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Approach to mediastinal masses: a comparison of open surgery and uniportal video-assisted thoracoscopic surgery techniques

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ABSTRACT

Aims: This study aimed to compare perioperative and postoperative outcomes in patients who underwent uniportal video-assisted thoracoscopic surgery (U-VATS) and open surgery for mediastinal mass resection.

Methods: A total of 62 patients who underwent mediastinal mass resection in the thoracic surgery clinic were included. The patients were separated into the open surgery group (n=30) and the U-VATS group (n=32). The groups were compared in terms of perioperative and postoperative outcomes including operative time, blood loss, chest tube removal time, drainage volume, pain, and hospital stay.

Results: The distributions of age and gender were similar between the groups. Median operation time (120 vs. 180 minutes, P<0.001), median intraoperative blood loss (50 vs. 100 mL, P<0.001), median time of chest drain removal (4 vs. 6 days, P<0.001) and median postoperative drainage volumes were lower in the U-VATS group than the open surgery group. The U-VATS group exhibited a lower VAS score, return time to daily activity (1 vs. 4 days, P<0.001) and length of hospital stay (4 vs. 6 days, P<0.001). A postoperative myasthenic crisis was not observed in all cases. One thymoma patient in the open surgery group had a recurrence, but not in the U-VATS group.

Conclusion: The U-VATS approach had better intraoperative safety and lower postoperative outcomes than open surgery. U-VATS, which has the potential to enhance postoperative recovery and quality of life, may be a safe and effective treatment option for patients with mediastinal mass resection.

Keywords: Mediastinal lesions, minimally invasive surgery, sternotomy, thymoma, video-assisted thoracoscopic surgery

INTRODUCTION

Mediastinal masses are a diverse group of lesions, including bronchogenic cysts, thymomas, neurogenic tumors, and thyroid tumors, and account for approximately 3% of thoracic lesions.[1] Thymomas are tumors that arise from thymic epithelial cells and are located in the anterior mediastinum, while bronchogenic cysts are derived from the embryonic foregut and can be found in the middle or posterior mediastinum.[2] Neurogenic tumors arise from neural crest cells and are most commonly located in the posterior mediastinum, while thyroid tumors can be located in the anterior or middle mediastinum.[3] The location and origin of the mediastinal mass can sometimes provide important clues about the nature of the lesion and influence the choice of surgical approach.[4]

Traditionally, open surgical procedures such as median sternotomy, posterolateral thoracotomy, and hemi-clamshell sternotomy have been the preferred approaches for resection of mediastinal masses.[5] However, these procedures are associated with substantial surgical trauma and morbidity. Video-assisted thoracoscopic surgery (VATS) is a minimally invasive surgical technique that involves the use of a thoracoscope and specialized instruments to access and remove the mediastinal mass through small incisions in the chest wall.[6] As a result of advancements in thoracoscopic instruments and surgical techniques and the evolution of minimally invasive concepts, the requirement for ports in VATS has been gradually reduced from three or four to just one.[7]

The VATS technique has been shown to be effective and safe for the resection of mediastinal masses, with a lower rate of morbidity and a shorter hospital stay compared to open procedures.[8,9] However, there are few studies on the effectiveness of uniportal VATS (U-VATS) for mediastinal mass resection. In these studies, the postoperative outcomes are in favor of the U-VATS, while the perioperative outcomes are inconsistent. Thus, further research is required to investigate the efficacy of U-VATS. This study aimed to compare perioperative and postoperative outcomes in patients who underwent U-VATS and open surgery for mediastinal mass resection.

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METHODS

Following the principles set forth in the Declaration of Helsinki, this prospective study was conducted at the Erciyes University Faculty of Medicine Department of Thoracic Surgery from January 2018 to January 2020. The study received approval from the Erciyes University Faculty of Medicine Ethics Committee (Date: 12.2017, Decision No: 2017-548). All participants provided their written informed consent.

A total of 74 patients planned for mediastinal mass resection between the years of the study were evaluated for eligibility. Cases with significant cognitive difficulties (vision, hearing, and mental disabilities) (n=1), preoperative chronic pain syndrome (n=3), use of opioid pain relievers (n=3), and history of thoracotomy or sternotomy (n=5) were excluded from the study. Finally, 62 cases were included in the study, and no cases were excluded during the follow-up period.

