Original Article

Robot-assisted thoracic surgery versus video-assisted thoracic surgery for mediastinal lesions

Takahiro Ochi[#], Hidemi Suzuki[#], Yuki Hirai, Takahiro Yamanaka, Hiroki Matsumoto, Taisuke Kaiho, Terunaga Inage, Takamasa Ito, Kazuhisa Tanaka, Yuichi Sakairi, Ichiro Yoshino

Department of General Thoracic Surgery, Chiba University Graduate School of Medicine, Chiba, Japan

Contributions: (I) Conception and design: T Ochi, H Suzuki; (II) Administrative support: I Yoshino; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: T Ochi, H Suzuki; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Hidemi Suzuki, MD, PhD. Department of General Thoracic Surgery, Chiba University Graduate School of Medicine, 1-8-1 Inohana, Chiba 260-8670, Japan. Email: hidemisuzukidesu@yahoo.co.jp.

Background: Robot-assisted thoracic surgery (RATS) has become widely used for mediastinal procedures since 2018 when it was included in insurance coverage in Japan. Few studies have compared the surgical outcomes of RATS with the more established video-assisted thoracic surgery (VATS) approach to mediastinal surgery. We aimed to compare the perioperative outcomes of VATS and RATS to examine the advantages of the RATS approach in a single institutional cohort.

Methods: A total of 144 patients who underwent VATS and 46 who underwent RATS mediastinal surgery between 2014 and 2022 were enrolled. We compared clinicopathological features such as age, sex, smoking history, respiratory function, surgical field, laterality, surgical procedure, board certification of the surgeon, and histology between the two groups. Perioperative outcomes including operation time, volume of blood lost, number of conversion cases to open surgery, duration of chest drainage, postoperative hospital stay, and postoperative complications were also reviewed.

Results: The comparison of patient characteristics between the groups showed significant differences in median age (VATS, 52.5 years; RATS, 67.0 years; P=0.001), combined resection of surrounding tissues of the tumor (VATS, 2.1%; RATS, 10.9%; P=0.02), board certification of the surgeon (VATS, 53.5%; RATS, 100.0%; P<0.001), and histology (RATS group had a higher percentage of thymic epithelial tumors, P=0.01). Regarding perioperative outcomes, the median operation time was 120 min in the VATS group and 88 min in the RATS group, showing a significant difference (P=0.03). There were no significant differences in the volume of blood lost, incidence of conversion to open chest surgery, duration of chest drainage, postoperative length of stay in hospital, and incidence of perioperative complications. In the perioperative outcomes of cases operated on by board-certified surgeons, the median operation time (VATS, 117 min; RATS, 88 min; P=0.02) and median postoperative length of stay in hospital (VATS, 7 days; RATS, 6 days; P=0.001) showed significant differences, while other postoperative outcomes were not significantly different.

Conclusions: RATS for mediastinal surgery is as safe as the VATS approach and may result in a shorter operative time and postoperative hospital stay. Further analysis of RATS for mediastinal surgery in a larger cohort is warranted.

Keywords: Endoscopic surgery; robot-assisted thoracic surgery (RATS); video-assisted thoracic surgery (VATS); mediastinal surgery

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Introduction

Background

Video-assisted thoracic surgery (VATS) has long been used as a minimally invasive alternative to open chest surgery for mediastinal surgery. In contrast, robot-assisted thoracic surgery (RATS), which was introduced for use in thoracic surgery in Japan in 2001 (1), has not become widely used owing to several reasons, including insurance coverage. However, RATS for mediastinal tumor surgery and lobectomy for lung cancer was added to insurance coverage in 2018, followed by thymectomy for myasthenia gravis and segmentectomy for lung cancer in 2020. The RATS approach is therefore now becoming popular in clinical practice, second only to VATS. Currently, approximately 6,000 thoracic surgeries are performed annually in Japan using the RATS approach.

Rationale and knowledge gap

Most comparisons of VATS and RATS as approaches to mediastinal surgery have focused only on surgery for thymoma and few studies have targeted all areas of the mediastinum.

