of our hospital was retrospectively analyzed. Patient's age, gender, body mass index, preoperative lung function, symptoms, smoking history, combined underlying diseases, tumor diameter (calculated under the largest tumor diameter), tumor location, pathological type of tumor and resection of lung segment were collected. Perioperative data, including surgical approach, operative time, intraoperative blood loss, convert rate to thoracotomy, the group and the number of lymph node dissection, postoperative duration of chest drainage, total volume of postoperative drainage, postoperative pain score, chronic cough after surgery, postoperative complications (prolonged air leak, pulmonary infection, hydrothorax, atrial fibrillation and chylothorax), perioperative death, readmission 30 days after surgery, postoperative hospitalization time and hospital expenses were also collected and analyzed.

1.4 Criteria for efficacy

Pain level was assessed by Numeric Rating Scales (NRS)[5] and scored on the first, second and third days after surgery, score of 0 means no pain, 1 to 3 indicates mild pain(no affect to sleep), 4 to 6 for moderate pain(mildly affecting sleep), 7 to 10 suggests severe pain(cause inability to sleep or waking from sleep). Postoperative chronic cough is defined as a cough last for over 8 weeks or longer after surgery, with the main symptoms of dry cough, it often requires drug intervention and there is frequently no obvious indicators as to the underlying diagnosis[6]. Prolonged air leakage is the pulmonary air leakage lasts over 5 days after pneumonectomy[7]. Postoperative pulmonary infection can be confirmed when any 4 of the following 5 events occur: (1) Routine blood test indicates white blood cell count was more than 15×10^9/L; (2) Body temperature is over 38℃; (3) Cough and expectoration; (4) Rales; (5) Chest X-ray or chest CT suggests pulmonary exudative lesions. Hydrothorax is the pathological fluid accumulation in the pleural cavity, which can be assessed by chest X-ray or chest CT.

1.5 Statistical analysis

All data were analyzed using SPSS 22.0 (IBM Corp, Armonk, NY). Continuous variables were descripted as Mean ± SD ($\bar{x} \pm s$), independent sample t-test were used. The statistics of the classification data were described by frequency and percentage (%). Pearson Chi-square test or Fisher's exact test was used for analysis and comparison. Two-sided test was used for all data analysis in this study, and a difference greater than 0.05 was considered as statistically significant.

2 Results

2.1 Characteristics of patients

There were 19 males (38.8%) among the 49 patients in RATS group and 21 males (36.8%) among the 57 patients in VATS group. No significant differences on gender, age, BMI, clinical symptoms, smoking history, preoperative mean FEV1, underlying diseases, tumor diameter, pathological type of tumor, and tumor location between the two groups were found (P>0.05) (Table 1). According to preoperative chest CT and other imaging data, surgical resection sites were planned. Among which, 22 cases (44.9%) were combined with pulmonary segmental resection and 27 cases (55.1%) were only given pulmonary segmental resection in the robot group. While 27 cases (47.4%) were combined with pulmonary segmental resection and 30 cases (52.6%) were only given pulmonary segmental resection in the video-assisted group. No significant difference between the two groups (P>0.05) was found, and the specific distribution of resected lung segments was shown in Table 2.

2.2 Comparison of perioperative results

The perioperative data of patients in the robot group and the thoracoscopic group were shown in Table 3. Compared to the VATS group, the RATS group had a longer operative time (P=0.007), less blood loss (P=0.016), more group of lymph node dissection (P<0.001) and number of lymph node dissection (P=0.023), and the difference was statistically significant.The RATS group had a shorter duration of chest drainage (P=0.005), less total thoracic drainage volume (P=0.011), shorter postoperative hospital stay (P=0.008), lower pain score 1d after surgery (P=0.031), 2d after surgery (P=0.025) and 3d after surgery (P=0.006) than those in the VATS group, and the difference was statistically significant. There were no significant differences in respect of intraoperative conversion to thoracotomy (P=0.894), postoperative chronic cough (P=0.642), and readmission 30 days after surgery (P=0.543) between the two groups. All the cases was completed successfully and no perioperative death was found (Table 3).