The arterial blood gas, electrocardiography, pulmonary function tests and posteroanterior chest radiographs (PAAG), thorax computed tomography (CT) (**Figure 1**), and positron emission tomography with CT (PET/CT) were performed in all cases. Histopathological diagnoses for the patients were obtained with transthoracic needle aspiration (TTNA), endobronchial ultrasonography (EBUS), fiberoptic bronchoscopy (FOB), and endosonography (EUS). Mediastinal and distant metastases were evaluated with PET/CT. Oral intake of patients was discontinued for 24 hours before the operation. Following the cessation of oral intake, patients with chronic renal failure and diabetes mellitus were hydrated with neutralizing fluid, and their blood sugars were controlled. All patients were evaluated preoperatively by the anesthesiology and reanimation department, while patients over the age of 65 were consulted preoperatively by cardiology. The patients were divided into two groups based on the surgical procedure, which was either open surgery or U-VATS.

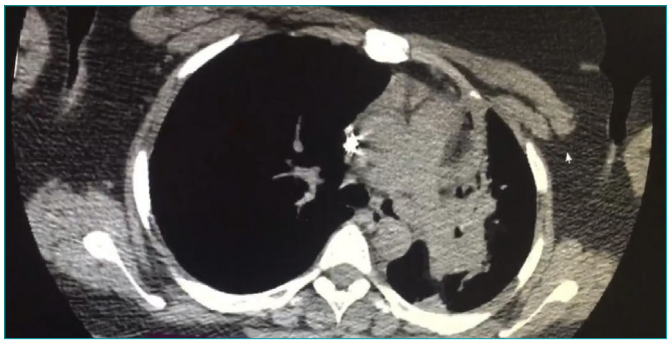

Figure 1. The thorax computed tomography image of the patient who underwent open surgery due to suspicion of mediastinal invasion

Surgical Procedure

Under general anesthesia, patients undergoing open surgery were intubated with a single-lumen endotracheal tube, while those undergoing U-VATS procedures were intubated with a double-lumen tube to facilitate access and management of lesions on the contralateral side. In myasthenic patients, a central venous catheter was placed in the subclavian vein or the internal jugular vein. Invasive arterial monitoring was provided. All patients undergoing U-VATS were placed in the posterolateral thoracotomy position, while those undergoing open surgery were placed in both the posterolateral thoracotomy (n=6) and sternotomy positions (n=24), and a thoracotomy pillow was utilized.

A uniportal incision was made on the anterior axillary line through the 4th or 5th intercostal space. From this range, a high-resolution thoracoscope, which has a 30° optic with a 10-mm diameter, and 5-mm angled hand tools such as staple systems and endoscopic polymer clips, which allow work in the thoracic cavity, were used. Postoperatively, a single drain was placed in the same incision.

Patients who underwent open surgery with muscle-sparing posterolateral thoracotomy in the lateral decubitus position had their serratus anterior muscle preserved. Patients who underwent sternotomy were placed in the supine position. After surgery, a chest drain was placed in the thoracic cavity. In patients undergoing thoracotomies, a costa retractor was used.

After surgery, the patients were transferred to the intensive care unit. Every 4 to 6 hours, hemograms were monitored, and PAAG was performed daily. The patients' fluid intake and output were monitored hourly. When the daily drainage fell below 200 ml and the air leak ceased, the chest tube drain was removed. These patients were discharged after a control PAAG, which was evaluated 24 hours later.

Postoperative Pain Evaluation

The VAS scale was used for the evaluation of postoperative pain. The pain intensity is expressed on a scale from 0 (not painful) to 10 (extremely painful). A single physician explained each patient on how to properly score their level of pain. At the 4th, 8th, 12th, 24th, 48th, and 72nd hours after surgery, each patient completed a pain evaluation.

In both open and minimally invasive surgical techniques, the same pain management strategy was employed. This involved administering analgesic medication to all patients in equal dosages and at the same intervals postoperatively, regardless of the surgical approach used. Patients with pain were given paracetamol first, while nonsteroidal anti-inflammatory drugs were given if the pain started again. Analgesics were administered at 8-hour intervals. Opioid analgesics were not used.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) for Windows 23 (IBM SPSS, Chicago, IL, USA). The extent to which the data followed a normal distribution was evaluated using the Shapiro-Wilk test. Numeric variables with and without a normal distribution were plotted as mean±standard deviation and median (min-max), respectively. The student-T test or Mann-Whitney U test was used for the comparison of numeric variables between the two groups according to the distribution of normality. Categorical variables were indicated as numeric and percentile values. Chi-square, Yates correction and Fischer's exact tests were used for the comparison of categorical data. A p-value of less than 0.05 was considered significant in statistical analyses.

