

The Safety and Feasibility of Laryngeal Mask Airway (LMA) Management in Non-intubated Subxiphoid-subcostal Thoracoscopic Thymectomy: Preliminary Results

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Abstract

Intubated general anesthesia and single-lung ventilation are considered mandatory for conventional thoracoscopic surgery. Non-intubated thoracoscopic thymectomy is technically challenging. The aim of this article was to present the initial results of non-intubated subxiphoid-subcostal thoracoscopic thymectomy (NI-STT) under LMA management for patients with thymic tumor or myasthenia gravis (MG) and to investigate the feasibility and safety of the procedure. A retrospective analysis of patients undergoing NI-STT for thymic tumor or MG at our department from January 2017 to January 2020 was performed. The clinical characteristics and perioperative outcomes of the patients were reviewed and analyzed. A total of 61 patients were received NI-STT in this analysis, of which 19 patients with MG undergone an extended thymectomy and the rest (n=42) undergone a partial thymectomy. The anesthetic induction duration, surgical duration and global operating room duration were 24.83 ± 12.27 min, 118.75 ± 32.49 min and 173.51 ± 41.80 min, respectively. The lowest SpO₂ and peak EtCO₂ during operation were 96.15 ± 2.93 mmHg and 41.79 ± 7.53 mmHg, respectively. The mean duration of chest drainage and postoperative hospital stays were 1.87 days, and 2.91 days, respectively. Three cases had sore throat and irritable cough and two cases suffered nausea and vomiting occurred. one patient suffered from an atrial fibrillation, two patients experienced pneumonia, and one patient suffered wound infection, respectively. There were no phrenic nerve paralysis and mortality occurred in the study group. The postoperative pain was low on 1,3, 7, 14, 30, 90 and 180 postoperative days. NI-STT was a technically safe and feasible approach for treating thymic tumors or MG. It could be an alternative to intubated single-lung ventilation for thymectomy in selected patients.

Introduction

Thymectomy plays an important role in the management of thymic tumors and MG. Video-assisted thoracoscopic surgery (VATS) for thymectomy has been widely used in selected patients with the benefits of better cosmetic results, less trauma, fewer complications, shorter hospital stays and equivalent efficacy compared with conventional open thymectomy¹⁻². However, previously lateral approach VATS thymectomy still has drawbacks, such as poor visualization of neck region and contralateral phrenic nerve, intercostal nerve impairment leading to intercostal numbness and pain. Hence recently, subxiphoid approach VATS thymectomy has been successfully applied in clinical practice and favored by surgeons during the past decade. The major advantages of this modality are as follows: broader visual field of bilateral phrenic nerves and neck region, less pains, and better cosmetic results³⁻⁶.

Traditionally, double-lumen endotracheal intubation and endobronchial blocker for one-lung ventilation are considered as s mandatory and indispensable part for thoracoscopic surgery, including lateral approach VATS thymectomy. Nonetheless, complications and adverse effects after tracheal intubation and general anesthesia could not be neglected, such as barotraumas, vocal cords injury, sore throat, postoperative dysphagia, irritating cough and increased sputum and risk of pneumonia⁷⁻¹⁰. For the above disadvantages of intubated anesthesia, non-intubated spontaneous ventilation thoracoscopic surgery was established and adapted by thoracic surgeons with encouraging results. And now it has gradually

become another option for various thoracoscopic surgeries, such as bullectomy, wedge sections and lobectomy of lung, and mediastinal tumor resection [7-10]. However, as the diaphragm movement under non-intubated spontaneous ventilation anesthesia will interfere with the surgical instruments and further increase the difficulty of surgery, there are few reports of subxiphoid thoracoscopic thymectomy under non-intubation spontaneous ventilation anesthesia¹¹.

In view of this, we adopted a LMA for non-intubated anesthesia and mechanically controlled ventilation to avoid the side effects of tracheal intubation and extubation. In the present retrospective study, we reported our preliminary experiences of NI-STT with mechanically controlled ventilation under LMA management to evaluate its safety and feasibility.

