Review Article

Literature review: non-intubated (tubeless) VATS for lung volume reduction surgery

Yi Zhang, Xin Jin

Thoracic Surgery Department, Xuanwu Hospital, Capital Medical University, Beijing, China

Contributions: (I) Conception and design: Both authors; (II) Administrative support: Y Zhang; (III) Provision of study materials or patients: Both authors; (IV) Collection and assembly of data: X Jin; (V) Data analysis and interpretation: X Jin; (VI) Manuscript writing: Both authors; (VII) Final approval of manuscript: Both authors.

Correspondence to: Yi Zhang. Thoracic Surgery Department, Xuanwu Hospital, Capital Medical University, No. 45 Changchun St., Beijing 100053, China. Email: zhangyi@xwhosp.org.

Objective: To describe the reproducible surgical and anesthesia techniques of lung volume reduction surgery (LVRS) under non-intubation. In addition, the advantages of modified non-intubated unilateral LVRS are also introduced in this article.

Background: The perioperative complications and unsatisfied mortality of the typical LVRS under general anesthesia hinder the popularity of the surgery. In recent years, the concept of non-intubation has been introduced to LVRS. However, the reports and researches in this field are not so common.

Methods: We searched current literature related to LVRS and non-intubated LVRS of recent 20 years in PubMed and compared different resection ranges and methods of LVRS under non-intubation.

Conclusions: Our group reviewed the current papers in this field and found that the poor lung quality (and cardiac function in some cases) of the target patient is not the absolute contradiction to adopting the non-intubation anesthesia technique in LVRS. On the contrary, the non-intubated LVRS may be even safer and bring more benefits than the traditional operation method among selected patients. Furthermore, the modified non-intubated unilateral LVRS can reduce perioperative complications by comparing to the traditional bilateral LVRS. The LVRS on the opposite side is unnecessary if no significant progression is found by regular follow-up. In summary, the surgical team can make an attempt to non-intubation in LVRS after thorough evaluation.

Keywords: Lung volume reduction surgery (LVRS); non-intubated anesthesia; video-assisted thoracoscopic surgery (VATS)

Received: 21 March 2021; Accepted: 22 June 2021; Published: 15 September 2021.
doi: 10.21037/vats-21-23
View this article at: https://dx.doi.org/10.21037/vats-21-23

The non-intubated video-assisted thoracoscopic surgery (NI-VATS) is developed from traditional video-assisted thoracoscopic surgery (VATS). In NI-VATS, deep anesthesia is avoided, and a face or laryngeal is used instead of ordinary tracheal intubation. Patients usually have fewer complaints of postoperative discomfort and recover faster by this method. Since the first report of NI-VATS wedge resection, surgical teams from all over the world have enlarged the range of non-intubation to almost all kinds of VATS treatments, such as mediastinal tumor resection (1), carinal reconstruction (2), and lobectomy (3).

Lung volume reduction surgery (LVRS) is taken as an interventional therapy for severe emphysema caused by chronic obstructive pulmonary disease (COPD), smoking, or other factors. In LVRS, the damaged emphysematous upper lobe tissue is resected, in which the expiratory airway collapses, gas traps severely, and the alveolus is over-inflated. Then the remaining lung expands, and the patient's symptoms like shortness of breath or dyspnea may improve (4,5).

Dr. Brantigan conducted the first reported case of the open surgical approach LVRS at the University of Maryland in the 1950s, though with a high mortality rate of 18% (6,7). Then in 1995, Dr. Cooper in St. Louis improved upon Dr. Brantigan's method by using modern surgical developments, resulting in decreased mortality and morbidity rates (8). In 1997, Dr. McKenna proved the safety of thoracoscopic LVRS (9). Since then, the LVRS officially stepped into the era of minimally invasive thoracic surgery.

In 2006, Dr. Mineo and Dr. Pompeo conducted a pilot study using 12 patients with awake nonresectional LVRS, the first attempt to conduct LVRS under NI-VATS. Comparing with normal resectional LVRS under mechanical ventilation, their study resulted in a shorter operating room time and non-prolonged hospital stay (90±17 *vs.* 145±19 mins, P<0.01 and 7.8±5 *vs.* 11.7±4 d, P=0.02, respectively), which supported the feasibility and safety of NI-VATS LVRS (10). In the following years, Dr. Pompeo's team enlarged the sample size and further researched NI-VATS for LVRS. They found fewer surgery/anesthesia-related traumas and faster postoperative recovery in the NI-VATS group, suggesting that NI-VATS LVRS could be a potentially better choice than the ordinary LVRS for strictly selected patients (11-13).