RESULTS

The mean age of the 62 cases with mediastinal masses included in the study was 49.2±15.4 years, and the majority of them had additional diseases (77.4%). The demographic and clinical characteristics of the cases are presented in

Table 1. The mean age, rates of females and smokers were similar in the open surgery group compared to the U-VATS group. The rates of hypertension, coronary artery disease and Myasthenia gravis were higher in the open surgery group compared to the U-VATS group. Mass localization had a similar distribution in both groups.

Table 1. Demographic and clinic characteristics of the study population

Variables	All patients	Open surgery	U-VATS	P value
	n=62	n=30	n=32	
Age, years	49.2±15.4	48.1±15.2	50.2±15.8	0.609
Gender, n (%)				0.585
Male	27 (43.5)	12 (40.0)	15 (46.9)	
Female	35 (56.5)	18 (60.0)	17 (53.1)	
Smoking, n (%)	17 (27.4)	10 (33.3)	7 (21.9)	0.312
ASA grade, n (%)				0.261
I	6 (9.7)	3 (10.0)	3 (9.4)	
II	48 (77.4)	21 (70.0)	27 (84.4)	
III	8 (12.9)	6 (20.0)	2 (6.3)	
Comorbidities, n (%)				
Hypertension	19 (30.6)	17 (56.7)	2 (6.3)	<0.001
Coronary artery disease	10 (16.1)	9 (30.0)	1 (3.1)	0.004
Rheumatoid arthritis	7 (11.3)	3 (10.0)	4 (12.5)	0.756
Myasthenia gravis	7 (11.3)	6 (20.0)	1 (3.1)	0.036
Asthma	6 (9.7)	4 (13.3)	2 (6.3)	0.346
Diabetes mellitus	6 (9.7)	4 (13.3)	2 (6.3)	0.346
Mass localization, n (%)				0.485
Anterior	33 (53.2)	16 (53.3)	17 (53.1)	
Middle	12 (19.4)	6 (20.0)	6 (18.7)	
Posterior	17 (27.4)	8 (26.7)	9 (28.2)	

Data are mean±standard deviation or median (min-max), or number (%). ASA, American Society of An-esthesiologists; U-VATS, Uniportal video-assisted thoracoscopic surgery.

Cyst tumor excision was performed in the majority of cases (60%) who underwent open surgery, while mass excision was performed in the majority of cases (65.6%) who underwent U-VATS. Median operation time (120 vs. 180 minutes, P<0.001) and median intraoperative blood loss (50 vs. 100 mL, P<0.001) were lower in the U-VATS group compared to the open surgery group. In all of the cases that underwent U-VATS, the procedure was completed without additional port incisions or conversion to a thoracotomy / sternotomy. Median pathological mass size was lower in the U-VATS group compared to open surgery (8 vs. 4 cm, P<0.001). In terms of pathological findings, the rates of malignant lesions and lymph nodes did not differ significantly between the groups (Table 2). The histopathological diagnosis distributions were as follows: 18 cases of thymoma, 8 cases of bronchogenic cyst, 7 cases of pericardial cyst, 7 cases of schwannoma, 6 cases of hydatid cyst, 4 cases of thymic hyperplasia, 3 cases of teratoma, 2 cases of enteric cyst, and one case each of cystic thyroid, hemangiopericytoma, and granulomatous events. A malignant neurogenic tumor was not detected. The rate of patients with thymoma was similar in both surgical groups. Three of the patients with thymoma were Stage II and above.

The median time of chest drain removal (4 vs. 6 days, P<0.001) and median postoperative drainage volumes were lower in the U-VATS group compared to the open surgery group. During the postoperative 72 hours, the U-VATS group exhibited lower postoperative VAS scores compared to the open surgery group (Figure 2). Median return time to daily activity (1 vs. 4 day, P<0.001) and median length of hospital stay (4 vs. 6 days, P<0.001) were lower in the U-VATS group compared to the open surgery group (Table 3).