Materials And Methods

Study Design and Patients

We performed the subxiphoid-subcostal approach thoracoscopic surgery since 2013 and non-intubation thoracoscopic surgery since 2015. Thereafter, we performed NI-STT under LMA management in some cases in 2016. After reviewing the patients' medical records and discussing the procedures with the patients, the surgeons and anesthesiologists selected patients who were considered for NI-STT. All operations were performed by the same surgical team and anesthesia team using the same clinical protocols, care patterns, and perioperative orders. A series of consecutive patients with anterior mediastinal tumors or MG were admitted and received NI-STT between January 2017 and January 2020 in our department. The data of these patients were retrospectively collected and analyzed through patient medical notes and computerized records. Informed consent about operative and anesthesia techniques and data use agreement were obtained from all patients prior to surgery. All methods were carried out in accordance with relevant guidelines and regulations. This retrospective descriptive study was reviewed and approved by the institutional review board (IRB) of Tongji Hospital. The primary outcome of present study was the feasibility and safety of NI-STT.

The inclusion criteria for NI-STT were: (I) Diagnosis of thymic tumors by using chest computed tomography or magnetic resonance imaging; (II) American Society of Anesthesiologists (ASA) classification \leq III. (III) Aged 18 to 65 years. Patients with obvious tumor invasion of surrounding organs, previous thoracic surgery, potential pleural adhesions, overweight (body mass index (BMI) >30 kg/m²), sleep apnea, deranged preoperative arterial blood gases analysis, impaired preoperative forced expiratory volume in 1 second (FEV₁) and forced vital capacity (FVC), a heart failure, bleeding disorder or unfavorable features of airway, chest wall or spine were excluded. The patients combined with MG were discussed with neuroscientists through a multidisciplinary committee and treated with pyridostigmine or prednisone, for the purpose of determining the indications for surgery, and more importantly, determining the appropriate timing of surgery based on the stability of MG symptoms to reduce the risk of postoperative myasthenia crisis.

Anesthetic setting, induction, and maintenance

The anesthesia techniques for non-intubated VATS were described previously⁷⁻¹¹. All patients fasted for at least 8 hours before surgery. The pulse oxygen saturation (SpO₂), electrocardiogram (ECG), noninvasive arterial blood pressure, bispectral index (BIS) and end-tidal carbon dioxide (EtCO₂) were routinely monitored. Fiberoptic bronchoscope and endotracheal intubation equipment should be provided before anesthesia, and tracheal intubation could be performed immediately if necessary. The operation and positioning of the disposable Supreme™ laryngeal mask airway (SLMA) were performed by experienced and professional anesthesiologists. The correct position of LMA was judged by lung and neck auscultation, airway pressure waveform, the capnography waveform, and fiberoptic bronchoscope. If LMA was not in the correct position, it should be removed and reinserted.

Anesthesia was induced by intravenous injection of sufentanil (0.5ug/kg), propofol (1.5-2.0mg/kg), and rocuronium (1mg/kg) and intravenous dexmedetomidine (0.5-1ug/kg) using a target-controlled infusion (TCI) method. When the patients' consciousness disappeared, the prelubricated LMA was inserted for volume-control ventilation (8ml/kg/min) with 100% inspired oxygen to keep SpO₂ above 95%. The maintenance of anesthesia was done with intravenous TCI of propofol (5mg/kg/h), dexmedetomidine (0.5–1µg/kg/h) and remifentanyl (0.1–0.2µg/kg/min) and sevoflurane inhalation (1-1.5%). BIS was maintained between 40 and 60 (about D–E stage). The frequency of mechanical ventilation was 12 to 20 times/min. Rocuronium (0.2mg/kg) was added every 40 minutes depending on the progress of surgery. Intercostal nerve block (at surgical incision and one intercostal space above and below the surgical incision) and rectus abdominis sheath block were performed with 0.4% ropivacaine.

Surgical technique

Following the induction and maintenance of general anesthesia and mechanically controlled ventilation with LMA, all patients underwent subxiphoid thoracoscopic thymectomy, which was similar to that reported previously¹². Patients were placed in a supine position with legs spread out and shoulders raised by a cushion. During the operation, the surgeon stood between the patient's legs, while the assistant was on the right side and operated the camera. The nurse stood on the left side of the patients and the monitor was placed at the cranial side. A 3.0-cm longitudinal skin incision was made first to expose the xiphoid and serve as observation hole. The retrosternal space was created and enlarged by blunt dissection with oval forceps or fingers. Under the guidance of fingers, two 0.5-cm subcostal holes were created at the midclavicular lines under bilateral costal arches and served as operation holes. Thereafter, a 10 mm, 30-degree angled thoracoscope was placed into the retrosternal space through the observation hole. Artificial pneumothorax was created by carbon dioxide (CO₂) insufflation under a positive pressure of 8cm-H₂O, which could expand the retrosternal space and ensure a sufficient surgical field. The procedure for patients without MG was a partial thymectomy, which was defined as complete removal of the entire thymic gland along with the surrounding adipose tissues. While the surgery for patients