We present the following article in accordance with the Narrative Review reporting checklist (available at https://dx.doi.org/10.21037/vats-21-23).

Patient selection

As mentioned above, the mortality of ordinary LVRS is not satisfactory. One of the reasons is the limited respiratory reservoir and impaired cardiac function in this patient group. Improper application of non-intubated anesthesia may aggravate the symptoms and cause severe complications during the surgery so that the patient's section should be more cautious. Those patients whose forced expiratory volume in 1 second (FEV1) ≤20% predicted, with severe chronic bronchitis and massive airway secretion, with either homogeneous emphysema or diffusing capacity for carbon monoxide (DLCO) ≤20% predicted are considered non-eligible for the surgery as a mortality rate of 16% following ordinary LVRS (14). Other general contraindications include unstable circulation, acute cardio-cerebrovascular accident, coagulation disorders, computed tomography (CT)-confirmed obliterated pleural cavity, and difficulty in applying thoracic epidural anesthesia (TEA), etc. (15-17).

On the other hand, if a patient fits for the LVRS indication such as extreme dyspnea, limited exercise capacity failing to recover from maximized medical therapy, and respiratory rehabilitation caused by emphysema and at a moderate and stable stage, NI-VATS LVRS should be considered for its potential benefits in the fewer intraoperative risks and faster postoperative recovery. Pulmonary function examination shows FEV1 <50% and residual volume (RV) >150%. The 6-minute walking test distance (6MWT, should >200 m) is also suggested to assess the activity capacity and reserve function. Blood gas analysis results in a carbon dioxide tension ($PaCO_2$) <55–60 mmHg and arterial oxygen tension (PaO_2) >45 mmHg on room air. A high-resolution computed tomography (HRCT) must be appointed to identify the pattern of emphysema because only patients with heterogeneous and severe emphysema, especially in the upper lobe, will benefit most from the surgical treatment (18).

Complete quitting smoking for at least >12 weeks is compulsory to reduce the risk of postoperative pulmonary complications (19).

Other general requirements for NI-VATS include being between 18 to 80 in age, having a body mass index (BMI) of less than 25, having an American Society of Anesthesiologists status ≤3, having had no thoracic surgery history on the operating side, and having no severe disease of the critical organs such as heart, brain, liver, kidney, etc. (1,20).

Human factors such as the skill level of the surgeons and anesthetists at operation should also be taken into account. Patients should also be made aware of the innovation and accept potential risks during the surgery.

Anesthesia technique

The core of NI-VATS LVRS is non-intubation. To achieve this, muscle relaxants are not used, and spontaneous respiration is maintained at a rate of 12–20/min. Venturi face mask or laryngeal mask is applied with supplementary oxygen (2–10 L/min) to maintain oxygen saturation (SpO_2) above 90% during the entire surgery procedure.

Midazolam (0.06 mg/kg) and atropine (0.01 mg/kg) are injected intramuscularly 30 min before anesthesia (21). Patients can stay fully awake for those planning to receive nonresectional LVRS and be carried out with TEA. If so, place the epidural catheter into T4–T5 space. Infuse the space with ropivacaine 0.5% and sufentanil 1.66 μg/mL continuously to block the somatosensory and motor between T1–T8 level. When the surgery is near completion, change the anesthetic regimen with ropivacaine 0.16% and

sufentanil 1 μg/mL at 2–5 mL/h (10).

If the patient is to receive a resectional LVRS or cannot cooperate in an awake status, intravenous anesthesia can be induced with target-controlled infusion (TCI) of propofol (target plasma concentration of 2–3 μg/mL) and sufentanil 0.1–0.2 μg/kg under routine monitoring of electrocardiography, heart rate, blood pressure, SpO_2, end-tidal carbon dioxide ($EtCO_2$), bispectral index (BIS) (maintained at 40–60), etc. During the surgery, maintain the anesthesia with TCI of propofol (target plasma concentration of 1–2 μg/mL) and dexmedetomidine 0.5–1 μg/kg/h combined with TEA (21).

