Short-term and long-term outcomes of non-tracheal intubation anesthesia in thoracoscopic lobectomy for lung cancer: A systematic review and meta-analysis

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Abstract. The present study compared the efficacy and safety of non-intubated video-assisted thoracoscopic surgery (NIVATS) with intubated video-assisted thoracoscopic surgery (IVATS) for lobectomy in the treatment of lung cancer through a systematic review and meta-analysis. A total of six electronic databases were searched for studies comparing NIVATS and IVATS published up to October 2024. After rigorous screening and quality assessment, perioperative outcomes and postoperative complications were systematically analyzed from 18 studies, comprising three randomized controlled trials, six propensity score-matched studies and nine retrospective studies. A total of 2,313 patients with lung cancer underwent thoracoscopic lobectomy, of whom 1,082 underwent NIVATS and 1,231 underwent IVATS. The results revealed that NIVATS significantly reduced operative time [mean difference (MD)=11.02; 95% confidence interval (CI), -18.78 to -3.27], lymph nodes harvested (MD=-0.67; 95% CI, -1.24 to -0.11), anesthesia waking time (MD=-22.88; 95% CI, -33.13 to -12.64), feeding time (MD=-4.53; 95% CI, -5.74 to -3.32), chest tube indwelling time (MD=-0.68; 95% CI, -1.16 to -0.21) and hospital stay (MD=-1.16; 95% CI, -1.57 to -0.74) compared with the IVATS group. Total complications [odds ratio (OR)=0.53; 95% CI, 0.31 to 0.90], particularly sore throat (OR=0.18; 95% CI, 0.10 to 0.33) and pneumonia (OR=0.54; 95% CI=0.30 to 0.98) were significantly lower in the NIVATS group than in the IVATS group. Re-intubation occurred in 4.33% of NIVATS patients, while conversion to thoracotomy rates were similarly low in the NIVATS (0.69%) and IVATS (0.60%) groups. Importantly, NIVATS was associated with significantly improved overall survival [hazard ratio (HR)=0.63; 95% CI, 0.40 to 0.98] and recurrence-free survival (HR=0.62; 95% CI, 0.46 to 0.85). No significant differences were observed for anesthesia time, blood loss, hoarseness, air leakage or arrhythmia. Under the enhanced recovery after surgery framework, NIVATS appears to be a safe and technically feasible alternative to IVATS, with the potential to improve patient outcomes based on the available evidence. Its clinical adoption is supported by the evidence in the present study, offering a basis for informed decision-making.

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Abbreviations: IVATS, intubated video-assisted thoracic surgery; NIVATS, non-intubated video-assisted thoracic surgery; ERAS, enhanced recovery after surgery; ASA, American Society of Anesthesiologists; RCT, randomized controlled trials; NOS, Newcastle-Ottawa Scale; HRs, hazard ratios; CIs, confidence intervals; ORs, odds ratios; MDs, mean differences; PSM, propensity score matching; NSCLC, non-small cell lung cancer

Key words: thoracoscopic lobectomy, non-tracheal intubation anesthesia, NIVATS, lung cancer, meta-analysis

Introduction

Lung cancer remains one of the most common and lethal malignancies worldwide. According to the International Agency for Research on Cancer, in 2020, lung cancer accounted for 11.4% of newly diagnosed cancer cases and 18.0% of cancer-related mortalities worldwide, representing a notable public health burden (1,2). Current clinical management involves multidisciplinary approaches, including surgery, chemotherapy, radiotherapy and molecular targeted therapy, which have effectively reduced mortality and improved the quality of life of patients with lung cancer. Among these approaches, surgical resection remains the primary treatment strategy for treating lung cancer (3,4). Thoracic surgery has progressively shifted from conventional thoracotomy to minimally invasive thoracoscopic surgery over the past two decades (4). Particularly, intubated video-assisted thoracic surgery (IVATS) has traditionally been the standard anesthetic approach for thoracoscopic surgery. However, this method is associated with several complications, including airway injury, persistent dry cough, sore throat, nausea and vomiting, which may prolong postoperative recovery (5). Therefore, its safety and effectiveness need to be improved. With the increasing adoption of the enhanced recovery after surgery (ERAS) concept, a multimodal, multidisciplinary approach designed to reduce surgical stress and accelerate postoperative recovery (6), perioperative anesthesia management has received growing attention to minimize postoperative airway complications, shorten hospital stays and accelerate postoperative recovery, thereby improving overall patient outcomes.

In recent years, non-intubated VATS (NIVATS) with spontaneous breathing emerged as an alternative, initially applied in procedures such as pulmonary wedge resection, pulmonary bullae resection, sympathectomy and pleural mass resection (7). Evidence suggests that NIVATS is associated with reduced postoperative airway complications, shorter chest drainage duration and hospital stay, and faster recovery (8). However, compared with these procedures, thoracoscopic lobectomy requires more stringent anesthetic management due to its longer operative time and greater complexity. Few systematic reviews have specifically evaluated the safety and feasibility of NIVATS vs. IVATS in thoracoscopic lobectomy, and existing syntheses have largely focused on short-term perioperative endpoints. Therefore, the present study aimed to comprehensively and systematically evaluate the safety and feasibility of NIVATS in thoracoscopic lobectomy and its potential benefits in enhancing postoperative recovery and long-term outcomes.