2.3 Comparison of postoperative complications

The total incidence of postoperative

Table 1 Characteristics of patients [($\bar{x} \pm s$), *n* (%)]

Index	RATS(*n*=49)	VATS(*n*=57)	χ^2/*t* Value	*P*–Value
Gender [*n* (%)]			0.042	0.838
male	19(38.8)	21(36.8)		
female	30(61.2)	36(63.2)		
Age (years)	59.13 ± 9.38	60.36 ± 10.06	0.647	0.235
BMI (kg/m^2)	22.61 ± 2.92	22.81 ± 3.05	0.343	0.194
Clinical symptoms [*n* (%)]			0.145	0.092
medical examination found	39(79.6)	41(71.9)		
cough and sputum	6(12.3)	9(15.8)		
blood-stained sputum	1(2.0)	2(3.5)		
stethalgia	2(4.1)	2(3.5)		
chest tightness shortness of breath	1(2.0)	3(5.3)		
Smoking history [*n* (%)]			0.273	0.602
Yes	6(12.2)	9(15.8)		
No	43(87.8)	48(84.2)		
Preoperative mean FEV1 (L)	2.93 ± 0.62	3.02 ± 0.74	0.672	0.326
Underlying disease [*n* (%)]	21(42.9)	28(49.1)	0.416	0.519
Tumor diameter (cm)	1.33 ± 0.72	1.52 ± 0.81	1.267	0.071
Histology of primary lung cancer [*n* (%)]			3.562	0.237
adenocarcinoma in situ	29(59.2)	34(59.6)		
microinvasive adenocarcinoma	8(16.3)	6(10.5)		
infiltrating adenocarcinoma	7(14.3)	10(17.6)		
squamous carcinoma	5(10.2)	7(12.3)		
Tumor location [*n* (%)]			2.756	0.353
superior lobe of right lung	13(26.5)	11(19.3)		
inferior lobe of right lung	10(20.4)	14(24.6)		
superior lobe of left lung	18(36.7)	22(38.6)		
inferior lobe of left lung	8(16.3)	10(17.5)		

RATS: Robot-assisted thoracoscopic surgery; VATS: Video-assisted thoracoscopic surgery; BMI: Body mass index; FEV1: Forced expiratory volume in 1 second.

complications in the two groups was 17.9% (19/106), including 16.3% (8/49) in the RATS group and 19.4% (11/57) in the VATS group, with no statistically significant difference (*P*=0.816). Prolonged air leak (6.6%) was the most common complication, followed by pulmonary atelectasis (3.8%), pneumonia (2.8%), atrial fibrillation (1.9%), hydrothorax (1.9%), and chylothorax (0.9%). No significant difference on complications between the two groups was found (*P*<0.05) (see Table 3).

Table 2　Features of segmentectomies [*n* (%)]

Status	RATS(*n*=49)	VATS(*n*=57)
Left lung	26(53.1)	32(56.1)
S1+S2+S3	8(16.3)	10(17.5)
S1+S2	5(10.2)	4(7.0)
S3	2(4.1)	3(5.3)
S4+S5	3(6.2)	5(8.8)
S6	7(14.3)	8(14.0)
S7+S8+S9+S10	1(2.0)	2(3.5)
Right lung	23(46.9)	25(43.9)
S1	4(8.2)	2(3.5)
S2	3(6.2)	4(7.0)
S3	2(4.1)	1(1.8)
S1a+S2	1(2.0)	2(3.5)
S1+S2	2(4.1)	1(1.8)
S1+S3	1(2.0)	1(1.8)
S6	6(12.2)	7(12.2)
S8	1(2.0)	2(3.5)
S7+S8	1(2.0)	2(3.5)
S9	2(4.1)	1(1.8)
S10	0(0.0)	2(3.5)

RATS: Robot-assisted thoracoscopic surgery; VATS: Video-assisted thoracoscopic surgery.