combined with MG was an extended thymectomy, which was defined as removal of entire thymus and adipose tissues from mediastinal, pericardiophrenic, aorta-pulmonary window and cervical area. The bilateral mediastinal pleurae were firstly dissected with an ultrasonic scalpel to expose the bilateral phrenic nerves. Along the front of the bilateral phrenic nerves to the neck, the lateral margin of thymus and its surrounding fat and adipose tissues at bilateral cardiophrenic angle were dissected. Great attention should be taken to the protection of bilateral phrenic nerves during the operation. The posterior border of the thymus was meticulously separated from the anterior edge of the pericardium to confirm the superior vena cava and bilateral innominate veins. The thymic veins were identified prior to draining into the innominate vein and meticulously sealed using an ultrasonic scalpel. By gently grasping the thymus, the bilateral superior poles of thymus were conveniently dissected by using an ultrasonic scalpel. Finally, the whole thymus and the surrounding adipose tissues excised en-bloc from pericardium, cardiac diaphragmatic angle, innominate veins, brachiocephalic artery, trachea, and cervical area were placed in a plastic bag and removed from the subxiphoid incision (*Figure 1*). A 20-Fr chest drainage tube was inserted into the mediastinum through subxiphoid incision the after the surgical field was evaluated. The bilateral subcostal incisions were sutured. The LMA was removed immediately after operation.

Postoperative management and data collection

Dynamic monitoring of ECG and SpO₂ were performed in the early postoperative period. For patients with MG, the same medications used preoperatively were restarted postoperatively under the guidance of the neurologists. Chest radiography was performed at the first day postoperatively and after the extubation of chest drainage tube. Blood detection was performed on the first and third postoperative days. Early removal of pleural drainage tube was encouraged postoperatively, if total drainage was less than 200 mL/day with no air leakage and chest X-ray chest radiographies and vital signs were normal. All patients were discharged without a pleural drainage tube. In general, no postoperative analgesics were used. Unless the pains were intolerable, low-dose diclofenac sodium could be used. The visual analog scale (VAS) was used to evaluated the pain on 1, 3, 7, 14, 30, 90, and 180 postoperative days (POD). The demographic data, duration of hospital stay and chest drainage, operative and anesthetic results, side effects and complications were obtained from the institutional database, anesthesia and surgical notes, and the medical and nursing records.

Statistical analysis

All data analyses were conducted using SPSS version 22.0 (IBM SPSS Statistics, Chicago, USA). If the continuous variables had a normal distribution, it would be represented as mean \pm standard deviation, otherwise it should be described as the median and range. Categorical variables were expressed as count and proportion.

Results

A total of 61 patients between January 2017 and January 2020 were received NI-STT under LMA management in this analysis, of which 19 patients with MG undergone an extended thymectomy and the rest (n=42) undergone a partial thymectomy. The demographic and clinical characteristics of the patient's cohort were summarized in Table 1. There were 33 males and 28 females in this study, with a mean age of 48.25 years and a mean BMI of 22.74 kg/m². 6 patients had a history of smoking. The pulmonary function of the patients was generally normal, with a mean FVC of 107.92% predicted and FEV₁ of 105.49% predicted. At the time of the surgery, the ASA classification was I in 22 patients, II in 30 patients, and III in 9 patients. Preoperatively, 10 patients were in stage I, 7 in stage II and 2 in stage III according to the Myasthenia Gravis Foundation of America (MGFA) classification, and all 19 patients with MG received anticholinesterase or prednisone therapy to ensure perioperative safety under the guidance of experienced neurologists. The pathology of the tumors was thymoma in 21 patients, thymic hyperplasia in 25 patients, thymic cyst in 13 patient, and thymus atrophy in 2 patients, with a mean diameter of the resected tumor of 3.41cm. According to the Masaoka-Koga stage classification, there were 12 patients with stage I (19.7%), and 9 patients with stage II (14.8%). The World Health Organization (WHO) histology was type A in 3 patients (4.9%), AB in 8 patients (13.1%), B1 in 6 patients (9.8%), B2 in 3 patients (4.9%), and B3 in 1 patient (1.6%).