We strongly suggest that surgeons and anesthetists comprehensively evaluate and discuss the ventilation method before surgery. To do no harm to patients is the first and most important principle when applying surgical innovations. The complexity of NI-VATS is not necessarily related to feasibility as long as thoroughly evaluated. However, a backup plan of re-intubation should be prepared in advance and deployed immediately when severe complications occur, such as uncontrollable bleeding, significant mediastinal movement, and persistent hypoxemia or carbon dioxide retention (3). Intraoperative switch from non-intubation to general anesthesia is conducted with the aid of a video laryngoscope to facilitate tracheal intubation and a fiberoptic bronchoscope to place the double-lumen tube at a correct position for single-lung ventilation (11).

Cough reflex irritated by instrument stimulation or manipulation could be inhibited with lidocaine (6 mL, 2%) spray on the lung surface or levobupivacaine (2 mL, 0.25%) intrathoracic/paravertebral vagal blocks (3,21). A combined block of the vagus and phrenic nerves under ultrasound control at the neck level is also recommended (22,23). Incisions are sutured after a local anesthetic of 0.2% ropivacaine to reduce postoperative discomfort.

Surgical procedure

NI-VATS LVRS does not have much difference from ordinary LVRS. The patient is placed in a full lateral decubitus position. All kinds of approaches (like 4-flexible trocar access, three-port access, and uniport access) are feasible during the operating. Tenderly establish the surgical pneumothorax and obtain a well-exposed surgical space while monitoring the change of vital signs (24). The surgery aims to reduce 20–30% overall lung volume. Insert the 30° camera, explore the lung with instruments, and identify the most severely emphysematous lung tissue. Carefully remove the pathological tissue with staplers and avoid stretching the hilum to reduce the cough reflex. Chest drainages are inserted at the end of surgery (25,26).

For selected patients who can stay awake and cooperate with instruction during surgery, the awake nonresectional LVRS should be considered because it accelerates postoperative recovery and improves prognosis (11,27). Grasp the redundant lung margin with forceps and introflex the target area with a cotton swab. Then use one forceps to grasp both lung margins together and apply a 45-mm, 3.5-mm cartridge, no-knife stapler on the plicated region starting at the apex of the upper lobe. Repeat the procedure twice on the ventral and dorsal sides of the target area to perform a linear interrupted suture line. With this method, 50% of the upper lobe is reduced without cutting. Besides, the lung reexpansion force is dispersed on the plicated visceral pleural instead of impacting the suture line directly, which avoids the tear of fragile lung tissue, resulting in a shortened air leak and decreased morbidity (10-12,27).

With those receiving ordinary intubated LVRS, the patients usually have to fast and stay in the intensive care unit for at least 24 hours postoperatively. However, the patients receiving awake nonresectional LVRS can be transferred to the post anesthesia care unit (PACU) for short monitoring or to the ward directly and resume a regular diet. The chest drainage can be removed if there is no massive pleural effusion, air leak, or other abnormality on the X-ray or CT, the duration of which is often shorter than ordinary LVRS patients. In addition, a more noticeable improvement of respiration function in PaO_2/fraction of inspired oxygen (FiO_2) and $PaCO_2$ is observed in the awake LVRS group (13). We assume that this improvement also enhanced the patients' activity and metabolism. All these enhanced recovery after surgery (ERAS) advantages fasten the recovery and shorten the postoperative hospital stay of patients with awake nonresectional LVRS.

The traditional LVRS is usually performed bilaterally, but changing the patient's position raises the risk of complications, especially during NI-VATS. Simplification of the surgical procedure can reduce the duration and difficulty of NI-VATS LVRS so that scholars are investigating whether it is enough to perform unilateral LVRS. In these cases, patients keep routine postoperative follow-ups with the MDT monitoring lung functions and life quality. The opposite side LVRS is unnecessary unless there is a continuous and unacceptable deterioration (17).

According to the report of 11 staged bilateral uniportal VATS-LVRS by Dr. Zhang (28), both unilateral and

bilateral LVRS improve the pulmonary function and activity capacity. However, there is no significant difference in life quality measured with a short form 36-item health survey questionnaire (SF-36) between unilateral and bilateral LVRS. More extensive research conducted by Dr. Oey included 26 bilateral patients and 39 unilateral patients (29). After 24 months of follow-up, results reveal that the patients undergoing unilateral LVRS had a shorter hospital stay (16 *vs.* 28 d, P=0.004) and less need for postoperative ventilation (5% *vs.* 42%, P=0.002) comparing with those receiving bilateral LVRS. Moreover, the decline of FEV1 during the first postoperative year is significant in the bilateral group but not in the unilateral group (–313 mL/y, P=0.04 *vs.* –50 mL/y, P=0.18, respectively). These studies suggest that an extended surgery may not bring a greater reward to the patient, and a staged LVRS could be more suitable for emphysema patients before they receive lung transplantation ultimately.

