Original Article

Cost-effectiveness and postoperative outcomes of spontaneous *vs.* mechanical ventilation during video-assisted thoracoscopic surgery: a retrospective study

Jingyan Wang[1#], Yanran Zhou[2#], Zongming Jiang[1], Shenghua Yi[1], Yulong Wang[1]

[1]Department of Anesthesia, Shaoxing People's Hospital, Shaoxing, China; [2]Department of Anesthesiology, The First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China

Contributions: (I) Conception and design: J Wang, Y Zhou, Y Wang; (II) Administrative support: J Wang, Y Zhou, Y Wang; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: J Wang, Z Jiang, S Yi, Y Wang; (V) Data analysis and interpretation: J Wang, Y Zhou, Y Wang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Yulong Wang, BMed. Department of Anesthesia, Shaoxing People's Hospital, North Zhongxing Road No. 568, Yuecheng District, Shaoxing 312000, China. Email: wyl871015@outlook.com.

Background: Video-assisted thoracoscopic surgery (VATS) is known to have the advantages of being minimally invasive, reducing complications, and shortening hospitalization time. However, related cost surveys have been inconsistent. In recent years, a new concept of tubeless anesthesia has been introduced, but its impact on the cost-effectiveness of VATS is unclear. This study compared the hospitalization costs and postoperative outcomes in patients undergoing spontaneous ventilation VATS (SV-VATS) and mechanical ventilation VATS (MV-VATS).

Methods: We retrospectively analyzed data on the VATS procedures performed at the Shaoxing People's Hospital from June 2022 to July 2023. Overall, 386 patients who met the inclusion criteria were treated with SV-VATS (n=57) or MV-VATS (n=329). Comprehensive cost comparisons were performed between the groups.

Results: The two groups shared comparable clinical characteristics, such as age (P=0.64), sex (P=0.72), body mass index (BMI) (P=0.68), and type of procedure (P=0.43). All costs are expressed in U.S. dollars ($). The overall, diagnostic, operation, and material costs of SV-VATS and MV-VATS were $3,858.71±$746.32 *vs.* $3,870.26±$990.69 (P=0.94), $911.83 *vs.* $908.73 (P=0.51), $875.58 *vs.* $875.58 (P=0.51), and $1,560.5 *vs.* $1,596.91±$727.18 (P=0.31), respectively. In addition, the median costs of anesthesia materials and total medications were $233.51 *vs.* $324.02 and $290.63 *vs.* $364.14, respectively (P<0.001). Among medications, the cost of anesthesia medicine was $179.6±$45.48 *vs.* $224.12±$54.67, respectively (P<0.001). Postoperative complications, including sore throat, hoarseness, and expectoration, did not occur in the SV-VATS group, whereas 13, 11, and 10 cases were noted, respectively, in the MV-VATS group (13.5%, 11.5%, and 10.4%, respectively; P=0.01, P=0.03, P=0.041). The time to extubation in the SV-VATS and MV-VATS groups was 4 and 10 min, respectively (P<0.001). No intermediate surgery was performed in either group.

Conclusions: Compared with SV-VATS, MV-VATS can reduce patients' anesthesia and medicine costs and has similar postoperative adverse event rates in VATS patients, which is conducive to accelerating patient recovery. Therefore, tubeless anesthesia is recommended for future VATS.

Keywords: Tubeless anesthesia; cost-effectiveness; spontaneous ventilation (SV); video-assisted thoracoscopic surgery (VATS)

Submitted May 27, 2024. Accepted for publication Aug 16, 2024. Published online Oct 11, 2024.
doi: 10.21037/jtd-24-869
View this article at: https://dx.doi.org/10.21037/jtd-24-869

© AME Publishing Company.

Introduction

Video-assisted thoracoscopic surgery (VATS) has replaced open surgery as a minimally invasive alternative and has become an inevitable choice for thoracic surgeons. In 2015, lobectomy under VATS was performed in 86.6% of tertiary hospitals in China (1).

VATS has clear advantages, as it is known to reduce complications, readmission rates, and postoperative hospitalization time (2,3). However, the results of studies on the equipment costs and economic burden of VATS have been inconsistent (4,5). Therefore, it is necessary to identify and assess the costs associated with medical procedures at an early stage (6).

Tubeless anesthesia is a new anesthetic strategy that involves changing general anesthesia to targeted anesthesia. A laryngeal mask combined with vagus and/or intercostal nerve blocks is a safe way to avoid side effects associated with mechanical ventilation (MV), including airway injury, postoperative respiratory failure, respiratory paralysis due to residual inotropes, and imbalances in the ventilated blood flow ratio (7,8). An expert consensus has also declared that tubeless anesthesia can be applied in thoracic surgery (9). In addition, recent studies have shown that tubeless anesthesia improves intraoperative local cerebral oxygen saturation (SpO_2) by inducing hypercapnia but does not affect the incidence of postoperative cognitive dysfunction within 1 month (10); it even reduces the magnitude of D-dimer elevation (577 *vs.* 1,624 μg/L, P<0.001) and thus reduces the risk of postoperative thromboembolism (11). Liu *et al.* (12) performed tubeless anesthesia in 162 patients with spontaneous pneumothorax, and intraoperative intubation was performed in only one case. The advantages of tubeless anesthesia are becoming increasingly apparent, and this intervention contributes to more efficient healthcare delivery. Due to budgetary constraints, tubeless anesthesia must not only demonstrate safety (13,14) and feasibility (15,16) but also assess the cost-effectiveness of VAT procedures, which facilitates the adoption and dissemination of tubeless anesthesia.