Materials and methods

Search strategy. The present study systematically searched major databases to evaluate the efficacy and safety of NIVATS in thoracoscopic lobectomy for lung cancer. The databases PubMed (https://pubmed.ncbi.nlm.nih.gov), Cochrane Library (https://www.cochranelibrary.com), Web of Science (https://www.webofscience.com), Embase (https://www.embase.com), CNKI (https://www.cnki.net) and Wanfang (https://www.wanfangdata.com.cn) were searched from inception to October 2024, without restrictions on language or geographic regions. Additionally, manual searches of relevant references were conducted. The search strategy combined MeSH and free text terms, including 'non-intubation', 'non-tracheal intubation', 'non-intubated video-assisted thoracic surgery', 'NIVATS', 'thoracic surgery', 'thoracoscopic surgery', 'thoracoscopic lobectomy', 'video-assisted thoracic surgeries' and 'lobectomy'. The detailed search strategies for PubMed and Embase are shown in Tables SI and SII, respectively. The present systematic review was registered in PROSPERO (registration no. CRD420251065395; registered on 07 June 2025).

Inclusion and exclusion criteria. Strict inclusion and exclusion criteria were applied to ensure the quality and relevance of the included literature. The inclusion criteria were as follows: i) Patients who signed informed consent for general anesthesia, scheduled for thoracoscopic lobectomy and with an American Society of Anesthesiologists (ASA) score of ≤3; ii) patients in the intervention group were subjected to non-tracheal intubation anesthesia, while those in the control group received conventional double-lumen endotracheal intubation anesthesia; iii) studies reporting at least one predefined outcome, including operative time, lymph nodes harvested, anesthesia time, blood loss, anesthesia waking time, feeding time, chest tube indwelling time, hospital stay, total complications, sore throat, pneumonia, hoarseness, air leakage, arrhythmia, re-intubation, conversion to thoracotomy, overall survival or recurrence-free survival; and iv) study designs were limited to randomized controlled trials (RCTs) and observational studies. Furthermore, the following exclusion criteria were applied: i) Studies without a control group; ii) studies with inconsistent or varied interventions; iii) studies without extractable data; iv) reviews, animal studies, letters, conference articles and case reports; and v) duplicate publications or studies with overlapping data, in which case the most recent or highest-quality study was included.

Literature screening, data extraction and quality assessment. Following the study objectives, two authors independently conducted the literature search and screening according to the predefined inclusion and exclusion criteria. Duplicate publications were identified and removed using EndNote 20 software (Clarivate). Titles and abstracts were initially reviewed to identify those potentially meeting the inclusion criteria. Subsequently, the full-text articles were thoroughly screened to select eligible studies. Data extraction was performed by one reviewer and verified by another to ensure accuracy. The extracted data included: First author, publication year, country, study design, sample size, mean age, sex distribution, tumor stage and size, intervention details, ASA score, and reported outcomes. All data were directly extracted from the original text to ensure accuracy and completeness. Units for the outcome measures were defined as follows: Operative time (min), lymph nodes harvested (n), anesthesia time (min) blood loss (ml), anesthesia waking time (min), feeding time (h), chest tube indwelling time (days) and hospital stay (days). All data were directly extracted from the original text to ensure accuracy and completeness. When necessary, corresponding authors were contacted for additional information.

The quality of each study was independently assessed by two reviewers according to the specified criteria. For subject selection, comparability and outcomes, observational studies were evaluated using the Newcastle-Ottawa Scale (NOS) (9), with scores >6 indicating high quality. For RCTs, the modified Jadad scale (10) was used to evaluate methodological quality, including random sequence generation, allocation concealment, blinding and reporting of withdrawals. Scores ranged from 0 to 7, with 1-3 indicating low quality and 4-7 indicating high quality. Discrepancies in literature screening, data extraction and quality assessment were resolved through discussion or, when necessary, consultation with a third reviewer.

Statistical analysis. All statistical analyses were performed using STATA version 15.1 (StataCorp LP) (11,12). For overall survival and recurrence-free survival, hazard ratios (HRs) with 95% confidence intervals (CIs) were used as effect measures and were extracted directly from the original studies. For binary and continuous variables, odds ratios (ORs) and mean differences (MDs) were calculated, respectively. Forest plots were generated to visualize the results of each study. All statistical tests were two-sided, with $P<0.05$ considered to indicate a statistically significant difference. Heterogeneity among studies was assessed using the χ^2 (Q) test and the I^2 statistic. A fixed-effects model was applied when heterogeneity was low ($P>0.10$ and $I^2\leq50\%$), whereas a random-effects model was applied when $P\leq0.10$ and $I^2>50\%$ (significant heterogeneity). Sensitivity analyses were performed by excluding individual studies to evaluate the robustness and reliability of the results. Publication bias was assessed using Egger's linear regression test, with $P<0.05$ indicating potential publication bias (13). In addition, Duval and Tweedie's trim-and-fill method was used to evaluate the stability of the pooled results. A spliced