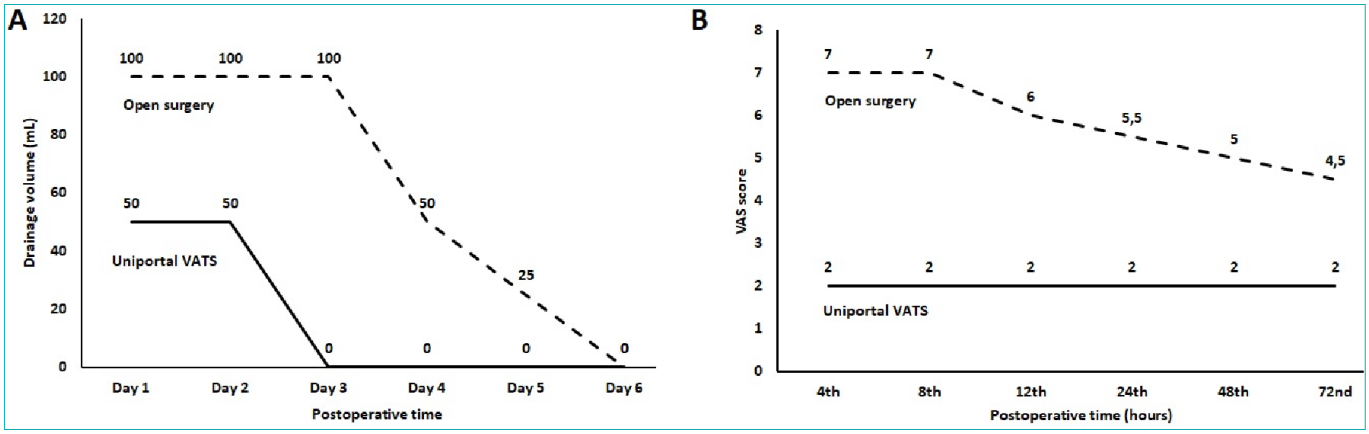

Figure 2. Variations in postoperative drainage volume (A) and VAS score (B) by surgical group

Table 2. Perioperative and histopathological findings

Variables	All patients	Open surgery	U-VATS	P-value
	n=62	n=30	n=32	
Type of surgery, n (%)				<0.001
Cyst tumor excision	18 (29.0)	18 (60.0)	0	
Mass excision	23 (37.1)	2 (6.7)	21 (65.6)	
Maximal thymectomy	21 (33.9)	10 (33.3)	11 (34.4)	
Operation time, minutes	165 (60-260)	180 (120-260)	120 (60-240)	<0.001
Intraoperative blood loss, mL	50 (20-200)	100 (30-200)	50 (20-80)	<0.001
Wound length, cm	3.5 (2.5-16.9)	15.5 (8-16.9)	3.0 (2.5-3.5)	<0.001
Pathological mass size, cm	5.5 (1-22)	8 (2-22)	4 (1-12)	<0.001
Thymoma, n (%)	18 (29.0)	10 (33.3)	8 (34.4)	0.579
Capsule invasion, n (%)	5 (8.1)	3 (10.0)	2 (6.3)	0.067
Metastatic lymph node, n (%)	1 (1.6)	0	1 (3.1)	0.974

Data are mean±standard deviation or median (min-max), or number (%). U-VATS, uniportal video-assisted thoracoscopic surgery.

Table 3. Postoperative findings

Variables	All patients n=62	Open surgery n=30	U-VATS n=32	P-value
Chest drain removal, day	5 (3-7)	6 (5-7)	4 (3-5)	<0.001
Drainage volume, mL				
Day 1	100 (50-150)	100 (50-150)	50 (50-100)	<0.001
Day 2	80 (0-150)	100 (50-150)	50 (0-100)	<0.001
Day 3	50 (0-350)	100 (50-350)	0 (0-100)	<0.001
Day 4	0 (0-150)	50 (0-150)	0 (0-50)	<0.001
Day 5	0 (0-100)	25 (0-100)	0	<0.001
Day 6	0 (0-100)	0 (0-100)	0	0.009
Day 7	0	0	0	1.000
VAS score				
4th hours	4 (1-10)	7 (5-10)	2 (1-4)	<0.001
8th hours	3.5 (2-10)	7 (4-10)	2 (2-4)	<0.001
12th hours	3 (2-10)	6 (2-10)	2 (2-3)	<0.001
24th hours	3 (2-9)	5.5 (2-9)	2 (2-3)	<0.001
48th hours	2 (1-8)	5 (2-8)	2 (1-2)	<0.001
72nd hours	2 (1-8)	4.5 (2-8)	2 (1-3)	<0.001
Return time to daily activity, day	2.5 (1-6)	4 (3-6)	1 (1-3)	<0.001
Length of hospital stay, day	6 (3-9)	8 (6-9)	5 (3-7)	<0.001

Data are mean±standard deviation or median (min-max), or number (%). U-VATS, uniportal video-assisted thoracoscopic surgery; VAS, visual analogue scale.