Therefore, this study aimed to compare the hospitalization costs in patients undergoing VATS under tubeless and intubated anesthesia to determine whether tubeless anesthesia may have a lesser economic burden on patients. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-869/rc).

Highlight box

Key findings

- Tubeless anesthesia can reduce costs for video-assisted thoracoscopic surgery (VATS), especially for anesthesia materials and medications.

What is known and what is new?

- Studies on economic burden of VATS have been inconsistent.
- Tubeless anesthesia could have a lower economic burden on VATS.

What is the implication, and what should change now?

- Patients who meet the requirements can choose tubeless anesthesia to obtain comfortable medical treatment at lower costs.

Methods

Study design

This was a retrospective cohort study of a database of patients who underwent thoracoscopic surgery for lung masses (pulmonary wedge resection, segment resection, or lobectomy) under tubeless and double-lumen tube (DLT) intubation anesthesia from June 2022 to July 2023 at Shaoxing People's Hospital. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Ethics Review Board of the Shaoxing People's Hospital (2023 Scientific Research Project) (No. 110-Y-01). As this was a retrospective study, the requirement for informed consent was waived.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (I) adults with scheduled thoracoscopic resection of lung lesions; (II) no obvious anesthesia, surgical, paravertebral nerve block, or intercostal nerve block contraindications; (III) American Society of Anesthesiologists class I–II and New York Heart Association classification I–II; (IV) age between 18 and 80 years, with no restrictions on sex; and (V) body mass index (BMI) ≤28 kg/m^2.

The exclusion criteria were as follows: (I) allergy to anesthetic drugs; (II) difficult airway management; (III) severe pneumonia, respiratory and circulatory system dysfunction, abnormal lung function [forced expiratory volume in 1 second, (FEV1)% <50%], and hypoxemia before surgery; (IV) a clinically significant history of cardiac or nervous system disorders, such as ischemic

© AME Publishing Company.

heart disease, valvular heart disease, rhythm disturbances (rapid atrial fibrillation or ventricular premature beats), cardiac ejection fraction <50% of expected value or significant lacunar cerebral infarction, and ischemic stroke; (V) mediastinal surgery; (VI) history of ipsilateral surgery and other surgeries that may result in extensive pleural adhesion disease; (VII) intraoperative hemorrhage (bleeding volume >500 mL) or intraoperative change of surgical plan (changed to thoracotomy); and (VIII) uncontrolled hypertension or cardiovascular disease.

Comparison group

We compared the spontaneous ventilation VATS (SV-VATS) and MV-VATS groups according to the anesthesia and the type of surgery which was determined from electronic medical records. After propensity-score matching (PSM), we examined the electronic medical records of 51 patients in whom tubeless anesthesia was applied. These patients were then matched with 96 other patients in whom routine MV was performed. A total of 147 patients were ultimately included. In order to mitigate potential sources of bias, all patients were treated under tubeless anesthesia by the same surgical and anesthesia teams. Our uniportal VATS procedure was performed using an incision of 3 to 5 cm at the fifth intercostal space of the anterior axillary line. The same surgical access was used for all patients.

Tubeless anesthesia methods

All patients were treated with tubeless anesthesia, total intravenous anesthesia with laryngeal mask ventilation, local incision block, T2–T8 intercostal nerve block, pleural surface anesthesia, and surgical vagus nerve block. The local incision block consisted of 1% lidocaine with 5–10 mL of layer-by-layer infiltration. The intercostal nerve block consisted of 0.5% ropivacaine combined with 20 mL of 1% lidocaine and was used to block the T2–T8 intercostal nerve under VATS at a 2–3 mL dose. Pleural surface anesthesia consisted of a 5–10 mL mixture of 2% lidocaine sprayed on the lung surface. The surgical vagus nerve block was used with a 5 mL mixture of 0.5% ropivacaine combined with 1% lidocaine. The insertion point of the right vagal nerve block was above the superior vena cava, and the insertion point of the left vagal nerve block was below the aortic arch. If the heart rate increased significantly after anesthetic injection, a vagal nerve block was considered adequate.

Induction of anesthesia

Midazolam 0.05 mg/kg, propofol 2–2.5 μg/mL [target-controlled infusion (TCI)], and sufentanil 0.1 μg/kg were administered to induce anesthesia. No muscle relaxants were used in this study. When the bispectral index (BIS) values dropped to 60 and below, a laryngeal mask was placed to connect to an anesthesia machine for synchronous intermittent MV.

Maintenance of anesthesia

Anesthesia was maintained intravenously. Propofol 2–2.5 μg/mL (TCI) was maintained until the surgical incision was closed; remifentanil 0.03–0.1 μg/kg/min was maintained until the surgical incision was closed; and dexmedetomidine 0.3–1 μg/kg/h was maintained until the pleural space closed.