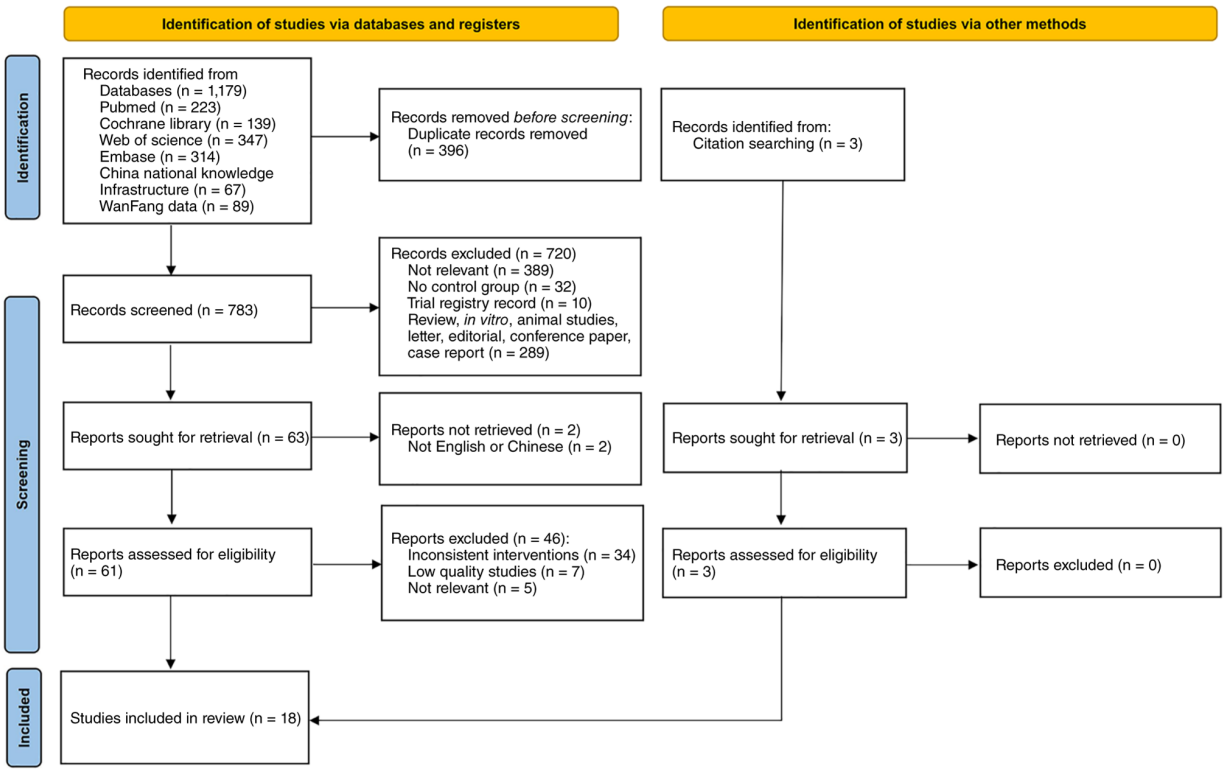

Figure 1. Flowchart of study selection.

and significantly varied pooled effect sizes indicated potential instability, warranting further analysis (14).

Results

Study selection. A total of 1,179 potentially relevant studies were identified through the literature search. After screening titles and abstracts, 61 articles were selected for full-text review. Finally, 18 studies (15-32) met the inclusion criteria, including three RCTs, six propensity score matching (PSM) studies and nine retrospective studies. The detailed study selection process is illustrated in Fig. 1.

Characteristics of the included studies and quality assessment. A total of 2,031 patients undergoing thoracoscopic lobectomy were included, with study sample sizes ranging from 40 to 400. Among them, 1,082 patients (46.78%) underwent NIVATS and 1,231 patients (53.22%) underwent IVATS. A total of nine studies employed laryngeal mask airway anesthesia, whereas nine used mask anesthesia. Seven studies included patients diagnosed with lung cancer, and nine studies included patients diagnosed with non-small cell lung cancer (NSCLC). Regarding tumor baseline characteristics, all patients had ASA scores of ≤3, indicating comparable preoperative health status. Six studies explicitly enrolled patients with stage I-II NSCLC, while four studies included patients with stage III/IIIb disease, accounting for <16% of the total sample. Tumor diameter was reported as <6 cm in nine studies, consistent with early-stage disease. Finally, four studies did not report tumor stage or tumor size. In terms of quality, all three RCTs were classified as high quality. Random sequence generation using computer-generated methods was reported in all RCTs. Appropriate allocation concealment using sealed envelopes was described in two studies. Blinding of outcome assessors was reported in two trials (one single-blind, one double-blind); complete blinding of patients and surgeons was not feasible due to the nature of the surgical intervention. Additionally, all six PSM studies and nine retrospective studies were judged to be of high methodological quality. Detailed characteristics and quality assessment of all the included studies are shown in Table I (15-32).