Objective

We aimed to compare the perioperative outcomes of VATS and RATS in all areas of the mediastinum to examine the advantages of the RATS approach in a single institutional cohort. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-377/rc).

Highlight box

Key findings

- Robot-assisted thoracic surgery is as safe as video-assisted thoracic surgery in mediastinal surgery and had a reduced operation time.

What is known and what is new?

- Robot-assisted thoracic surgery is becoming more widely used in mediastinal surgery; however, most comparisons of robot- and video-assisted thoracic surgery have focused only on anterior mediastinal surgery.
- This study provides a comparison of robot- and video-assisted thoracic surgery in all areas of the mediastinum.

What is the implication, and what should change now?

- Robot-assisted thoracic surgery is a feasible alternative to video-assisted thoracic surgery in mediastinal surgery.

Methods

Study design

This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethical Committee of Chiba University Graduate School of Medicine (No. M10557), and the need for informed consent from each individual was waived due to the retrospective nature of the study. A total of 190 patients underwent endoscopic mediastinal surgery at Chiba University Hospital between January 2014 and November 2022. An endoscopic approach was selected for patients without major vascular involvement. Among these patients, 144 and 46 underwent mediastinal surgery with VATS and RATS, respectively. All patients had not previously undergone thoracic surgery. In the RATS approach, only board-certified surgeons performed surgeries, while in the VATS approach, some surgeries were performed by board-certified surgeons and others were performed by non-certified surgeons.

To compare the characteristics of the patients who underwent RATS with those who underwent VATS, the following clinicopathological variables were assessed: age at surgery, sex, smoking history, % forced vital capacity (%FVC), forced expiratory volume in one-second percentage (FEV1%), surgical field in the mediastinum, laterality of approach, surgical procedure, board certification of the surgeon, and histology. Perioperative outcomes included operation time, volume of blood lost, number of conversion cases to open surgery, duration of chest drainage, postoperative length of stay in hospital, and postoperative complications. Operation time was defined as the interval between the start and end of surgery; in the case of RATS, this was determined by the sum of console time, open/closed chest time, and roll-in/roll-out time of the patient trolley. Postoperative complications in this report were defined as grade three or higher according to the Common Terminology Criteria for Adverse Events version 5.0.

Surgical procedure

The fourth-generation da Vinci Xi system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) is used in our institution. In principle, endoscopic mediastinal surgery,

including VATS and RATS, is performed from one side with the patient in a semi-supine position. The AirSeal® System (Conmed Corp., Utica, NY, USA) was used as the port of the RATS for CO_2 insufflation to ensure a sufficient field of view. The port position is generally based on the midaxillary line in the third, fifth, and seventh intercostal space, with the addition of an assistant port, if necessary. In cases of mediastinal tumors, simple extirpation with an adequate margin was performed from either side, and combined resection of the surrounding tissues, such as the lung or pericardium, was an option if necessary. Lymphadenectomy was not routinely performed because the indication for endoscopic surgery was limited to the cases without obvious invasion of surrounding tissues, lymph nodes, or distant metastases on imaging studies in our institution. In cases of myasthenia gravis, extended thymectomy was performed using a bilateral approach, in which the right-sided surgery was performed first, followed by the left side, to ensure identification of the left brachiocephalic vein by dissecting toward the cephalic and central sides along the phrenic nerve and superior vena cava.

Statistical analysis

Data are presented as median [range] or number (percentage). Pearson's chi-square test or Fisher's exact test was used for the analysis of dichotomous data and Mann-Whitney U test was used for the analysis of continuous covariates, respectively. All tests were two-sided, and P values <0.05 were considered to indicate statistical significance. All statistical analyses were performed using JMP software version 15.2 (SAS Institute, Cary, NC, USA, RRID:SCR_014242).