Ventilation

When anesthesia induction was completed, a laryngeal mask was placed to assist in ventilation control and airway monitoring. If transient respiratory depression occurred after anesthesia induction, the laryngeal mask was connected to the anesthesia machine for synchronous intermittent MV [tidal volume (VT), 3–5 mL/kg; respiratory rate (RR), 12–15 times/min; fraction of inspired oxygen (FiO_2), 100%; and oxygen flow, 3–4 L/min], and the anesthesia machine ventilation mode was changed to the spontaneous breathing mode [adjustable pressure-limiting (APL), 0 cmH_2O] when the skin was incised. During anesthesia, if the patient's spontaneous breathing did not return to the ideal level (VT, 3–5 mL/kg; and RR, 12–15 times/min), SpO_2 dropped below 90% or partial pressure of arterial carbon dioxide ($PaCO_2$) rose to 60 mmHg or above, the infusion rate of the anesthetic drugs was adjusted according to the electrocardiography (ECG) and BIS. Thereafter, intermittent MV, other assisted ventilation modes, or manual assisted ventilation were synchronized until spontaneous breathing was achieved.

Emergency protocol

Conversion criteria to intubated VATS include surgical complications, such as major bleedings, persistent hypoxemia (SpO_2 <85%) or severe hypercapnia ($PaCO_2$ ≥80 mmHg) with acidosis (pH <7.1), persistent coughing, excessive

© AME Publishing Company.

diaphragm movement, significant increase in airway secretions or bloody secretions, hemodynamic instability, severe pleural adhesion, massive sputum, which compromise safety of the surgical procedure. We usually apply the same criteria as those indicated in the expert consensus (9).

Primary outcomes (cost-effectiveness)

The main objective of this experiment was to determine the hospitalization-related expenses. Therefore, the main outcomes evaluated included the total cost of treatment, including anesthesia, surgery, medicine, tests, and consumables, during the perioperative period in both groups. The total cost of treatment during the perioperative period was obtained from the hospital billing data system: (I) materials (examination, surgery, and treatment of disposable materials); (II) diagnostic (including pathological, laboratory, imaging, and clinical diagnostics); (III) drug (use of medications during the hospital stay); (IV) anesthetic materials and medications (specifically recorded in the anesthesia system); and (V) operation costs. All costs are expressed in U.S. dollars ($) according to the 2023 average exchange rate [$1 for 7.0467 Chinese Yuan (CNY)] issued by the National Institute of Statistics.

Secondary outcomes (postoperative outcomes)

Electronic medical records were used to collect data on baseline characteristics (age, sex, BMI, surgery type, clinically significant disease) and postoperative clinical outcomes. Postoperative complications and definitions included (I) incision pain, patient reports incision pain ≥4 on Numerical Rating Scale (NRS); (II) sore throat, patient reports sore throat ≥4 on NRS; (III) fever, temperature above 38 ℃ (17); (IV) atelectasis, diagnosed by imaging methods (18); (V) pneumonia, European Perioperative Clinical Outcome (EPCO) definitions (19); (VI) arrhythmia, diagnosed by ECG and requiring medication (19); (VII) hypotension, systolic arterial pressure <90 mmHg (20); (VIII) nausea and vomiting, occurred in the post-anesthesia care unit (PACU) to within 24 h postoperatively (17); (IX) other complications reported by the patient. Postoperative recovery indicators mainly included the extubation time (time from the end of anesthesia to the removal of the laryngeal mask or DLT, min), PACU length of stay (time from admission to the anesthesia resuscitation room to the time of discharge from the anesthesia resuscitation room, min), time to discharge (time period from the date of surgery to the date of discharge), and the duration of chest tube use.

Statistical analysis

Two patients who underwent MV-VATS were matched with one patient who underwent SV-VATS using nearest-neighbor PSM without replacement (caliper =0.1). PSM was used to reduce the differences among the baseline variables between groups. Patients were matched for age, sex, preoperative BMI, and type of surgery, and PSM was performed using Statistical Package for Social Sciences (SPSS version 26.0) and R (version 3.5.1). The measurement data were expressed as standard deviation or median and quartile interval description, *t*-test and the rank-sum test were used for between-group comparisons. Count data were expressed as a percentage or a number, and differences between groups were tested using χ^2 or the Fisher exact test; all statistical tests were two-sided with 95% confidence intervals (P<0.05).

Results

Screening process

Between June 2022 and July 2023, 449 patients who underwent VATS at Shaoxing People's Hospital were included. A total of 386 patients were included in the study based after applying the exclusion criteria. Fifty patients were excluded because of the presence of underlying diseases, such as coronary artery disease, arrhythmia, and chronic bronchitis. Thirteen patients with BMI >28 kg/m^2 were excluded. We used PSM to reduce and balance baseline confounders and successfully matched 147 patients. A patient-specific screening flowchart is shown in *Figure 1*.

Baseline clinical characteristics of the patients

There were no differences between the tubeless and intubated groups in terms of sex, age, BMI, or type of procedure (*Table 1*).

Cost analysis

The SV-VATS group had significantly lower anesthesia material, anesthesia medicine, and total medication costs than those of the MV-VATS group ($233.51 *vs.* $324.02, $179.6±$45.48 *vs.* $ 224.12±$54.67, and $290.63 *vs.* $364.14, respectively; P<0.001). However, there were no differences in the overall costs ($3,858.71±$746.32 *vs.*

© AME Publishing Company.