Intraoperative parameters. Patients in the NIVATS group displayed a significantly shorter operative time (MD=-11.02; 95% CI, -18.78 to -3.27; I^2=68.1%) and a slightly lower number of lymph nodes harvested (MD=-0.67; 95% CI, -1.24 to -0.11; I^2=22.3%) compared with the IVATS group. No statistically significant differences were observed between groups for anesthesia time (MD=-9.35; 95% CI, -21.02 to 2.33; I^2=86.9%) or intraoperative blood loss (MD=-9.38; 95% CI, -19.53 to 0.78; I^2=51.8%) (Fig. 2).

Postoperative recovery. The NIVATS group showed significantly shorter anesthesia waking time (MD=-22.88; 95% CI, -33.13 to -12.64; I^2=98.4%), feeding time (MD=-4.53; 95% CI, -5.74 to -3.32; I^2=95.0%), chest tube indwelling time (MD=-0.68; 95% CI, -1.16 to -0.21; I^2=75.2%), and hospital stay (MD=-1.16; 95% CI, -1.57 to -0.74; I^2=52.1%) compared with the IVATS group (Fig. 3).

Safety and complications. The pooled incidence of overall complications was 15.79% in the NIVATS group and 23.13% in the IVATS group. The most common events included sore throat (6.20 vs. 26.03%), pneumonia (3.47 vs. 5.95%) and air leakage (8.50 vs. 10.17%). Re-intubation was required in 4.33% of NIVATS

Table I. Characteristics of the studies included in the present meta-analysis.

First author, year	Country	design	No. of cases (NIVATS/ IVATS)	Sex, male (NIVATS/ IVATS)	Age, years (NIVATS/ IVATS)	Tumor stage	Tumor size	Intervention method	ASA score	Outcomes[a]	Quality score	(Refs.)
Wu *et al*, 2013	China	Retrospective	36/48	21/27	72.9 (65-84)/ 73.0 (65-87)	Stage I-II NSCLC	<6 cm	Epidural anesthesia, intrathoracic vagusblock + mask	1-3	1/2/3/4/8/ 9/10/11	NOS, 6	(19)
Liu *et al*, 2016	China	PSM	116/116	66/62	56.0±10.3/ 57.3±10.5	Stage Ia NSCLC	<6 cm	Epidural anesthesia + mask	1-3	1/3/4/6/7/ 8/9/11	NOS, 6	(26)
Zhang *et al*, 2017	China	Retrospective	20/20	10/11	58.6±8.1/ 61.7±7.8	Lung cancer	<6 cm	Intercostal nerve block+laryngeal mask	1-2	1/5/8/9	NOS, 6	(17)
Fang *et al*, 2018	China	Retrospective	31/31	16/17	/	Stage I-IIIb NSCLC	-	Thoracic vagus block, 3-7 intercostal block + laryngeal mask	1-2	1/3/5/6/7/ 8/9	NOS, 6	(29)
AlGhamdi *et al*, 2018	Korea	Retrospective	30/30	10/12	64.9±10.5/ 66.1±9.5	Stage I-II NSCLC	<6 cm	Intrathoracic vagusblock + mask	1-3	1/2/3/7/8/ 9/10/11	NOS, 7	(32)
Lan *et al*, 2018	China	PSM	119/119	69/68	56.9±11.1/ 55.3±13.8	Lung cancer	-	Epidural anesthesia, intrathoracic vagus nerve block, intercostal nerve block + laryngeal mask	1-3	1/3/5	NOS, 6	(27)
Zhao *et al*, 2021	China	RCT	30/30	13/15	58.7±4.9/ 58.8±6.5	Lung cancer	<5 cm	Intercostal nerve block + laryngeal mask	1-2	1/3/7/8/9	Jadad, 4	(16)
Jeon *et al*, 2021	Korea	RCT	20/20	13/12	57.4±11.1/ 61.8±7.6	Stage I NSCLC	-	Intercostal nerve block + mask	1-2	1/2/3/4	Jadad, 7	(28)
Wang *et al*, 2021	China	PSM	97/97	41/40	59.6±11.3/ 61.9±11.5	Stage I NSCLC	<6 cm	Epidural anesthesia + mask	1-2	12/13	NOS, 7	(20)
Zheng *et al*, 2021	China	Retrospective	200/200	107/105	/	Stage I-III NSCLC	<10 cm	Thoracic vagus nerve block, pleural surface block, intercostal nerve block + laryngeal mask	1-3	1/2/3/7/ 12/13	NOS, 7	(15)
Pathonsamit *et al*, 2022	Thailand	PSM	52/52	22/24	55 (43.5-65.5) 59.5/ (40.5-68)	Lung cancer	-	Total intravenous anesthesia + mask	1-3	1/2/3/8/ 9/10	NOS, 6	(24)

Table I. Continued.