Results

Patient characteristics

Patient characteristics are listed in *Table 1*. The median age at surgery was 52.5 [10–83] years for VATS and 67.0 [28–78] years for RATS; 84 patients (58.3%) in the VATS group and 28 patients (60.9%) in the RATS group were men. A total of 55 patients (38.2%) in the VATS group and 20 patients (43.5%) in the RATS group had a history of smoking. The %FVC was 100.0% [68.4–140.4%] in the VATS group and 99.2% [65.9–130.9%] in the RATS group, while the FEV1/FVC was 79.7% [43.0–99.2%] in the VATS group and 78.5% [60.3–97.1%] in the RATS group. With regard to the surgical field, the anterior mediastinum was dominant in both groups. Unilateral surgery was the most common in both groups; bilateral surgery was performed in 37 patients (25.7%) in the VATS group and in eight patients (17.4%) in the RATS group. The majority of surgical procedures were tumor resections. Three patients (2.1%) in the VATS group and five patients (10.9%) in the RATS group underwent combined resection of the surrounding tissues, including the lung, pericardium, and phrenic nerve, owing to tumor invasion. The number of operations performed by board-certified surgeons was 77 (53.5%) and 46 (100.0%) in the VATS and RATS groups, respectively. Pathological examination revealed that thymic lesions were predominant in both the groups. The comparison of patient characteristics between the two groups showed significant differences in age (P=0.001), combined resection of surrounding tissues (P=0.02), board certification of the surgeon (P<0.001), and histology (P=0.01), indicating that the RATS group had an older patient population, a higher percentage of thymic epithelial tumors, more cases requiring combined resection of surrounding tissues, and more cases performed by board-certified surgeons.

Perioperative outcomes

The perioperative outcomes in each group are listed in *Table 2*. There were no significant differences in the volume of blood lost, incidence of conversion to open chest surgery, duration of chest drainage, postoperative length of stay in hospital, or incidence of perioperative complications. The median operation time was 120 min in the VATS group and 88 min in the RATS group, which showed a significant difference (P=0.003) (*Figure 1*). The median operation time for the unilateral approach was 98 min in the VATS group and 79 min in the RATS group, also showing a significant difference (P=0.002). The median operation time for the bilateral approach was 191 min in the VATS group and 208 min in the RATS group (P=0.63).

Perioperative outcomes were also examined with a focus on cases operated on by board-certified surgeons (*Table 3*): the comparison of patient characteristics of these limited cases between the VATS and RATS groups was similar to that of all patients (*Table 4*). There were no significant differences in the volume of blood lost, incidence of conversion to open chest surgery, duration of chest drainage, or incidence of perioperative complications, as in the whole-group analysis, while the median operation

Table 1 Patient characteristics

Characteristics	VATS (n=144)	RATS (n=46)	P value
Age (years), median [range]	52.5 [10–83]	67.0 [28–78]	0.001
Sex (male), n (%)	84 (58.3)	28 (60.9)	0.86
Smoking history (yes), n (%)	55 (38.2)	20 (43.5)	0.60
%FVC, median [range]	100.0 [68.4–140.4]	99.2 [65.9–130.9]	0.91
FEV1/FVC (%), median [range]	79.7 [43.0–99.2]	78.5 [60.3–97.1]	0.49
Surgical field in the mediastinum, n (%)			0.10
Anterior	107 (74.3)	41 (89.1)	
Middle	8 (5.6)	1 (2.2)	
Posterior	29 (20.1)	4 (8.7)	
Laterality of approach, n (%)			0.32
Unilateral	107 (74.3)	38 (82.6)	
Right	56 (38.9)	24 (52.2)	
Left	51 (35.4)	14 (30.4)	
Bilateral	37 (25.7)	8 (17.4)	
Surgical procedure, n (%)			0.39
Tumor resection	105 (72.9)	38 (82.6)	
Simple thymectomy	2 (1.4)	0 (0.0)	
Extended thymectomy	37 (25.7)	8 (17.4)	
Combined resection of adjacent tissue (yes), n (%)	3 (2.1)	5 (10.9)	0.02
Operation performed by board-certified surgeon, n (%)	77 (53.5)	46 (100.0)	<0.001
Histology, n (%)			0.01
Thymoma	50 (34.7)	29 (63.0)	
Thymic cyst	22 (15.3)	8 (17.4)	
Thymic carcinoma	6 (4.2)	1 (2.2)	
Neurogenic tumor	21 (14.6)	1 (2.2)	
Bronchogenic cyst	10 (6.9)	1 (2.2)	
Mature teratoma	7 (4.9)	0 (0.0)	
Others	28 (19.4)	6 (13.0)	

VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery; FVC, forced vital capacity; FEV1, forced expiratory volume in one-second.

time (VATS, 117 min; RATS, 88 min; P=0.02) (*Figure 1*) and postoperative length of stay (VATS, 7 days; RATS, 6 days; P=0.001) showed significant differences. The median operation time for the unilateral approach was 85 min in the VATS group and 79 min in the RATS group (P=0.12). The median operation time for the bilateral approach was 178 min in the VATS group and 208 min in the RATS group (P=0.25).

Discussion

Key findings

In this study, we compared the perioperative outcomes of

Table 2 Perioperative outcomes

Outcomes	VATS (n=144)	RATS (n=46)	P value
Operation time (min), median [range]	120 [34–476]	88 [31–229]	0.003
Operation time (unilateral surgery)	98 [34–476]	79 [31–158]	0.002
Operation time (bilateral surgery)	191 [116–296]	208 [156–229]	0.63
Volume of blood lost (g), median [range]	0 [0–1,810]	0 [0–75]	0.97
Conversion to open surgery (yes), n (%)	1 (0.7)	0 (0.0)	>0.99
Duration of chest drainage (days), median [range]	1 [1–6]	1 [1–3]	0.39
Postoperative hospital stay (days), median [range]	6 [2–49]	6 [2–11]	0.05
Postoperative complication[†] (yes), n (%)	8 (5.6)	1 (2.2)	0.69

[†], grade three or higher complication according to the Common Terminology Criteria for Adverse Events version 5.0. VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery.