In the U-VATS group, partial pneumothorax developed in one patient who underwent thymectomy after drainage was terminated. This patient underwent clinical follow-up with nasal oxygen therapy and the air in the thorax was resorbed without the need for additional intervention. A postoperative myasthenic crisis was not observed in all cases. The median follow-up period for the patients was 18 months, ranging from 1 to 25 months. In the group undergoing open surgery, a patient with thymoma had a recurrence, while there were no recurrences in the U-VATS group.

DISCUSSION

This study of mediastinal masses, which is frequently observed in thoracic surgery, showed that when compared to open surgery, U-VATS was associated with better outcomes in terms of perioperative blood loss, postoperative drainage volumes, postoperative pain, return to daily activities, and length of hospital stay. The findings of this study indicated that VATS is safe and feasible for the resection of mediastinal masses.

Although surgical treatment is usually the first option for mediastinal lesions, technological advancements have increased the trend toward minimally invasive approaches in recent years.[10] Increasing evidence indicates that minimally invasive surgeries involving the use of smaller incisions are equivalent to open surgery.[11] Previous studies have reported that minimally invasive surgery provides better outcomes than open surgery because of reduced blood loss, chest tube time, and hospital stay.[12,13] On the other hand, traditional thoracoscopic surgery has several restrictions. The procedure necessitates 3–4 ports, which result in many scars and severe intercostal discomfort. In addition, there are some unique challenges with the technology, such as the two-dimensional field, limited processing capacity in a small location, and sewing difficulties.14 In VATS, the number of ports that are required has been decreased to a single incision as a result of technological advancements, and this approach has shown comparable perioperative and postoperative outcomes compared to other approaches.

In a study that compared the median sternotomy with the multiportal VATS in the treatment of early-stage thymoma, the duration of the operation and the amount of blood loss were partially lower in the multiportal VATS.[10] Two different meta-analyses involving patients with non-small cell lung cancer and spontaneous pneumothorax reported that there was no difference between U-VATS and multiportal VATS in terms of perioperative outcomes such as operative time, blood loss amounts, and conversion rate.[15,16] Another study evaluating patients who underwent minimally invasive mediastinal lesion resection demonstrated similar perioperative outcomes.[17] However, there are studies reporting more favorable outcomes for U-VATS.[18,19] These results indicate that U-VATS does not extend the duration of operation. Besides, the incision size was smaller in the U-VATS group compared to the open surgery group, which was consistent with previous studies.[20] Theoretically, a smaller incision could make surgery more challenging and lengthen the duration of the procedure. This may also depend on the experience of the surgeons. Since 2014, our clinic has utilized the U-VATS approach, which has been linked to superior perioperative results as compared to open surgery.

The difficulty of applying the single-port technique to mediastinal masses is observed in tumors larger than 5.0 cm in diameter. In these cases, an extended thymectomy may be required. A larger mass may impede the surgeon's vision, necessitating the opening of the mediastinal pleura. There is also a risk of vascular injury and compression and proximal vessel control are required to control bleeding.[21] In different cohorts, the rate of conversion to thoracotomy in VATS varies widely, from 1% to 43%.[22] In the present study, clinical and pathological mass sizes were consistent in patients who received U-VATS, and the mass size was less than 5 cm in the majority of patients. Despite the fact that several patients had masses larger than 5 cm, thoracoscopic surgery was effectively performed without the need for further port incisions or conversion to a thoracotomy/sternotomy. This suggests that single-port surgery is a safe and practical procedure for the removal of mediastinal masses.

This study also supports that maximal thymectomy can be performed safely with a single port incision in thymic pathologies. Thymoma was detected in 29% of patients with mediastinal masses, and the proportion of these patients did not differ significantly between surgical groups. In cases of early-stage thymoma, the survival rate with surgery alone is over 80% at a 10-year follow-up. The efficacy of postoperative prophylactic radiotherapy in patients with stage II disease has not yet reached consensus.[23] In the U-VATS group, 3 of 8 thymoma patients were Stage II or higher. Two of these patients received chemotherapy plus radiotherapy in the postoperative period, while the remaining patient received chemotherapy alone. Although surgical procedures and the presence of thymoma are important factors for myasthenic crises,[24] no postoperative myasthenic crises were detected in the present study.