First author, year	Country	design	No. of cases (NIVATS/ IVATS)	Sex, male (NIVATS/ IVATS)	Age, years (NIVATS/ IVATS)	Tumor stage	Tumor size	Intervention method	ASA score	Outcomes[a]	Quality score	(Refs.)
Qi *et al*, 2022	China	Retrospective	50/50	23/21	59.3±15.1/ 53.4±11.9	Lung cancer	-	Vagus block, intercostal block, thoracic paravertebral block + laryngeal mask	1-2	1/3/5/6/7/ 8/9	NOS, 6	(23)
Chen *et al*, 2022	China	PSM	79/158	33/72	79.4±3.7/ 79.3±3.6	Stage I-III NSCLC	-	Epidural anesthesia, intercostal nerve block, vagus nerve block + mask	1-3	1/3/4/7/ 8/9/11/ 12/13	NOS, 6	(30)
Liu *et al*, 2023	China	Retrospective	28/32	15/15	51.7±13.0/ 54.4±7.3	Lung cancer	-	Anterior serratus and intercostal nerve block + laryngeal mask	1-3	3/9	NOS, 7	(25)
Wang *et al*, 2024	China	RCT	60/60	18/24	51.9±6.4/ 51.4±7.7	Lung cancer	<5 cm	Paracosternal nerve block, vagus nerve block + laryngeal mask	1-2	1/2/4/5/7/ 8/9/10	Jadad, 7	(21)
Chen *et al*, 2011	China	Retrospective	30/30	7/13	57.9±10.4/ 56.5±9.5	Stage I-III NSCLC	<5 cm	Serratus anterior, intercostal nerves, parasternal, vagusnerve + laryngeal mask	1-3	1/2/3/4/7/ 8/10/11	NOS, 7	(31)
Udelsman *et al*, 2024	USA	PSM	30/60	-	-	Stage I	-	Paravertebral or intercostal nerve block, vagus nerve infiltration + mask	1-3	12	NOS, 7	(22)
Yu *et al*, 2024	Thailand	Retrospective	54/78	20/38	65 (55.5-72)/ 65 (59-73)	T1-T4	<5 cm	No regional block + mask	1-2	1/3/4/7/8/9	NOS, 7	(18)

[a]Outcomes: 1, operative time; 2, anesthesia time; 3, blood loss; 4, lymph nodes harvested; 5, anesthesia waking time; 6, feeding time; 7, chest time indwelling time; 8, hospital stay; 9, postoperative complications (including total complications, sore throat, pneumonia, hoarseness, air leakage and arrhythmia); 10, re-intubation; 11, conversion to thoracotomy; 12, overall survival; 13, recurrence-free survival. RCT, randomized controlled trials; PSM, propensity score matching; NIVATS, non-intubated video-assisted thoracic surgery; IVATS, intubated video-assisted thoracic surgery; NSCLC, non-small cell lung cancer; ASA, American Society of Anesthesiologists, NOS, Newcastle-Ottawa Scale.