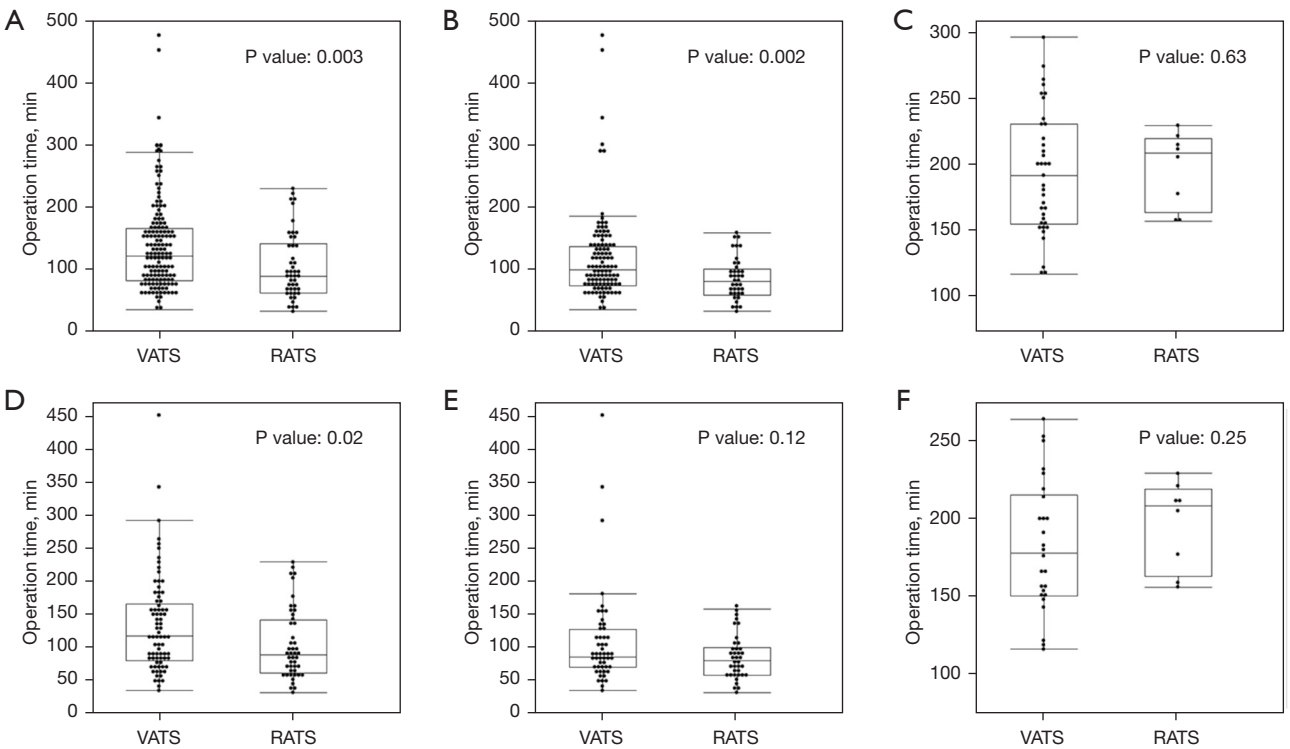

Figure 1 Operation time in the VATS and RATS groups. (A) The median operation times were 120 min in the VATS group and 88 min in the RATS group (P=0.003). (B) The median operation times for the unilateral approach were 98 min in the VATS group and 79 min in the RATS group (P=0.002). (C) The median operation times for the bilateral approach were 191 min in the VATS group and 208 min in the RATS group (P=0.63). (D) The median operation times were 117 min in the VATS groups and 88 min in the RATS group (P=0.02), including only cases operated on by board-certified surgeons. (E) The median operation times for the unilateral approach were 85 min in the VATS group and 79 min in the RATS group (P=0.12), including only cases operated on by board-certified surgeons. (F) The median operation times for the bilateral approach were 178 min in the VATS group and 208 min in the RATS group (P=0.25), including only cases operated on by board-certified surgeons. RATS, robot-assisted thoracic surgery; VATS, video-assisted thoracic surgery.

Table 3 Perioperative outcomes limited to cases performed by board-certified surgeons

Outcome	VATS (n=77)	VATS (n=46)	P value
Operation time (min), median [range]	117 [34–452]	88 [31–229]	0.02
Operation time (unilateral surgery)	85 [34–452]	79 [31–158]	0.12
Operation time (bilateral surgery)	178 [116–264]	208 [156–229]	0.25
Volume of blood lost (g), median [range]	0 [0–210]	0 [0–75]	0.41
Conversion to open surgery (yes), n (%)	0 (0.0)	0 (0.0)	–
Duration of chest drainage (days), median [range]	1 [1–6]	1 [1–3]	0.36
Postoperative hospital stay (days), median [range]	7 [3–49]	6 [2–11]	0.001
Postoperative complication[†] (yes), n (%)	6 (7.8)	1 (2.2)	0.25

[†], grade three or higher complication according to the Common Terminology Criteria for Adverse Events version 5.0. VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery.

VATS and RATS mediastinal surgery in a single institute and found that the RATS approach reduced operation time, despite the factors that could prolong operation time, such as higher age, higher rate of malignancy and more cases with complicated resection of surrounding tissue in this group: as for complicated resection cases, there was a possibility of accidental error, since the number of the cases in both groups was small. The results of the subgroup analysis, which included only cases performed by board-certified surgeons, similarly showed a reduction in operative time and a possible reduction in the length of postoperative hospital stay.