Table 1
Demographic and clinical characteristics

Variable	NI-STT(n = 61)
Age(years)	48.25 ± 13.72
Sex, n (%)	33(54.1%)
Male	28(45.9%)
Female	
BMI (kg/m ²)	22.74±3.51
Smokers, n (%)	6(9.8%)
Pulmonary function test (% of prediction)	107.92±16.52
FVC	105.49±14.81
FEV ₁	
ASA classification, n (%)	22(36.0%)
I	30(49.2%)
II	9(14.8%)
III	
Comorbidity, n (%)	3(4.9%)
Diabetes mellitus	7(11.5%)
Cardiovascular diseases	19(31.1%)
MG	2(3.3%)
Others	
MGFA clinical classification, n (%)	10(16.4%)
I	7(11.5%)
II	2(3.3%)
III	
Diameter (cm)	3.41±2.19

BMI: body mass index; ASA: American Society of Anesthesiologists; MG: myasthenia gravis; MGFA: the Myasthenia Gravis Foundation of America; WHO: World Health Organization;

Variable	NI-STT(n = 61)
Extent of thymectomy, n (%)	42(68.9%)
Partial	19(31.1%)
Extended	
Pathology, n (%)	21(34.4%)
Thymoma	25(41.0%)
Thymic hyperplasia	13(21.3%)
Thymic cyst	2(3.3%)
Thymus atrophy	
WHO classification of thymomas, n (%)	3(4.9%)
A	8(13.1%)
AB	6(9.8%)
B1	3(4.9%)
B2	1(1.6%)
B3	
Masaoka stage of thymomas, n (%)	12(19.7%)
I	9(14.8%)
II	
BMI: body mass index; ASA: American Society of Anesthesiologists; MG: myasthenia gravis; MGFA: the Myasthenia Gravis Foundation of America; WHO: World Health Organization;	

The anesthetic induction duration, surgical duration and global operating room duration were 24.83±12.27 min, 118.75±32.49 min and 173.51±41.80 min, respectively. The lowest SpO₂ and peak EtCO₂ during operation were 96.15±2.93 mmHg and 41.79±7.53 mmHg, respectively. There was one patient converted to double-lumen tracheal intubation because of hypercapnia and one patient converted to a median sternotomy due to the dense adhesion of mediastinum. Table 2 showed that the mean intraoperative blood loss was 46.37ml.

Table 2
Surgical and anesthesia results

Variable	NI-STT(n = 61)
Anesthetic induction duration (min)	24.83±12.27
Surgical duration (min)	118.75±32.49
Global operating room duration (min)	173.51±41.80
Lowest SpO ₂ during operation (mmHg)	96.15±2.93
Peak EtCO ₂ during operation (mmHg)	41.79±7.53
Conversion to intubation, n (%)	1(1.6%)
Blood loss (ml)	46.37±21.41
Conversion to thoracotomy, n (%)	1(1.6%)
SpO ₂ : pulse oxygen saturation; EtCO ₂ : end-tidal carbon dioxide;	

The LMA was removed immediately after operation in all patients. The mean duration of chest drainage was 1.87 days, and mean postoperative hospital stays was 2.91 days. The hospitalization expenses were 5.03±0.95 thousand US dollars (USD). Side effects of anesthesia occurred in three cases of sore throat and irritable cough and two cases of nausea and vomiting. One patient suffered from an atrial fibrillation and received treatment of amiodarone. Two patients experienced pneumonia, and one patient suffered wound infection. All the patients recovered well when discharged. There were no phrenic nerve paralysis and mortality occurred in the study group. Table 3 showed that the postoperative pain (VAS score) was low on POD 1,3, 7, 14, 30, 90 and 180. No tumor recurrence or metastasis was found during follow-up.