3　Discussion

With the popularization of low-dose spiral CT, more and more pulmonary nodules have been detected clinically, especially ground-glass opacity (GGO), most of which are malignant[2]. These malignant nodules usually have low tumor aggressiveness and lymph node metastasis rate[3]. Current studies suggest that anatomical pulmonary segmentectomy is more advantageous than standard lobectomy for the above malignant nodules[3]. Anatomical segmental pulmonary resection can completely remove the tumor and the target segment, as well as complete resection of intra-segmental or inter-segmental lymph nodes, which has a similar long-term effect to lobectomy. It can preserve lung function better and improve postoperative quality of life, which makes it the preferred surgical method for early lung cancer[4]. Currently, there are three surgical approaches for segmental pulmonary resection: traditional thoracotomy surgery, VATS and RATS. Compared with traditional thoracotomy surgery, RATS and VATS can significantly reduce postoperative pain, shorten hospital stay and better oncology efficacy[8]. Compared with VATS, the RATS has the 3D HD vision, flexible manipulator arm and vibration filtering system, which can make the surgery more precise and stable. With similar safety and effectiveness to VATS, RATS is better on dissection of N1 and N2 lymph node[9]. Therefore, the application of RATS segmentectomy in the treatment of early lung cancer is increasing.

In clinical practice, we also found that the effect of robot in pulmonary segmental resection and lymphatic dissection was better than that of thoracoscopy, which is same with several studies[9–13]. Since the installation of Da Vinci Surgical System in our hospital in 2016, our department has completed 284 cases of lung cancer surgery with Da Vinci robot, including 68 cases of pulmonary segmental resection. Finally, 49 cases underwent RATS and 57 cases underwent VATS for lung resection of early lung cancer were included in this study, found that RATS had less intraoperative blood loss and total thoracic drainage volume, shorter postoperative duration of chest drainage, lower postoperative pain score for 3 consecutive days and shorter length of post-operative hospital stay than that in the VATS, the difference was statistically significant (P<0.5). It shows that

Table 3 Comparison of perioperative outcomes [($\bar{x} \pm s$), n (%)]

Variations	RATS(n=49)	VATS(n=57)	χ^2/t Value	P–Value
Operating time (min)	126.42 ± 24.02	110.23 ± 23.32	3.515	0.007
Blood lost (ml)	40.46 ± 30.01	62.23 ± 47.44	2.770	0.016
Group of lymph node dissection (group)	6.32 ± 1.81	5.21 ± 1.64	3.311	<0.001
Lymph node dissection	13.29 ± 6.21	10.81 ± 4.75	2.061	0.023
Conversion to thoracotomy [n (%)]	1(2.0)	2(3.5)	0.018	0.894
Duration of chest drianage (days)	4.29 ± 1.71	5.66 ± 1.47	4.436	0.005
Total thoracic drainage volume (ml)	772.53 ± 432.14	995.34 ± 479.66	2.495	0.011
Post-operative chronic cough [n (%)]			0.216	0.642
Yes	21(42.9)	27(47.4)		
No	28(57.1)	30(52.6)		
Post–operative complications [n (%)]	8(16.3)	11(19.4)	0.158	0.691
prolonged air leak	3(6.2)	4(7.0)		
atrial fibrillation	1(2.0)	1(1.8)		
pulmonary atelectasis	2(4.1)	2(3.5)		
pneumonia	1(2.0)	2(3.5)		
chylothorax	0(0.0)	1(1.8)		
hydrothorax	1(2.0)	1(1.8)		
Post-operative pain score (score)				
day 1	1.67 ± 1.73	2.59 ± 1.68	2.773	0.031
day 2	2.74 ± 1.59	3.71 ± 1.53	3.196	0.025
day 3	1.02 ± 0.56	1.92 ± 0.96	5.770	0.006
Perioperative death [n (%)]	0(0.0)	0(0.0)	—	—
Post-operative hospital stay (days)	4.45 ± 0.82	6.39 ± 1.53	−2.736	0.008
Readmission post-operative 30 days [n (%)]	1(2.0)	1(1.8)	0.369	0.543
Hospital expenses (RMB, CNY)	90 463.37 ± 14 563.34	69 872.21 ± 12 876.67	7.726	<0.001