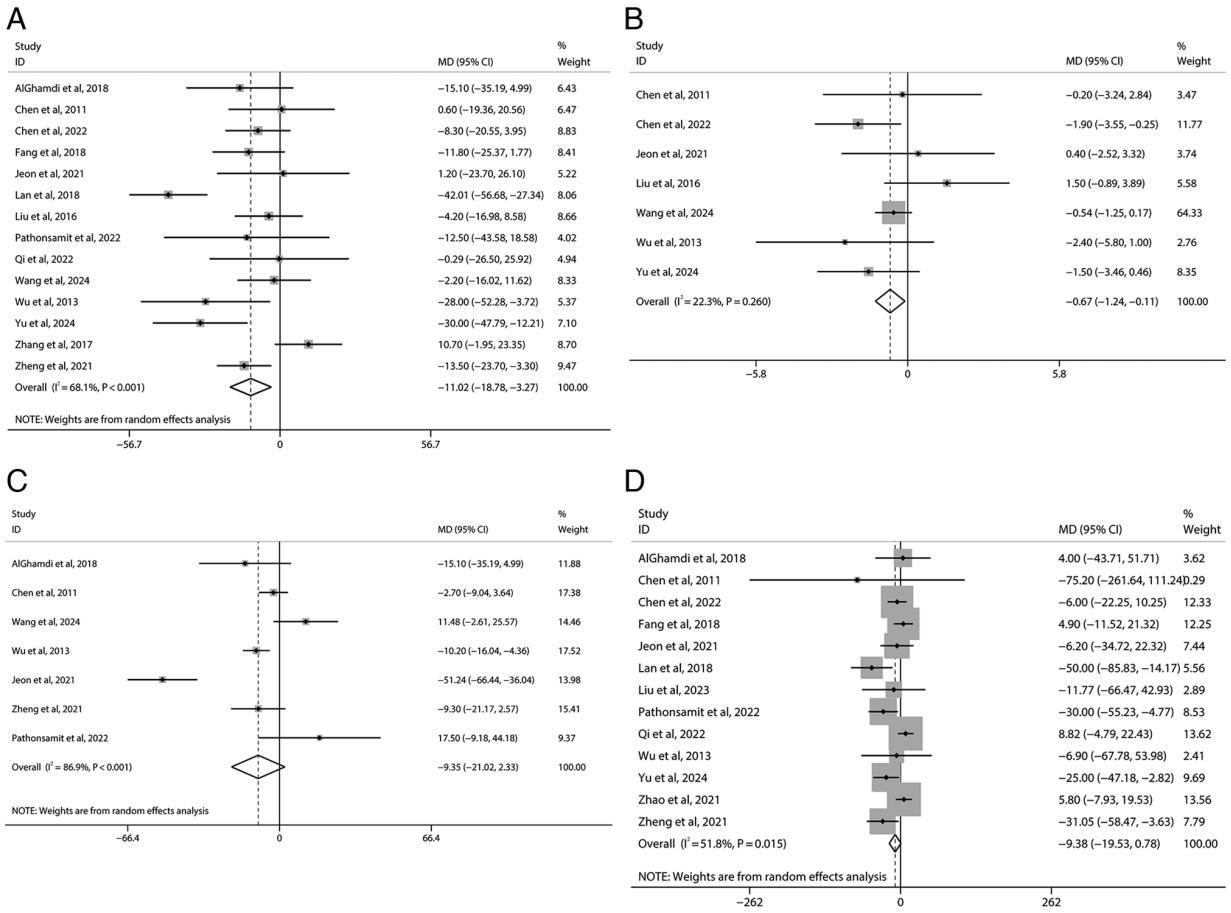

Figure 2. Forest plots of intraoperative parameters for non-intubated video-assisted thoracoscopic surgery vs. control group. (A) Operative time, (B) lymph nodes harvested, (C) anesthesia time and (D) blood loss. WMD, weighted mean difference; CI, confidence interval.

patients, while conversion to thoracotomy rates were similarly low in both groups (0.69 vs. 0.60%). The types and frequencies of individual complications are summarized in Table II. The pooled analysis demonstrated that the overall complication rate was significantly lower in the NIVATS group (OR=0.53; 95% CI, 0.31 to 0.90; I^2=58.0%). Specifically, sore throat (OR=0.18; 95% CI, 0.10 to 0.33; I^2=0%) and pneumonia (OR=0.54; 95% CI, 0.30 to 0.98; I^2=0%) were significantly reduced in the NIVATS group. No statistically significant differences were observed for hoarseness (OR=0.39; 95% CI, 0.10 to 1.49; I^2=0%), air leakage (OR=0.81; 95% CI, 0.42 to 1.57; I^2=0%) or arrhythmia (OR=0.85; 95% CI, 0.38 to 1.90; I^2=0%) (Fig. 4).

Oncological outcomes. The pooled analysis revealed a significantly lower mortality risk in the NIVATS group compared with the IVATS group (HR=0.63; 95% CI, 0.40 to 0.98; I^2=11.3%). Similarly, recurrence-free survival was significantly improved in the NIVATS group (HR=0.62; 95% CI, 0.46 to 0.85; I^2=0%) (Fig. 5).

Subgroup analysis. Subgroup analyses stratified by anesthesia modality (facemask vs. laryngeal mask) were performed for outcomes with substantial heterogeneity (I^2>50%). The complete results are summarized in Table SIII. In general, the direction and significance of effects were consistent across both modalities for most outcomes, although heterogeneity remained elevated in several subgroup analyses (such as anesthesia waking time: Facemask, I^2=94.5%; laryngeal mask, I^2=99.1%).

Publication bias and sensitivity analysis. Publication bias detection and sensitivity analysis were conducted for outcomes reported in ≥10 studies, including operative time, blood loss, chest tube indwelling time, hospital stay, total complications and pneumonia (Figs. S1-S6). Sensitivity analysis indicated that pooled estimates remained stable after stepwise deletion of the included studies, suggesting robust results. Egger's regression test showed no significant publication bias for most outcomes; however, bias was detected for hospital stay (t=-1.850; P=0.009). Therefore, the trim-and-fill method was applied to evaluate the stability of the combined results. The analysis revealed no potentially missing studies were imputed, and the pooled effect size remained unchanged, confirming that the combined results were robust. The detailed results of the publication bias assessment and sensitivity analysis are shown in Table SIV.

Discussion

The present study presents a systematic review and meta-analysis comparing the effectiveness of NIVATS and IVATS for thoracoscopic lobectomy. The results indicated that NIVATS