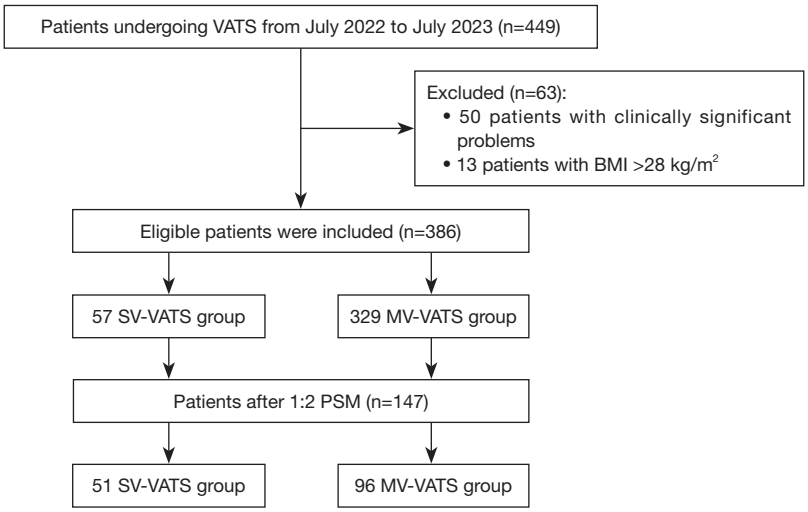

Figure 1 Participant flow of study population. VATS, video-assisted thoracoscopic surgery; BMI, body mass index; SV, spontaneous ventilation; MV, mechanical ventilation; PSM, propensity-score matching.

Table 1 Baseline clinical characteristics of patients

Characteristics	Unmatched patients			Propensity-matched patients		
	MV-VATS (n=329)	SV-VATS (n=57)	P value	MV-VATS (n=96)	SV-VATS (n=51)	P value
Gender			0.09			0.72
Male	138 (41.9)	17 (29.8)		31 (32.3)	15 (29.4)	
Female	191 (58.1)	40 (70.2)		65 (67.7)	36 (70.6)	
Age (years)	62 [54–71]	54 [40.5–60.5]	0.001	56 [49–62]	55 [46–62]	0.64
Surgery type			0.003			0.43
Wedge resection	122 (37.1)	35 (61.4)		50 (52.1)	29 (56.9)	
Segment resection	104 (31.6)	11 (19.3)		30 (31.3)	11 (21.6)	
Lobectomies	103 (31.3)	11 (19.3)		16 (16.7)	11 (21.6)	
BMI (kg/m^2)	22.56±2.61	21.54±2.02	0.001	21.95±2.64	21.79±1.89	0.68

Data are presented as n (%), median [P_{25}–P_{75}], or mean ± SD. MV-VATS, mechanical ventilation video-assisted thoracoscopic surgery; SV-VATS, spontaneous ventilation video-assisted thoracoscopic surgery; BMI, body mass index; P_{25}, 25th percentile; P_{75}, 75th percentile; SD, standard deviation.

\$3,870.26±\$990.69, P=0.94), diagnostic expenses (\$911.83 *vs.* \$908.73, P=0.51), surgical costs (\$875.58 *vs.* \$875.58, P=0.51), and material costs (\$1,560.5 *vs.* \$1,596.91±\$727.18, P=0.31) (*Figure 2*).

Postoperative complications

Perioperative complications are listed in *Table 2*. No postoperative symptoms of sore throat, hoarseness, or coughing occurred in the SV-VATS group, whereas 13, 11, and 10 cases of sore throat, hoarseness, or expectoration, respectively, occurred in the MV-VATS group (13.5%, 11.5%, and 10.4%, respectively, P=0.01, P=0.03, P=0.041). There were no differences between the two groups regarding arrhythmia, postoperative fever, pain score, nausea, vomiting, or degree of pulmonary infection. One case of postoperative pneumothorax occurred in the SV-VATS group with approximately 35% lung tissue compression, for which chest tube drainage was performed.

© AME Publishing Company.

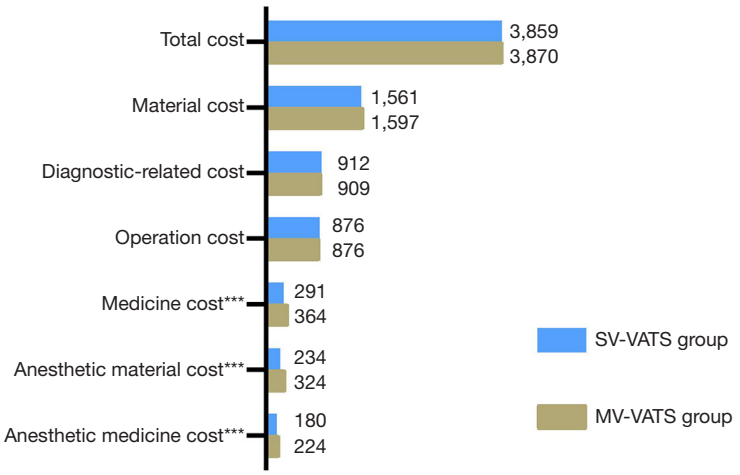

Figure 2 Total and component costs ($) after PSM (1:2) (x/$P_{50}$). ***, comparison between groups P<0.001. SV-VATS, spontaneous ventilation video-assisted thoracoscopic surgery; MV-VATS, mechanical ventilation video-assisted thoracoscopic surgery; PSM, propensity-score matching; P_{50}, 50th percentile.