RATS: Robot-assisted thoracoscopic surgery; VATS: Video-assisted thoracoscopic surgery; RMB: Ren Min Bi (CNY)

RATS has less trauma to patients than VATS, and patients feel less pain and recover faster. The number of lymph node dissection groups and the total number of lymph node dissection in RATS were higher, but operative time and hospital expenses in RATS group were greater than VATS, and the difference was statistically significant (P<0.5). However, there were no significant differences in respect of intraoperative conversion to thoracotomy, postoperative chronic cough, postoperative complications, and readmission 30 days after surgery between the two groups.

Lymphadenectomy plays an important role in the surgical treatment of lung cancer, and a good lymphadenectomy is very important to the accurate clinical staging of non-small cell lung cancer and guidance for subsequent treatment[9]. It is important that pulmonary segmentectomy also requires assessment of hilar, bronchus, and perivascular lymph nodes[10]. Krantz S B[11] reported that some patients with stage I NSCLC had lymph node metastasis, and patients with more than 14 lymph nodes removed had a better prognosis than patients removed less than 14 lymph nodes. Therefore, appropriate lymph node dissection in segmentectomy can improve the patient's prognosis. So we performed hilar and mediastinal lymphadenectomy after pulmonary segmentectomy. Groups 7~12, R4, 3, and R2 were usually dissected when the right approach was used. Groups 5~12, L4, 3 and L2 were often dissected in the left approach. In this study, RATS had a significant advantage in respect to the number and groups of lymph node dissection compared with VATS, which was consistent with relevant studies[12-13]. Lymphadenectomy is challenging for VATS, and some studies sugges that complete resection of pretracheal, paratracheal and subcarinal lymph nodes is difficult with the left approach[14]. However, with good maneuverability and sensitivity of the robotic arm, stable and clear three-dimensional field of vision, robotic surgery system makes surgeons more confident and more willing to remove lymph nodes in complex areas that difficult to be removed with VATS, and it is also relatively easy to dissect the mediastinal and hilar lymph nodes, especially in the subcarinal lymph nodes[15].

In this study, no major intraoperative bleeding was found in the two groups, but VATS group had more blood loss than that in RATS group, which is statistically different. Mungo B[16] found that RATS is more effective than VATS in reducing the occurrence of bleeding that is difficult to control during surgery, such as the removal of lymph nodes close to the surface of artery and vein. We believe that pulmonary segmental vessels and bronchus are hidden in the lung tissue, located at the distal end of the bronchus and bronchus. The adjacent area between pulmonary arteries and veins and bronchus is complex, and there are many variations. It is difficult to determine the intersegmental plane, and individual differences are great. However, robotic surgery system is more flexible and equipped with vibration filtering system, movement range is very small, makes it more accurate than thoracoscope in the separation of the complex structure of anatomy, deep tissue and lymph node excision for its smaller movement range, which can reduce bleeding and other complications, avoid unnecessary damages and reduce the possibility of blood transfusion, thus RATS has a faster postoperative recovery and less postoperative pain[17]. These advantages can also help shorten the postoperative hospital stay and thoracic drainage time and reduce the amount of postoperative drainage fluid. However, caution should be paid in dissecting lymph nodes adjacent to the arteries and veins. In addition, the hemostasis should be checked in time during tissue dissection and lymph dissection, and ligation should be performed for large blood vessels[18]. TAO S L's study included 100 cases of RATS and 90 cases of VATS, and the intraoperative blood loss [30(20~400)ml Vs 100(20~1 600)ml], postoperative drainage volume [755(200~3 980)ml Vs 815(280~3920)ml], and postoperative drainage time [4(1~15)d Vs 4(2~29)d] were compared respectively. The results indicate that RATS can significantly reduce intraoperative blood loss, volume of postoperative drainage and postoperative catheter insertion time[19]. Consistent with the results of this study, our study also found RATS is more minimally invasive and less traumatic to the body. Postoperative pain will affect patients' quality of life. This study shows that RATS has a lower postoperative pain score for 3 consecutive days compared to VATS, and the difference is statistically significant.