Conclusions

LVRS is recommended as a possible and effective treatment for patients with severe heterogeneous emphysema. However, mechanical ventilation during general anesthesia may cause further damage to the fragile pathological tissue and be the potential reason for air leaks or other postoperative complications. The unsatisfactory mortality and morbidity after LVRS prevent it from widespread popularization. According to the Society of Thoracic Surgeons database, only 528 patients underwent LVRS during 8.5 years period, despite the significant number of possible candidates (30).

NI-VATS is proven as a safe, less invasive method for various lung surgery. Avoiding the adoption of muscle relaxants and intubation accelerates the surgery process and postoperative recovery. Besides, a lower level of inflammation indicators such as IL-6 and TNF-α is observed postoperatively in non-intubated patients compared with the intubated (31), which reduces intubation-related complications and is another reason for patients planning to undergo LVRS. A series of research studies confirmed that the NI-VATS LVRS is feasible and promising among a specific group of emphysema patients. Short-term perioperative improvement and long-term prognosis benefits are both expected.

In conclusion, NI-VATS LVRS may not be suitable for every emphysema patient and their physicians. The mechanism by which the NI-VATS nonresectional LVRS shows a better clinical efficacy is not completely understood and therefore still needs more clinical and basic medicine research to confirm it. Nevertheless, it is our job to provide the best therapy for the most suitable patients. Stepping out of comfort zone could be difficult initially, but it is always worth trying this new method when fully prepared.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Francesco Guerrera, Paolo Albino Ferrari and Roberto Crisci) for the series "Non-Intubated Thoracic Surgery. A Global Perspective" published in *Video-Assisted Thoracic Surgery*. The article has undergone external peer review.

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://dx.doi.org/10.21037/vats-21-23