Table 2 Postoperative complications

Variables	MV-VATS (n=96)	SV-VATS (n=51)	P value
Incision pain	4 (4.2)	4 (7.8)	0.58
Sore throat	13 (13.5)	0 (0.0)	0.01
Fever	15 (15.6)	6 (11.8)	0.52
Atelectasis	0 (0.0)	1 (2.0)	0.35
Pneumonia	3 (3.1)	0 (0.0)	0.51
Arrhythmia	5 (5.2)	0 (0.0)	0.24
Hypotension	6 (6.3)	4 (7.8)	0.98
Dyspnea	0 (0.0)	1 (2.0)	0.35
Chest tightness	2 (2.1)	2 (3.9)	0.91
Cough	3 (3.1)	0 (0.0)	0.51
Expectoration	10 (10.4)	0 (0.0)	0.041
Hoarseness	11 (11.5)	0 (0.0)	0.03
Brain swelling	0 (0.0)	1 (2.0)	0.35
Dizziness	14 (14.6)	5 (9.8)	0.41
Nausea	25 (26.0)	13 (25.5)	0.94
Vomiting	15 (15.6)	4 (7.8)	0.18

Data are presented as n (%). MV-VATS, mechanical ventilation video-assisted thoracoscopic surgery; SV-VATS, spontaneous ventilation video-assisted thoracoscopic surgery.

Postoperative recovery indicators

There were no differences between the two groups (P=0.70, P=0.11, P>0.99) (*Table 3*) in the three indicators: PACU length of stay (40 *vs.* 43 min), postoperative hospitalization days (3 *vs.* 4 days), or duration of continuous chest tube drainage (2 *vs.* 2 days). However, the extubation time was 4 min in the SV-VATS group and 10 min in the MV-VATS group, and the difference between the two groups was

© AME Publishing Company.

Table 3 Recovery-related evaluation

Variables	MV-VATS (n=96)	SV-VATS (n=51)	P value
Extubation (min)	10 [4–18]	4 [0–9]	<0.001
PACU recovery (min)	43 [32.25–59]	40 [35–58]	0.70
Discharge (days)	4 [4–5]	3 [3–5]	0.11
Chest tube duration (days)	2 [2–3]	2 [2–3]	>0.99

Data are presented as median [P_{25}–P_{75}]. MV-VATS, mechanical ventilation video-assisted thoracoscopic surgery; SV-VATS, spontaneous ventilation video-assisted thoracoscopic surgery; PACU, post-anesthesia care unit; P_{25}, 25th percentile; P_{75}, 75th percentile.

statistically significant (P<0.001).

Discussion

In this study, we hypothesized that tubeless anesthesia use would reduce the cost of treating patients undergoing VATS and alleviate perioperative complications. Our study provides a breakdown of the expenses at the patient level, including studies on VATS costs and postoperative outcomes, as well as specific cost analyses between tubeless anesthesia and DLT intubation anesthesia.

Overall, total hospitalization costs were comparable between the two groups. Tubeless anesthesia significantly reduced the costs of anesthesia materials, medicine, and total medications use. The reduction in the cost of anesthesia materials was mainly due to the non-use of fibrinoscopes and laryngoscopes. The reduction of medications during the hospital stay was due to the non-use of cisatracurium besilate in tubeless anesthesia as well as a reduction in the use of medications for coughing and sputum relief and in the number of complications associated with tubeless anesthesia. These findings can be used to optimize the price of healthcare services and inform future sustainable health policies in hospitals (21). Therefore, from an economic standpoint, the tubeless VATS technique may reduce the cost of anesthesia materials and medications for the patient and provide surgical outcomes similar to the intubated VATS technique with the lowest expectations. In addition, because the costs of the fibrinoscope and DLT are much higher than that of the laryngeal mask, the need to adjust the position of the tube intraoperatively due to positional changes undoubtedly makes intraoperative anesthesia management more difficult. Moreover, VATS is more cost-effective than open surgery (22,23), and tubeless anesthesia reduces the cost of anesthesia and medication for patients with VATS without increasing the overall cost. We chose the same group of anesthesiologists and surgeons because of the high heterogeneity of experience among the different groups of surgeons, which avoids the economic impact of the surgeons' variable level of performance that leads to an amplified assessment (24). Robotic-assisted lobectomy may be more cost-effective than VATS-lobectomy (25-27). However, the operating costs of robotic equipment continue to increase, and whether it leads to a better prognosis for patients remains unclear. Compared with VATS, microwave ablation (28) provided a significant cost reduction (54,314.36 *vs.* 21,464.98 CNY, P<0.001) in the treatment of pulmonary ground glass nodules (≤30 mm in diameter). In contrast, the advantages of tubeless anesthesia are that it is simple and easy to perform and does not incur high equipment costs, and the anesthesiologists in our hospital are already able to meet the demands of thoracic surgery after specialized tubeless anesthesia training.