In this study, no recurrent nerve injury, bronchopleural fistula, heart failure or death were found. The major complications were prolonged air leakage, pulmonary infection, atrial fibrillation, and atelectasis. However, compared with VATS, there was no significant difference on the incidence of complication in RATS. 7 cases of prolonged air leakage were found in this study, all of which were emphysema, possibly due to pulmonary tissue malnutrition. Some studies believe that older age, low BMI, pleural adhesion, and poor preoperative lung function are risk factors for persistent pulmonary leakage[20]. Low BMI may be due to high negative chest pressure in thin and tall patients, which is prone to rupture of alveolar tissue or bronchial stump[20]. Preoperative basic pulmonary diseases and the number of lymph nodes dissected are risk factors for pleural effusion and pulmonary infection[20].

In this study, the results shows that RATS had a longer operation time and higher total hospitalization cost than VATS, which limits the promotion of RATS. The results of VATS and RATS segmental resection in terms of operative time are also different in different studies. Rinieri P[21] compared 16 patients who underwent RATS and 32 patients underwent VATS for pulmonary segmentectomy, and the average operative time was [150(120~180) min Vs 140(120~170) min; P=0.507]. In Demir's study[22], 34 cases of RATS and 65 cases of VATS segmentectomy were compared, and the average operative time was [(76 ± 23)min Vs (65 ± 22)min; P=0.018]. This may be due to the small number of robotic surgeries, unskilled technology and the process was not optimized[23]. Studies have suggested that the difference in operatve time may be due to different learning curves and lung segments studied[24-26]. Constance L G[24] reported that the median operative time during the initial learning period was 136(124~149) min and the median operative time during the consolidation period was 97(88~107) min, which was significantly shorter than that in the initial learning period. XIE B[25] compared different types of pulmonary segmentectomy and divided them into typical and atypical types. The operative time of atypical pulmonary segmentectomy was significantly longer than that of typical one, with a difference between the two types (131.68 ± 22.52 Vs 115.69 ± 22.32). Nakazawa S[26] reported that atypical segmentectomy is more complex than typical segmentectomy and may require more incision and dissection than typical segmentectomy, which is more suitable for robotic surgery. In terms of hospitalization costs, we found that in the robotic surgery, the total hospitalization costs of the latter 24 cases were significantly lower than those of the former 25 cases, since the shortened hospitalization. The decrease in hospitalization-related costs may be related to shortened hospital stay. It may also due to the decreased cost of surgery, which caused by the less instruments used for the technique is more proficient. At present, robotic surgery systems are still expensive, however, with the development of technology and domestic robotic systems, the cost will be significantly decreased[27].

4 Conclusion

RATS pulmonary segment resection is superior to VATS pulmonary segment resection in terms of intraoperative blood loss, group and number of lymph node dissection, postoperative pain, postoperative duration of chest drainage, total thoracic drainage volume, and postoperative hospital stay. In addition, the incidence of postoperative complications such as pneumonia, atrial fibrillation and postoperative pulmonary leakage was not increased. RATS has less bleeding, lighter pain and smaller trauma, but longer operation time and higher cost. Based on the results of our study, it can be confirmed that RATS will bring more advantages in the treatment of early NSCLC. However, this study involves no long-term survival and recurrence, and further studies shall be performed in terms of long-term prognosis. Moreover, this study is only an retrospective study in a single center with small sample size, more randomized controlled trials with large sample size are needed to support the results of this study.

Author contributions

WANG Bing and GOU Yunjiu conceived and designed the study. WANG Bing and LIU Lu performed the experiments. WANG Bing, YANG Ning and HE Xiaoyang analyzed the data. CUI Baiqiang contributed analysis tools. WANG Bing, HUANG Daxing, BAI Xiangdou, ZENG Weiqiang and GOU Yunjiu provided critical inputs on design, analysis, and interpretation of the study. All the authors had access to the data. All authors read and approved the final manuscript as submitted.

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