The U-VATS approach has been linked to superior post-operative outcomes in the resection of mediastinal masses

when compared to open and traditional thoracoscopic surgeries.[8,9,25] Previous research indicates that U-VATS is associated with earlier removal of chest drainage, lower drainage volume, pain intensity, and length of hospital stay compared to open surgery.[10] Several comparative studies between U-VATS and multiportal VATS demonstrated that U-VATS was partially more effective at the duration of chest drainage removal and drainage volume. However, post-operative pain and hospital stay duration favored U-VATS.[26,27] Multiportal VATS may cause further injury to the intercostal nerves and more residual neurologic symptoms such as paresthesia and postoperative pain.[28] In the present study, in the post-operative period, patients returned to their daily activities on day 1, chest drainage was removed on day 4. Besides, they had less pain in the first four hours after surgery and were discharged earlier compared to open surgery. The intercostal nerves may be affected less by a small wound incision, resulting in less postoperative pain. However, pain, which is a subjective evaluation, can be affected by a number of factors, such as the length of the surgical procedure, the size of the drainage tube, and the postoperative analgesic regimens.[29]

Limitations

This study has several limitations. Firstly, the sample size was modest. Secondly, the superiority of U-VATS over multiportal VATS cannot be determined as this study evaluated only U-VATS among minimally invasive techniques. Thirdly, the long-term survival results of the patients could not be evaluated. A larger, randomized, controlled trial design that incorporates these factors could shed more light on the clinical significance of U-VATS.

CONCLUSION

The U-VATS approach had better intraoperative safety and lower postoperative out-comes than open surgery. U-VATS, which has the potential to enhance postoperative recovery and quality of life, may be a safe and effective treatment option for patients with mediastinal masses.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was performed in accordance with the Declaration of Helsinki, and was approved by the Erciyes University Faculty of Medicine Ethics Committee (Date: 12.2017, Decision No: 2017-548).