Because postoperative adverse events delay hospital discharge and increase healthcare costs, we summarized the incidence of postoperative complications. Our results showed that the overall distribution of incision-pain NRS scores was similar in both groups, with most patients having NRS scores of or below and a few experiencing severe pain, which resolved rapidly with the administration of analgesics. Although we used a small dose of opioid induction combined with regional anesthesia during the operation, there was no difference between the groups in terms of postoperative incision pain, and the effect of the SV-VATS group surpassed that of the MV-VATS group for sore throat. This suggests that this anesthesia modality can meet patients' analgesic needs and may be an alternative to mechanically ventilated general anesthesia. Although there are effective drugs to alleviate postoperative sore throat after single-lumen tracheal intubation (29), there is no consensus on the effective drugs for treating postoperative sore throat after DLT intubation. Liang *et al.* (30) first found that preoperative ketamine gargling could reduce the incidence and severity of postoperative sore throat 24 h after DLT

© AME Publishing Company.

intubation via VATS. The present study demonstrated that the tubeless anesthesia technique as a nonpharmacological treatment modality significantly reduced the incidence of postoperative sore throat in patients undergoing VATS (one occurrence during the postoperative period up to the time of discharge was sufficient for recording); however, the exact time of occurrence was not recorded. In addition, the outcomes of our study showed a significant reduction in postoperative hoarseness, sore throat, and expectoration of adverse events in patients in the SV-VATS group. This may be advantageous for specific patients, such as those singers who make their voices a career or individuals with severe throat symptoms. This outcome seems to be better than that reported using a combination of the ProSeal laryngeal mask airway and a bronchial blocker (31), which may be related to the evaluation method and skill level of the trainee anesthesiologist. In addition, the tubeless group performed well in terms of pulmonary atelectasis and showed non-inferiority for some common complications of fever and pulmonary infection, suggesting that tubeless anesthesia does not affect postoperative pulmonary reopening and that permissive intraoperative hypercapnia does not increase the incidence of complications in patients (32). However, one case of pneumothorax occurred postoperatively in a patient under tubeless anesthesia, which may be an additional risk factor for tubeless anesthesia.

Our group continues to explore whether other factors can be utilized to select patients who are better suited for VATS with tubeless anesthesia. The results of this study could provide patients and healthcare professionals with information about the clinical effectiveness and economic costs of this technique and could help policymakers make informed decisions to improve healthcare outcomes. However, we are aware of the many limitations of our study. First, this was a single-center retrospective study; thus, our results are not representative of other regions. Second, we did not collect information on smoking history, lung function, and cancer stage, and PSM was performed only for the most essential clinical characteristics between the two groups, these factors may confound our findings. Third, we did not perform long-term assessment of patients undergoing VATS, especially for life-threatening diseases such as lung cancer, including tumor recurrence, readmission, metastasis, and survival-related oncological information. Therefore, a more rigorous design is required to address these issues. The primary study design was to confirm the economic cost and postoperative outcomes of the tubeless technique in patients who underwent VATS. Although several studies have reported data on the use of the tubeless technique in elderly patients (age >80 years) (33), patients with impaired lung function (34), and patients with a high BMI (BMI >30 kg/m^2) (35), none of these patients were included in the design of this study. This is because these populations may limit the dissemination of this technology and perhaps increase the perioperative risk. Finally, the learning curve remains unclear as only a few specialized centers can currently implement tubeless VATS. Further research is necessary to demonstrate the proficiency of this technique based on the required time and practice. Therefore, we advocate for more online courses and offline academic activities to promote skill development in this area.

With the development of advanced VATS and novel anesthesia protocols, both nononcologic and oncologic conditions (36,37) were successively approached. It is feasible now to perform SV-VATS without intubation in the management of wedge lung resection, anatomical lung segmentectomy, lobectomy, mediastinal mass resection (11,14,38) and even more complex surgeries including tracheal and carinal reconstruction (39), lung volume reduction surgery (40), and pleural or lung biopsy (41,42). Cui *et al.* (43) found that day VATS without intubation preoperation or placement of a chest tube postoperation could be achieved in 83% (49/59) of sympathectomies, 81% (17/21) of bullae resections, and 56% (5/9) of mediastinal tumor resections patients.

The safety and feasibility of tubeless anesthesia have been increasingly proven. The tubeless anesthesia provided similar cost outcomes to the intubated VATS technique with lowest expectations in our study. However, can tubeless anesthesia build on the strengths and weaknesses of non-thoracic surgery, surgery in special positions, and patients with co-morbidities? This is an important question. More studies are needed to evaluate the benefits of tubeless anesthesia from a patient-centered perspective, focusing on aspects like patients' tolerance and acceptance, rather than solely as a technique that can replace the DLT. Nevertheless, we believe that widespread use of this advanced technique is within the reach of the combined efforts of outstanding anesthesiologists and surgeons. Further research will help understand the long-term, cost-effective outcomes and whether the same outcomes can be obtained in other healthcare systems.

Conclusions

This study provides evidence that SV-VATS is comparable to MV-VATS, especially in the context of rising healthcare

© AME Publishing Company.

costs. However, tubeless anesthesia might be beneficial for certain patients, particularly those whose professions rely on their voices and who experience severe laryngeal symptoms. This is not only reflected in the significant reduction in anesthesia and medication costs in the SV-VATS group but also in the reduction of complications such as postoperative sore throat, hoarseness, and expectoration, as well as in the shortening of extubation time and improvement of the indicators of patient recovery.