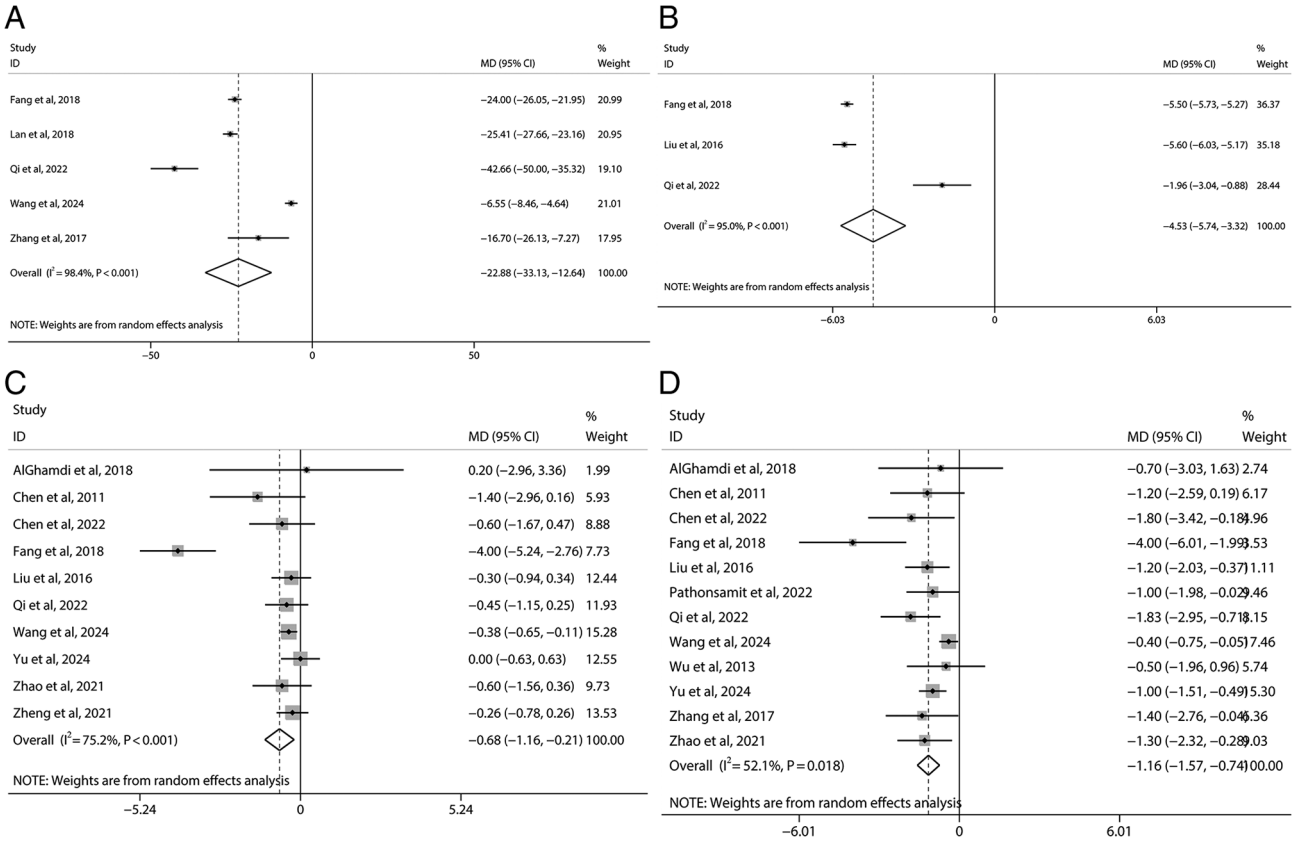

Figure 3. Forest plots of intraoperative parameters for non-intubated video-assisted thoracoscopic surgery vs. control group. (A) Anesthesia waking time, (B) feeding time, (C) chest tube indwelling time and (D) hospital stay. WMD, weighted mean difference, CI, confidence interval.

significantly reduced operative time, anesthesia waking time, feeding time, chest tube indwelling time, hospital stay, and was associated with fewer overall complications, particularly sore throat and pneumonia. Re-intubation was required in 4.33% of NIVATS patients, while conversion to thoracotomy rates were similarly low in both groups (0.69 vs. 0.60%). Additionally, the NIVATS group showed significantly improved overall survival and recurrence-free survival compared with the IVATS group. No significant differences were observed between the two approaches for anesthesia time, blood loss, hoarseness, air leakage or arrhythmia.

With ongoing advances of medical science, the concept of ERAS has gained increasing popularity. VATS has become a standard approach in thoracic surgery due to its minimally invasive nature, thus protecting chest wall integrity, reducing surgical trauma and accelerating postoperative recovery (33,34). Conventional intubated anesthesia is commonly associated with adverse postoperative reactions and prolonged recovery time (35,36). By contrast, NIVATS enables spontaneous respiration, thereby avoiding tracheal intubation and reducing airway-related complications, stress and inflammatory reactions, while improving cellular immune function and promoting rapid recovery (37,38). Standard techniques include intercostal nerve block, paravertebral block, thoracic epidural anesthesia and laryngeal mask-assisted spontaneous respiration anesthesia (39). However, NIVATS exhibits technical challenges, particularly for anesthesiologists who need to balance its benefits against potential risks, including the management of iatrogenic open pneumothorax (40). NIVATS has evolved from the use of single epidural anesthesia to a range of combined anesthetic techniques and is now applied in various thoracic surgeries, including wedge resection, bullectomy, sympathectomy and pleural mass resection (5). Initially, its application in more complex surgeries, such as lobectomies, was limited due to the cough reflexes. During surgery, manipulation of the hilum can irritate the vagus nerve, thus resulting in mediastinal oscillation and diaphragmatic elevation. Sevoflurane anesthesia can suppress cough reflexes, thereby facilitating a stable surgical environment and enabling anatomical lobectomy. Non-intubated anesthesia can be individualized based on patient characteristics through a combination of intravenous, epidural or local anesthesia, nerve blocks, and pleural infiltration (41). This strategy ensures intraoperative stability and promotes postoperative recovery. However, the safety and efficacy of NIVATS in thoracoscopic lobectomy remain controversial due to its high anesthesia requirements and the need for careful patient selection.