Informed Consent

A written informed consent form was obtained from all patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Aroor AR, Prakasha SR, Seshadri S, Teerthanath S, Raghuraj U. A study of clinical characteristicsof mediastinal mass. *J Clin Diagn Res.* 2014;8(2):77-80.
2. Bittman M. Mediastinal masses. *Probl Solving Pediatr Imaging.* 2021:33-52.
3. Taka M, Kobayashi S, Mizutomi K, et al. Diagnostic approach for mediastinal masses by imaging and histological analysis. *Eur J Radiol.* 2023;162:110767.
4. Li WW, van Boven WJ, Annema JT, Eberl S, Klomp HM, de Mol BA. Management of large mediastinal masses: surgical and anesthesiological considerations. *J Thorac Dis.* 2016;8(3):E175-E184.
5. Stremmel C, Passlick B. Surgery of mediastinal tumors. *Chirurg.* 2008;79(1):9-17.
6. Roviaro G, Rebuffat C, Varoli F, Vergani C, Maciocco M, Scalambra SM. Videothoracoscopic excision of mediastinal masses: indications and technique. *Ann Thorac Surg.* 1994;58(6):1679-1683.
7. Sihoe AD. The evolution of minimally invasive thoracic surgery: implications for the practice of uniportal thoracoscopic surgery. *J Thorac Dis.* 2014;6(Suppl 6):S604-S617.
8. Desai H, Natt B, Kim S, Bime C. Decreased in-hospital mortality after lobectomy using video-assisted thoracoscopic surgery compared with open thoracotomy. *Ann Am Thorac Soc.* 2017;14(2):262-266.
9. Yamashita SI, Tokuishi K, Moroga T, et al. Long-term survival of thoracoscopic surgery compared with open surgery for clinical N0 adenocarcinoma. *J Thorac Dis.* 2020;12(11):6523-6532.
10. Qian L, Chen X, Huang J, et al. A comparison of three approaches for the treatment of early-stage thymomas: robot-assisted thoracic surgery, video-assisted thoracic surgery, and median sternotomy. *J Thorac Dis.* 2017;9(7):1997-2005.
11. Gonzalez-Rivas D, Yang Y, Ng C. Advances in uniportal video-assisted thoracoscopic surgery: pushing the envelope. *Thorac Surg Clin.* 2016;26(2):187-201.
12. Pennathur A, Qureshi I, Schuchert MJ, et al. Comparison of surgical techniques for early-stage thymoma: feasibility of minimally invasive thymectomy and comparison with open resection. *J Thorac Cardiovasc Surg.* 2011;141(3):694-701.
13. Melfi FM, Fanucchi O, Mussi A. Minimally invasive mediastinal surgery. *Ann Cardiothorac Surg.* 2016;5(1):10-17.
14. Burt BM, Yao X, Shrager J, et al. Determinants of complete resection of thymoma by minimally invasive and open thymectomy: analysis of an international registry. *J Thorac Oncol.* 2017;12(1):129-136.
15. Yan Y, Huang Q, Han H, Zhang Y, Chen H. Uniportal versus multiportal video-assisted thoracoscopic anatomical resection for NSCLC: a meta-analysis. *J Cardiothorac Surg.* 2020;15(1):238.
16. Qin SL, Huang JB, Yang YL, Xian L. Uniportal versus three-port video-assisted thoracoscopic surgery for spontaneous pneumothorax: a meta-analysis. *J Thorac Dis.* 2015;7(12):2274-2287.
17. Zeng L, Wang W, Han J, Zhu L, Zhao J, Tu Z. Uniportal video-assisted thoracoscopic surgery and robot-assisted thoracoscopic surgery are feasible approaches with potential advantages in minimally invasive mediastinal lesions resection. *Gland Surg.* 2021;10(1):101-111.
18. Yang X, Li M, Yang X, et al. Uniport versus multiport video-assisted thoracoscopic surgery in the perioperative treatment of patients with T1-3N0M0 non-small cell lung cancer: a systematic review and meta-analysis. *J Thorac Dis.* 2018;10(4):2186-2195.
19. Wang BY, Liu CY, Hsu PK, Shih CS, Liu CC. Single-incision versus multiple-incision thoracoscopic lobectomy and segmentectomy: a propensity-matched analysis. *Ann Surg.* 2015;261(4):793-799.
20. Reinersman JM, Passera E, Rocco G. Overview of uniportal video-assisted thoracic surgery (VATS): past and present. *Ann Cardiothorac Surg.* 2016;5(2):112-117.
21. Wu CF, Gonzalez-Rivas D, Wen CT, et al. Single-port video-assisted thoracoscopic mediastinal tumour resection. *Interact Cardiovasc Thorac Surg.* 2015;21(5):644-649.
22. Power AD, Merritt RE, Abdel-Rasoul M, Moffatt-Bruce SD, D'Souza DM, Kneuertz PJ. Estimating the risk of conversion from video-assisted thoracoscopic lung surgery to thoracotomy-a systematic review and meta-analysis. *J Thorac Dis.* 2021;13(2):812-823.
23. Rico M, Flamarique S, Casares C, et al. GOECP/SEOR radiotherapy guidelines for thymic epithelial tumours. *World J Clin Oncol.* 2021; 12(4):195-216.
24. Juel VC. Myasthenia gravis: management of myasthenic crisis and perioperative care. *Semin Neurol.* 2004;24(1):75-81.
25. Li Q, Sihoe A, Wang H, et al. Short-term outcomes of single- versus multi-port video-assisted thoracic surgery in mediastinal diseases. *Eur J Cardiothorac Surg.* 2018;53(1):216-220.

26. Yang Z, Shen Z, Zhou Q, Huang Y. Single-incision versus multiport video-assisted thoracoscopic surgery in the treatment of lung cancer: a systematic review and meta-analysis. *Acta Chir Belg.* 2018;118(2):85-93.
27. Akter F, Routledge T, Toufektzian L, Attia R. In minor and major thoracic procedures is uniport superior to multiport video-assisted thoracoscopic surgery? *Interact Cardiovasc Thorac Surg.* 2015;20(4):550-555.
28. Jutley RS, Khalil MW, Rocco G. Uniportal vs standard three-port VATS technique for spontaneous pneumothorax: comparison of post-operative pain and residual paraesthesia. *Eur J Cardiothorac Surg.* 2005;28(1):43-46.
29. Wu CY, Heish MJ, Wu CF. Single port VATS mediastinal tumor resection: Taiwan experience. *Ann Cardiothorac Surg.* 2016;5(2):107-111.