Table 3
Postoperative outcomes

Variable	NI-STT(n = 61)
Duration of chest drainage (days)	1.87±0.65
Postoperative hospital stays (days)	2.91±0.73
Hospitalization expenses, (thousand USD)	5.03±0.95
Anesthetic side effects	3(4.9%)
Sore throat and irritable cough	2(3.3%)
Nausea and vomiting	
Complications, n (%)	1(1.6%)
Atrial fibrillation	2(3.3%)
Pneumonia	1(1.6%)
Wound infection	0
Phrenic nerve paralysis	0
Mortality	58(93.5%)
Free of complications	
Pain [VAS score, 0-10]	4.51±0.85
POD 1	2.61±0.77
POD 3	1.06±0.42
POD 7	0.62±0.32
POD 14	0.40±0.21
POD 30	0.22±0.15
POD 90	0.16±0.10
POD 180	
USD: United States Dollars; VAS: visual analog scale; POD: postoperative days;	

Discussion

With a combination of subxiphoid-subcostal access and non-intubated anesthesia with mechanically controlled ventilation under LMA management, our study showed that NI-STT was safe and feasible and resulted in excellent perioperative outcomes and short hospital stays. Thoracoscopic surgery without

endotracheal intubation avoids intubation-related complications, leading to relief of symptoms, a lower rate of complications and a fast recovery.

Over the past several decades, various surgical techniques have been advocated for thymectomy in treating anterior mediastinal tumors and MG. Although trans-sternal surgery remains the gold standard of thymectomy, with the improvements of thoracoscopic instruments and techniques, VATS surgery has been an alternative to thymectomy¹⁻². There are different approaches to VATS thymectomy, which includes the unilateral, bilateral, transcervical, robotic, subxiphoid or combination approach, and the main choice is the lateral approach^{13,14}. Although there were efforts to reach a consensus regarding the standard VATS thymectomy, but no consensus has been available now¹⁴. The choice of surgical approach is usually based on the experience and preference of the surgeon. However, the lateral VATS approach is associated with difficulties in identifying the contralateral phrenic nerve, narrow operative field in neck region and persistent intercostal nerve paralysis or neuralgia¹⁵. Hence, in recent years, Hsu et al.¹⁶ and Suda et al.^{4,5,15} previously reported a thoracoscopic thymectomy via the subxiphoid approach without any intercostal incision, which has several advantages^{4,5,12,15,16}. First, the excellent surgical field from subxiphoid approach is similar to the view of median sternotomy and helps confirm the superior poles of thymus and bilateral phrenic nerves. The adequate visualization allows the maximum resection of thymus and surrounding fat tissues, reducing the chance of accidental blood vessels or phrenic nerve injury. Second, with the help of artificial pneumothorax created by CO₂ insufflation instead of lifting of the sternum, the mediastinum is compressed and the bilaterally ventilated lungs are shifted away, greatly providing the operative vision and allowing for safer dissection. In our experience, low pressure CO₂ insufflation into the mediastinum does not cause the changes in hemodynamic status of the patients. In addition, subxiphoid approach thymectomy does not cause intercostal nerve injury by avoiding any intercostal incision. Therefore, the postoperative pain was significantly relieved, and there was no abnormal chest wall paresthesia in the study. Less pains mean less usage of analgesics. Also, there is no visible scar in the neck and upper chest area, which is also a clear cosmetic advantage. Furtherly, in our experiences, subxiphoid VATS thymectomy has short drainage duration, postoperative hospital stays and low hospitalization expenses, comparable to other studies^{15,17}.

Double-lumen intubation and single-lung ventilation general anesthesia technique were needed for conventional thoracoscopic surgery, which met the need of intraoperative lung ventilation and provided the surgeon with a broad surgical field. However, many complications are caused by intubation and extubation procedures, such as airway trauma, residual neuromuscular blockade, and ventilator-induced lung injury. To overcome the complications associated with endotracheal intubation, non-intubated VATS was recently described in selected patients with thoracic disease, including pulmonary and mediastinal diseases, and even minimally invasive esophagectomy and pleural empyema^{7-11,18-22}. Non-intubated anesthesia may avoid the potential complications that the intubation may result in, and may be helpful to judge the reason of postoperative irritable cough, sore throat, and hoarseness. One major concern about using the non-intubated anesthesia for VATS thymectomy was how respiratory function is maintained in a patient with an artificial pneumothorax under the management of LMA. To prevent respiratory failure,

we selected patients with good cardiopulmonary function for this study. Only one patient developed persistent hypoxia and was converted to intubated general anesthesia finally. In most of the non-intubated patients, SpO₂ was satisfactorily maintained above 90% during the whole operation. Nonetheless, patients with poor cardiopulmonary function should be carefully examined and selected before attempting this procedure.