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/vats-21-23). The series "Non-Intubated Thoracic Surgery. A Global Perspective" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Liang H, Liu J, Wu S, et al. Nonintubated spontaneous ventilation offers better short-term outcome for mediastinal tumor surgery. Ann Thorac Surg 2019;108:1045-51.
2. Jiang L, Liu J, Gonzalez-Rivas D, et al. Thoracoscopic surgery for tracheal and carinal resection and reconstruction under spontaneous ventilation. J Thorac Cardiovasc Surg 2018;155:2746-54.
3. Gonzalez-Rivas D, Yang Y, Guido W, et al. Non-intubated (tubeless) uniportal video-assisted thoracoscopic lobectomy. Ann Cardiothorac Surg 2016;5:151-3.
4. Young J, Fry-Smith A, Hyde C. Lung volume reduction surgery (LVRS) for chronic obstructive pulmonary disease (COPD) with underlying severe emphysema. Thorax 1999;54:779-89.
5. van Agteren JE, Carson KV, Tiong LU, et al. Lung volume reduction surgery for diffuse emphysema. Cochrane Database Syst Rev 2016;10:CD001001.
6. Brantigan OC, Mueller E. Surgical treatment of pulmonary emphysema. Am Surg 1957;23:789-804.
7. Brantigan OC, Mueller E, Kress MB. A surgical approach to pulmonary emphysema. Am Rev Respir Dis 1959;80:194-206.
8. Cooper JD, Trulock EP, Triantafillou AN, et al. Bilateral pneumectomy (volume reduction) for chronic obstructive pulmonary disease. J Thorac Cardiovasc Surg 1995;109:106-16; discussion 116-9.
9. McKenna RJ Jr, Brenner M, Fischel RJ, et al. Patient selection criteria for lung volume reduction surgery. J Thorac Cardiovasc Surg 1997;114:957-64; discussion 964-7.
10. Mineo TC, Pompeo E, Mineo D, et al. Awake nonresectional lung volume reduction surgery. Ann Surg 2006;243:131-6.
11. Pompeo E, Mineo TC. Two-year improvement in multidimensional body mass index, airflow obstruction, dyspnea, and exercise capacity index after nonresectional lung volume reduction surgery in awake patients. Ann Thorac Surg 2007;84:1862-9; discussion 1862-9.
12. Tacconi F, Pompeo E, Mineo TC. Duration of air leak is reduced after awake nonresectional lung volume reduction surgery. Eur J Cardiothorac Surg 2009;35:822-8; discussion 828.
13. Pompeo E, Tacconi F, Mineo TC. Comparative results of nonresectional lung volume reduction performed by awake or non-awake anesthesia. Eur J Cardiothorac Surg 2011;39:e51-8.
14. Fishman A, Fessler H, Martinez F, et al. Patients at high risk of death after lung-volume-reduction surgery. N Engl J Med 2001;345:1075-83.
15. Akopov A, Egorov V, Deynega I, et al. Awake video-assisted thoracic surgery in acute infectious pulmonary destruction. Ann Transl Med 2015;3:100.
16. Pompeo E, Rogliani P, Palombi L, et al. The complex care of severe emphysema: role of awake lung volume reduction surgery. Ann Transl Med 2015;3:108.
17. Rathinam S, Oey I, Steiner M, et al. The role of the emphysema multidisciplinary team in a successful lung volume reduction surgery programmedagger. Eur J Cardiothorac Surg 2014;46:1021-6; discussion 1026.
18. Pompeo E, Rogliani P, Cristino B, et al. Staged unilateral lung volume reduction surgery: from mini-invasive to minimalist treatment strategies. J Thorac Dis 2018;10:S2754-62.
19. Zaman M, Bilal H, Mahmood S, et al. Does getting smokers to stop smoking before lung resections reduce their risk? Interact Cardiovasc Thorac Surg 2012;14:320-3.
20. Li S, Cui F, Liu J, et al. Nonintubated uniportal video-assisted thoracoscopic surgery for primary spontaneous pneumothorax. Chin J Cancer Res 2015;27:197-202.
21. Guo Z, Yin W, Wang W, et al. Spontaneous ventilation anaesthesia: total intravenous anaesthesia with local anaesthesia or thoracic epidural anaesthesia for thoracoscopic bullectomy. Eur J Cardiothorac Surg 2016;50:927-32.
22. Gonzalez-Rivas D, Fernandez R, de la Torre M, et al. Single-port thoracoscopic lobectomy in a nonintubated patient: the least invasive procedure for major lung resection? Interact Cardiovasc Thorac Surg 2014;19:552-5.
23. Gonzalez-Rivas D, Bonome C, Fieira E, et al. Non-intubated video-assisted thoracoscopic lung resections: the future of thoracic surgery? Eur J Cardiothorac Surg 2016;49:721-31.
24. David P, Pompeo E, Fabbi E, et al. Surgical pneumothorax under spontaneous ventilation-effect on oxygenation and ventilation. Ann Transl Med 2015;3:106.
25. Lan L, Li J, Xu X, et al. Lung volume reduction under spontaneous ventilation in a patient with severe emphysema. Am J Case Rep 2019;20:125-30.
26. Pompeo E, Marino M, Nofroni I, et al. Reduction pneumoplasty versus respiratory rehabilitation in severe

emphysema: a randomized study. Pulmonary Emphysema Research Group. Ann Thorac Surg 2000;70:948-53; discussion 54.
27. Pompeo E, Rogliani P, Tacconi F, et al. Randomized comparison of awake nonresectional versus nonawake resectional lung volume reduction surgery. J Thorac Cardiovasc Surg 2012;143:47-54, 54.e1.
28. Zhang M, Wang H, Pan XF, et al. Staged bilateral single-port thoracoscopic lung volume reduction surgery: a report of 11 cases. Exp Ther Med 2016;12:2851-4.
29. Oey IF, Waller DA, Bal S, et al. Lung volume reduction surgery--a comparison of the long term outcome of unilateral vs. bilateral approaches. Eur J Cardiothorac Surg 2002;22:610-4.
30. Fishman A, Martinez F, Naunheim K, et al. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. N Engl J Med 2003;348:2059-73.
31. Tang C, Chai X, Kang F, et al. I-gel laryngeal mask airway combined with tracheal intubation attenuate systemic stress response in patients undergoing posterior fossa surgery. Mediators Inflamm 2015;2015:965925.

doi: 10.21037/vats-21-23
Cite this article as: Zhang Y, Jin X. Literature review: non-intubated (tubeless) VATS for lung volume reduction surgery. Video-assist Thorac Surg 2021;6:28.