Strengths and limitations

The present study compared VATS and RATS in all areas of the mediastinum, which few previous reports have focused on, and compared a multitude of clinicopathological variables and perioperative outcomes. The findings of the present study add to the existing literature to aid in the selection of an appropriate surgical approach. However, the present study has four limitations. First, this was a single-institutional retrospective study. A reduction in operative time with RATS was shown in this study, in contrast to most previous reports (2-6); therefore, this may be related to an institutional bias. Second, there may be a difference in surgical difficulty between VATS and RATS due to case selection. Certainly, the number of complicated resection cases was higher in the RATS group although RATS case selection was not intended; however, the localization of the lesion and its proximity to the great vessels may have increased surgical difficulty in the VATS group. Third, the distribution of the number of cases per year differed between the VATS and RATS groups. The number of RATS cases has increased over the past few years, and compared to VATS cases, most RATS cases were more recent. This result could indicate a possible advantage in the RATS group, considering the progress of medical technology over time. Fourth, the proportion of each surgical field in the mediastinum differed between the two groups, although the difference was not statistically significant. The middle and posterior mediastinal lesions tended to be more common in the VATS group, which might have affected the perioperative outcomes, including operative time.

Comparison with similar researches

Previous reports have indicated a reduction in the length of postoperative hospital stay when using RATS compared with VATS (7,8), which was also found in the subgroup analysis of the present study. Prolonged operation time has previously been shown to be a disadvantage of RATS in lung resection, as well as in other areas of surgery (2-6); however, the present study showed the potential for reduced operation time of mediastinal lesions using the RATS approach.

The RATS approach, which allows precise manipulation, is highly useful for resection of mediastinal tissues, and good results have been reported (9). Use of the RATS approach for thymoma is also increasing and has been shown to be non-inferior to VATS in terms of operative time, length of postoperative hospital stay, and recurrence rate (7). A comparison of the VATS and RATS approaches

Table 4 Patient characteristics limited to cases performed by board-certified surgeons

Characteristic	VATS (n=77)	RATS (n=46)	P value
Age (years), median [range]	51.0 [15–83]	67.0 [28–78]	0.001
Sex (male), n (%)	51 (66.2)	28 (60.9)	0.56
Smoking history (yes), n (%)	30 (39.0)	20 (43.5)	0.70
%FVC, median [range]	100.0 [68.4–140.4]	99.2 [65.9–130.9]	0.97
FEV1/FVC (%), median [range]	80.0 [43.0–99.2]	78.5 [60.3–97.1]	0.19
Surgical field in the mediastinum, n (%)			0.20
Anterior	58 (75.3)	41 (89.1)	
Middle	5 (6.5)	1 (2.2)	
Posterior	14 (18.2)	4 (8.7)	
Laterality of approach, n (%)			0.06
Unilateral	51 (66.2)	38 (82.6)	
Right	27 (35.1)	24 (52.2)	
Left	24 (31.2)	14 (30.4)	
Bilateral	26 (33.8)	8 (17.4)	
Surgical procedure, n (%)			0.06
Tumor resection	51 (66.2)	38 (82.6)	
Extended thymectomy	26 (33.8)	8 (17.4)	
Combined resection of adjacent tissue (yes), n (%)	1 (1.3)	5 (10.9)	0.02
Histology, n (%)			0.01
Thymoma	30 (39.0)	29 (63.0)	
Thymic cyst	9 (11.7)	8 (17.4)	
Thymic carcinoma	1 (1.3)	1 (2.2)	
Neurogenic tumor	13 (16.9)	1 (2.2)	
Bronchogenic cyst	2 (2.6)	1 (2.2)	
Mature teratoma	4 (5.2)	0 (0.0)	
Others	18 (23.4)	6 (13.0)	

VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery; FVC, forced vital capacity; FEV1, forced expiratory volume in one-second.

to thymoma surgery also reported that RATS had fewer adverse outcomes, including conversion to open thoracotomy, positive resection margins, unexpected rehospitalization within 30 days, and death within 90 days (8). Reports comparing the RATS approach with open thoracotomy in thymoma surgery showed the potential for less intraoperative blood loss and a shorter hospital stay (10,11). In addition to anterior mediastinal lesions, RATS facilitates approaches to middle and posterior mediastinal lesions as well as lesions near the apex of the thoracic cavity and diaphragm and can be used for larger tumors and invasive thymomas (9,10).