The other major concern is whether it is feasible and safe to perform a surgical procedure during non-intubated thoracoscopic thymectomy. Dissection of blood vessels, and bilateral phrenic nerves are more technically demanding because of the diaphragmatic movement during spontaneous breathing, especially when the respiratory rate was more than 20 breaths per minute. The surgeons must adjust the instruments according to the rhythm of the breathing and diaphragm movement to make a precise dissection, just like beating heart coronary bypass surgery. We performed the NI-STT since 2016. In our experiences, the diaphragmatic movement during spontaneous breathing would interfere with the surgical procedures, resulting in an increase in the difficulty of the operation and a prolonged learning curve. Therefore, in our patient cohort, we tried to perform NI-STT without spontaneous breathing under LMA management. The use of muscle relaxants inhibited the movement of diaphragm and spontaneous breathing, so that it did not interfere with surgical procedures. Besides, additional intrathoracic vagal blockade was not required to abolish the cough reflex by using the muscle relaxants during non-intubated thymectomy in our study group²². Finally, epidural anesthesia or paravertebral block was used traditionally for non-intubated spontaneous ventilation anesthesia, however, it may lead to side effects such as hypotension, bradycardia, urinary retention, epidural hematoma, or infection. In this present study, Intercostal nerve block and rectus abdominis sheath block were performed with 0.4% ropivacaine instead of epidural anesthesia or paravertebral block. And the results revealed that postoperative pain was mild in almost all cases, indicating that local anesthesia was also feasible and effective in this procedure.

However, the NI-STT also has disadvantages. Even with the presence of artificial pneumothorax, an excessively high BMI would lead to a narrow surgical field and further make surgery difficult. In addition, for patients with tumors invading surrounding organs or large vessels, this method may be not suitable, and open surgery should be recommended. In addition, we acknowledged that the present study was limited by its single-center retrospective nature and a small number of patients, and thus, intrinsic bias may exist. Besides, the lack of a control group who received endotracheal intubated anesthesia makes it difficult to confirm the specific benefits of NI-STT. However, the low conversion rate of non-intubated to intubated anesthesia and low complication incidence indicate that NI-STT could be safely performed in selected patients. Further research is encouraged to clarify the applicability and benefits of NI-STT for specific patient groups.

Conclusion

In summary, the present study showed that NI-STT under LMA management was technically feasible and clinically safe for treatment of anterior mediastinal tumors and MG. NI-STT avoided complications

related to endotracheal intubation and intercostal incision, leading to relief of symptoms, lower complication rate, and faster recovery. Although true benefits of NI-STT should be further verified in larger prospective randomized controlled studies, it could be an attractive alternative in selected patients with thymic tumor or MG.

List Of Acronyms

LMA	laryngeal mask airway
NI-STT	non-intubated subxiphoid-subcostal thoracoscopic thymectomy
MG	myasthenia gravis
VATS	video-assisted thoracoscopic surgery
IRB	institutional review board
ASA	American Society of Anesthesiologists
BMI	body mass index
FEV ₁	forced expiratory volume in 1 second
FVC	forced vital capacity
SpO ₂	pulse oxygen saturation
ECG	electrocardiogram
EtCO ₂	end-tidal carbon dioxide
BIS	bispectral index
TCI	target-controlled infusion
VAS	visual analog scale
POD	postoperative days
MGFA	the Myasthenia Gravis Foundation of America
USD	the United States dollars
WHO	World Health Organization

Declarations

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none.

Author contributions:

P.C., F.L., and B.Z. contributed to the study conception and design. Material or patients preparation, data collection and analysis were performed by P.C., S.H., Q.X., W.Q., K.K., P.H., J.Y., Z.Y., Y.D., and Z.Y. P.C., F.L. and B.Z. wrote the original manuscript. All authors supervised the procedures and revised the manuscript. All authors approved the final manuscript.

Founding:

none.

Competing interests:

The authors declare no competing interests.