Acknowledgments

We appreciate all the medical staff of Guangmao Yu's team in the Thoracic Surgery Department of Shaoxing People's Hospital.
Funding: This work was supported by the Shaoxing Health Science and Technology Program (No. 2023SKY028) and the Shaoxing Key Discipline of Anesthesia (No. 2019SZD04).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-869/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-869/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-869/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-869/coif). The authors have no 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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Shaoxing People's Hospital (2023 Scientific Research Project) (No. 110-Y-01) and individual consent for this retrospective analysis was waived.

Open Access Statement: This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: https://creativecommons.org/licenses/by-nc-nd/4.0/.

References

1. Liao H, Mei JD, Liu CW, et al. A survey on the current development of thoracic surgery in tertiary hospitals of China. Zhonghua Wai Ke Za Zhi 2018;56:888-91.
2. Re Cecconi E, Mangiameli G, De Simone M, et al. Vats lobectomy for lung cancer. What has been the evolution over the time? Front Oncol 2023;13:1268362.
3. Cao J, Zhang C, Zhang X, et al. The Clinical Outcomes of Thoracoscopic Versus Open Lobectomy for Non-Small-Cell Lung Cancer After Neoadjuvant Therapy: A Multi-Center Retrospective Cohort Study. Clin Lung Cancer 2024;25:e153-60.
4. Bailey KL, Merchant N, Seo YJ, et al. Short-Term Readmissions After Open, Thoracoscopic, and Robotic Lobectomy for Lung Cancer Based on the Nationwide Readmissions Database. World J Surg 2019;43:1377-84.
5. Marijic P, Walter J, Schneider C, et al. Cost and survival of video-assisted thoracoscopic lobectomy versus open lobectomy in lung cancer patients: a propensity score-matched study. Eur J Cardiothorac Surg 2020;57:92-9.
6. Kesselheim AS, Avorn J, Sarpatwari A. The High Cost of Prescription Drugs in the United States: Origins and Prospects for Reform. JAMA 2016;316:858-71.
7. Lirio F, Galvez C, Bolufer S, et al. Tubeless major pulmonary resections. J Thorac Dis 2018;10:S2664-70.
8. Yu J, Tantraworasin A, Laohathai S. Non-intubated versus intubated video-assisted thoracoscopic lobectomy for lung cancer patients. Asian J Surg 2024;47:402-6.
9. He J, Liang H, Wang W, et al. Tubeless video-assisted thoracic surgery for pulmonary ground-glass nodules: expert consensus and protocol (Guangzhou). Transl Lung Cancer Res 2021;10:3503-19.
10. Huang Y, Bo Y, Li Y, et al. The impact of tubeless anesthesia versus intubated anesthesia on cerebral oxygen saturation and postoperative cognitive function in patients undergoing video-assisted thoracoscopic surgery: a randomized trial. J Thorac Dis 2022;14:4012-30.
11. 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.
12. Liu J, Liang H, Cui F, et al. Spontaneous versus mechanical ventilation during video-assisted thoracoscopic surgery for spontaneous pneumothorax: A randomized trial. J Thorac Cardiovasc Surg 2022;163:1702-1714.e7.
13. Liu CY, Hsu PK, Leong KI, et al. Is tubeless uniportal video-assisted thoracic surgery for pulmonary wedge resection a safe procedure? Eur J Cardiothorac Surg 2020;58:i70-6.
14. Li S, Jiang L, Ang KL, et al. New tubeless video-assisted thoracoscopic surgery for small pulmonary nodules. Eur J Cardiothorac Surg 2017;51:689-93.
15. Tsukamoto Y, Odaka M, Nakada T, et al. Comparative study of local versus general anesthesia in video-assisted thoracoscopic surgery for empyema. Asian J Surg 2023;46:4208-14.
16. Kim HJ, Kim M, Park B, et al. Feasibility of ventilator-assisted tubeless anesthesia for video-assisted thoracoscopic surgery. Medicine (Baltimore) 2023;102:e34220.
17. Stephenson C, Mohabbat A, Raslau D, et al. Management of Common Postoperative Complications. Mayo Clin Proc 2020;95:2540-54.
18. Zeng C, Lagier D, Lee JW, et al. Perioperative Pulmonary Atelectasis: Part I. Biology and Mechanisms. Anesthesiology 2022;136:181-205.
19. Jammer I, Wickboldt N, Sander M, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions: a statement from the ESA-ESICM joint taskforce on perioperative outcome measures. Eur J Anaesthesiol 2015;32:88-105.
20. McEvoy MD, Gupta R, Koepke EJ, et al. Perioperative Quality Initiative consensus statement on postoperative blood pressure, risk and outcomes for elective surgery. Br J Anaesth 2019;122:575-86.
21. Cardoso RB, Marcolino MAZ, Marcolino MS, et al. Comparison of COVID-19 hospitalization costs across care pathways: a patient-level time-driven activity-based costing analysis in a Brazilian hospital. BMC Health Serv Res 2023;23:198.
22. Lim E, Harris RA, McKeon HE, et al. Impact of video-assisted thoracoscopic lobectomy versus open lobectomy for lung cancer on recovery assessed using self-reported physical function: VIOLET RCT. Health Technol Assess 2022;26:1-162.
23. Kneuertz PJ, Singer E, D'Souza DM, et al. Hospital cost and clinical effectiveness of robotic-assisted versus video-assisted thoracoscopic and open lobectomy: A propensity score-weighted comparison. J Thorac Cardiovasc Surg 2019;157:2018-2026.e2.
24. Buduhan G, Chand E, Kidane B, et al. Impact of cost-awareness education and surgeon-led positive deviance on intraoperative costs of thoracoscopic lobectomy. J Thorac Cardiovasc Surg 2023;165:1939-46.
25. Heiden BT, Mitchell JD, Rome E, et al. Cost-Effectiveness Analysis of Robotic-assisted Lobectomy for Non-Small Cell Lung Cancer. Ann Thorac Surg 2022;114:265-72.
26. Patel YS, Baste JM, Shargall Y, et al. Robotic Lobectomy Is Cost-effective and Provides Comparable Health Utility Scores to Video-assisted Lobectomy: Early Results of the RAVAL Trial. Ann Surg 2023;278:841-9.
27. Jin D, Dai Q, Han S, et al. Effect of da Vinci robot-assisted versus traditional thoracoscopic bronchial sleeve lobectomy. Asian J Surg 2023;46:4191-5.
28. Han X, Wei Z, Zhao Z, et al. Cost and effectiveness of microwave ablation versus video-assisted thoracoscopic surgical resection for ground-glass nodule lung adenocarcinoma. Front Oncol 2022;12:962630.
29. Kuriyama A, Maeda H, Sun R, et al. Topical application of corticosteroids to tracheal tubes to prevent postoperative sore throat in adults undergoing tracheal intubation: a systematic review and meta-analysis. Anaesthesia 2018;73:1546-56.
30. Liang J, Liu J, Qiu Z, et al. Effect of Esketamine Gargle on Postoperative Sore Throat in Patients Undergoing Double-Lumen Endobronchial Intubation: A Randomised Controlled Trial. Drug Des Devel Ther 2023;17:3139-49.
31. Nakanishi T, Sento Y, Kamimura Y, et al. Combined use of the ProSeal laryngeal mask airway and a bronchial blocker vs. a double-lumen endobronchial tube in thoracoscopic surgery: A randomized controlled trial. J Clin Anesth 2023;88:111136.
32. Song J, Shao YM, Zhang GH, et al. Examining the impact of permissibility hypercapnia on postoperative delirium among elderly patients undergoing thoracoscopic-laparoscopic esophagectomy: a single-center investigative study. Shock 2024;62:319-26.
33. Katlic MR, Facktor MA. Non-intubated video-assisted thoracic surgery in patients aged 80 years and older. Ann Transl Med 2015;3:101.
34. Wang ML, Hung MH, Hsu HH, et al. Non-intubated thoracoscopic surgery for lung cancer in patients with impaired pulmonary function. Ann Transl Med 2019;7:40.