The lateral approach is commonly used for resection in mediastinal RATS, and our institution also uses this approach, but the usefulness of the subxiphoid approach for thymomas has also been reported (12). While the subxiphoid approach has also been reported for single-portal VATS (13), the RATS approach is performed by

placing a camera port under the xiphoid process and access ports at the right and left sixth intercostal spaces on the anterior axillary lines. The advantages of this approach include cosmetic benefits, pain relief, ease of identification of the diaphragmatic nerve, and smooth transition to open chest surgery in cases of bleeding because positional change is not necessary. The da Vinci Single-Port Surgical System was introduced in Japan in January 2023. A camera and three dedicated forceps can be inserted into the body cavity through a 2.5-cm diameter cannula. The arm can rotate 360°, the camera has a wrist joint, and the dedicated forceps can bend in multiple directions, making it ideal for use in confined spaces. As noted above, single-port VATS anterior mediastinal surgery has been reported, but the indications for mediastinal surgical cases using the da Vinci Single-Port Surgical System may increase with the widespread use of RATS in the future. Theoretically, we use a lateral approach from both sides with a change of position, similar to the VATS approach for thymectomy and extended thymectomy, because seeding of the bilateral thoracic cavity may be avoided by performing the surgeries one side at a time in turn and is consistent with the field view of the VATS approach. In this study, the bilateral approach (extended thymectomy) did not show a reduction in operation time, which may be because roll-out and roll-in of the patient trolley was required for each position. It is estimated that using the RATS subxiphoid approach may reduce the prolonged operative time inherent to RATS, resulting in a shorter operative time for extended thymectomy.

Explanations of findings

A possible reason for the shorter operation time seen in RATS compared with VATS in the present study is that RATS has better operability than VATS because it has a three-dimensional constructed image and high maneuverability including forceps with joints. Regarding tumor resection, the three-dimensional visualization available with RATS may allow easier identification of tumors in cases with abundant mediastinal adipose tissue. The stereoscopic view could improve the visibility of minute blood vessels in the same way, and the robotic arm could compensate for vibrations caused by manipulation, which may reduce unexpected bleeding and contribute to the shortening of the operation time.

In the subgroup analysis of the patients operated by board-certified surgeons, comparison of operative time between the VATS and RATS groups showed a significant difference, however there were no significant differences, not only in the bilateral approach but also in the unilateral approach, which might be due to the result that the VATS group tended to have more bilateral surgeries, although the difference was not significant.

Implications and actions needed

Our findings imply that RATS is a feasible alternative to VATS in mediastinal surgery and could be utilized more frequently for these procedures, particularly with the development of more advanced RATS systems. In our institution, postoperative pain was evaluated generally using Numerical Rating Scale (NRS) since August 2017 and this score on postoperative day 1 and before discharge was confirmed. NRS on the postoperative day 1 was obtained for 80 patients in the VATS group and 39 in the RATS group, and NRS before discharge for 73 patients in the VATS group and 37 in the RATS group. Regarding NRS on the postoperative day 1, the median score was 2 (0 to 10) for VATS and 1 (0 to 6) for RATS, showing significant difference (P=0.001). Regarding NRS before discharge, the median score was 1 (0 to 7) for VATS and 0 (0 to 5) for RATS (P=0.27). These results could show that there was no difference between the VATS and RATS approaches in post-acute pain, but the RATS approach potentially contribute to pain reduction in the acute phase. To analyze not only precise perioperative results, including postoperative pain, but also long-term results, a prospective multicenter study of RATS mediastinal surgery is necessary.

Conclusions

In conclusion, RATS mediastinal surgery was shown to be as safe as VATS and result in a shorter operative time and shorter postoperative hospital stay. Even more investigation of RATS approach, including single portal subxiphoid approach, is expected to reduce patient invasion, such as pain relief in addition to reduction of operative time and postoperative hospital stay. Further analysis of RATS mediastinal surgery in a larger cohort is necessary to analyze the precise perioperative and long-term results.

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Footnote

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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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This retrospective study was approved by the ethical committee of Chiba University Graduate School of Medicine (No. M10557), and the need for informed consent from each individual was waived due to the retrospective nature of the study.

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