References

1. Maniscalco P. et al. Long-term outcome for early stage thymoma: comparison between thoracoscopic and open approaches. *Thorac Cardiovasc Surg.* 63(3):201-205 (2015).
2. Friedant AJ, Handorf EA, Su S & Scott WJ. Minimally invasive versus open thymectomy for thymic malignancies: systematic review and meta-analysis. *J Thorac Oncol.* 11: 30–8 (2016).
3. Kang CH. et al. The robotic thymectomy via the subxiphoid approach: technique and early outcomes. *Eur J Cardiothorac Surg.* 58(Suppl_1): i39-i43 (2020).
4. Suda T. Single-port thymectomy using a subxiphoid approach-surgical technique. *Ann Cardiothorac Surg.* 5(1):56-58 (2016).
5. Suda T. et al. Early outcomes in 147 consecutive cases of subxiphoid single-port thymectomy and evaluation of learning curves. *Eur J Cardiothorac Surg.* 58(Suppl_1): i44-i49 (2020).
6. Li J, Qi G, Liu Y, Zheng X & Zhang X. Meta-analysis of subxiphoid approach versus lateral approach for thoracoscopic Thymectomy. *J Cardiothorac Surg.* 15(1):89 (2020).
7. Pompeo E, Mineo D, Rogliani P, Sabato AF & Mineo TC. Feasibility and results of awake thoracoscopic resection of solitary pulmonary nodules. *Ann Thorac Surg.* 78(5):1761-8 (2004).
8. Kiss G & Castillo M. Nonintubated anesthesia in thoracic surgery: general issues. *Ann Transl Med.* 3(8):110 (2015).
9. Jiang L. et al. Spontaneous ventilation thoracoscopic thymectomy without muscle relaxant for myasthenia gravis: Comparison with "standard" thoracoscopic thymectomy. *J Thorac Cardiovasc Surg.* 155(4):1882-1889.e3 (2018).
10. Wen Y. et al. Non-intubated spontaneous ventilation in video-assisted thoracoscopic surgery: a meta-analysis. *Eur J Cardiothorac Surg.* 57(3):428-437 (2020).

11. Liu Z, Yang R & Sun Y. Non-intubated subxiphoid uniportal video-assisted thoracoscopic thymectomy. *Interact Cardiovasc Thorac Surg.* 29(5):742-745 (2019).
12. Chen X, Ma Q, Wang X, Wang A & Huang D. Subxiphoid and subcostal thoracoscopic surgical approach for thymectomy. *Surg Endosc.* 35(9):5239-5246 (2021).
13. Mineo TC & Ambrogi V. Surgical Techniques for myasthenia gravis: video-assisted thoracic Surgery. *Thorac Surg Clin.* 29(2):165-175 (2019).
14. Zieliński M. Definitions and standard indications of minimally-invasive techniques in thymic surgery. *J Vis Surg.* 3:99 (2017).
15. Suda T. et al. Video-assisted thoracoscopic thymectomy versus subxiphoid single-port thymectomy: initial results†. *Eur J Cardiothorac Surg.* 49 Suppl 1: i54-i58 (2016).
16. Hsu CP, Chuang CY, Hsu NY & Chen CY. Comparison between the right side and subxiphoid bilateral approaches in performing video-assisted thoracoscopic extended thymectomy for myasthenia gravis. *Surg Endosc.* 18(5):821-824 (2004).
17. Yano M. et al. The Subxiphoid Approach Leads to Less Invasive Thoracoscopic Thymectomy Than the Lateral Approach. *World J Surg.* 41(3):763-770 (2017).
18. Hung WT. et al. Nonintubated Thoracoscopic Surgery for Lung Tumor: Seven Years' Experience With 1,025 Patients. *Ann Thorac Surg.* 107(6):1607-1612 (2019).
19. Liang H. et al. Nonintubated Spontaneous Ventilation Offers Better Short-term Outcome for Mediastinal Tumor Surgery. *Ann Thorac Surg.* 108(4):1045-1051 (2019).
20. Zhang RX. et al. Is laryngeal mask airway general anesthesia feasible for minimally invasive esophagectomy? *J Thorac Dis.* 10(3): E210-E213 (2018).
21. Migliore M. Nonintubated Uniportal Video-Assisted Thoracic Surgery for Chest Infections. *Thorac Surg Clin.* 30(1):33-39 (2020).
22. Chen JS. et al. Nonintubated thoracoscopic lobectomy for lung cancer. *Ann Surg* 254(6):1038-43 (2011).