© AME Publishing Company.

35. Cherchi R, Ferrari PA, Guerrera F, et al. Lung Biopsy With a Non-intubated VATS Approach in an Obese Population: Indications and Results. Front Surg 2022;9:829976.
36. Prisciandaro E, Bertolaccini L, Sedda G, et al. Non-intubated thoracoscopic lobectomies for lung cancer: an exploratory systematic review and meta-analysis. Interact Cardiovasc Thorac Surg 2020;31:499-506.
37. Wen Y, Jiang Y, Liang H, et al. Tubeless video-assisted thoracic surgery for lung cancer: is it ready for prime time? Future Oncol 2020;16:1229-34.
38. Li H, Huang D, Qiao K, et al. Feasibility of non-intubated anesthesia and regional block for thoracoscopic surgery under spontaneous respiration: a prospective cohort study. Braz J Med Biol Res 2020;53:e8645.
39. Peng G, Cui F, Ang KL, et al. Non-intubated combined with video-assisted thoracoscopic in carinal reconstruction. J Thorac Dis 2016;8:586-93.
40. Elkhouly A, Pompeo E. Nonintubated Subxiphoid Bilateral Redo Lung Volume Reduction Surgery. Ann Thorac Surg 2018;106:e277-9.
41. Cherchi R, Grimaldi G, Pinna-Susnik M, et al. Retrospective outcomes analysis of 99 consecutive uniportal awake lung biopsies: a real standard of care? J Thorac Dis 2020;12:4717-30.
42. Liu M, Cui W, Peng G, et al. Novel Lung Biopsy Surgical Technique for Definitive Diagnosis of Pulmonary Capillary Hemangiomatosis. Ann Thorac Surg 2020;109:291-3.
43. Cui F, Liu J, Li S, et al. Tubeless video-assisted thoracoscopic surgery (VATS) under non-intubated, intravenous anesthesia with spontaneous ventilation and no placement of chest tube postoperatively. J Thorac Dis 2016;8:2226-32.

Cite this article as: Wang J, Zhou Y, Jiang Z, Yi S, Wang Y. Cost-effectiveness and postoperative outcomes of spontaneous *vs.* mechanical ventilation during video-assisted thoracoscopic surgery: a retrospective study. J Thorac Dis 2024;16(10):6888-6898. doi: 10.21037/jtd-24-869

© AME Publishing Company.