Figures

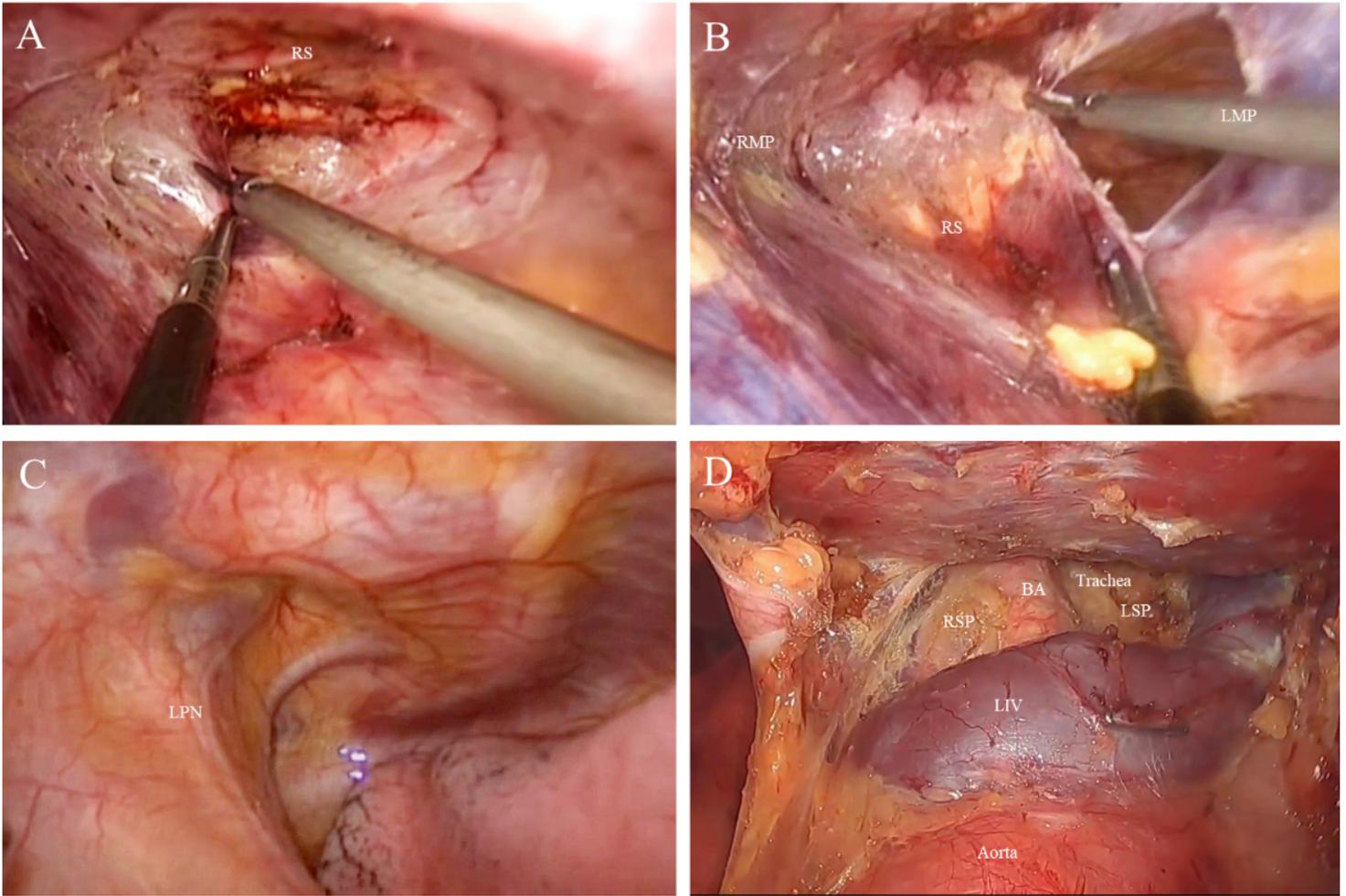


Figure 1

(A) Retrosternal space was created and enlarged by blunt dissection; (B) Bilateral mediastinal pleurae were cut with an ultrasonic scalpel; (C) Left phrenic nerve was exposed; (D) A view of the cervical region after division of the superior horns of the thymus. abbreviation: RS, retrosternal space; RMP, right mediastinal pleura; LMP, left mediastinal pleura; LPN, left phrenic nerve; RSP, right superior pole of thymus; LSP, left superior pole of thymus; LIV, left innominate vein; BA, brachiocephalic artery;