The results of the present study revealed no significant difference in intraoperative blood loss between the two groups. This finding could be due to the employment of modern minimally invasive techniques, such as VATS, which ensures accurate dissection while minimizing tissue injury (42). In addition, patients in both groups could experience intraoperative complications, such as coughing and involuntary movements, including mediastinal displacement, thus contributing to procedural complexity (43).

Notably, patients in the NIVATS group showed a significant advantage in reducing postoperative airway complications.

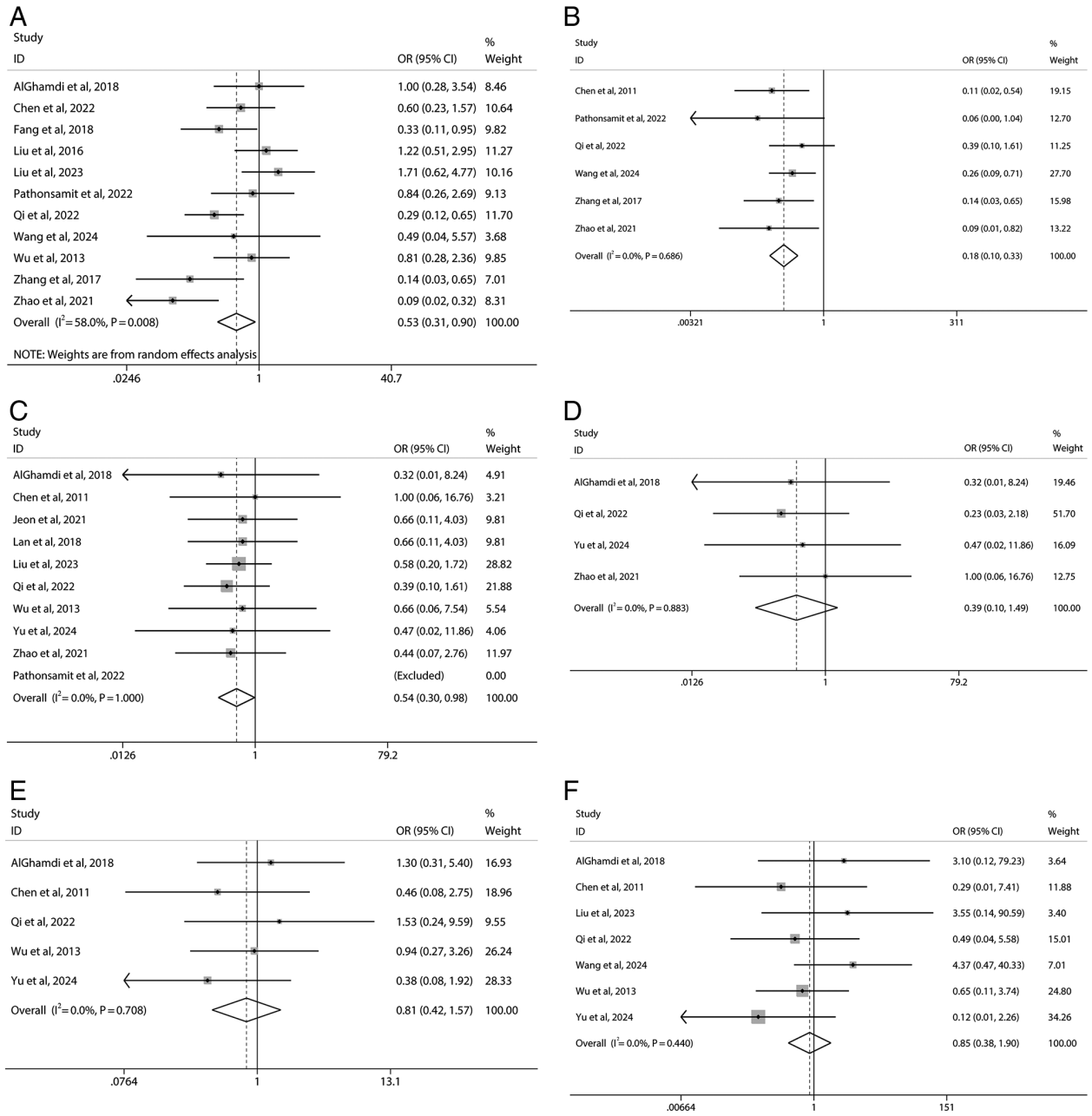

Figure 4. Forest plots of safety and complication outcomes for non-intubated video-assisted thoracoscopic surgery vs. control group. (A) Total complications, (B) sore throat, (C), pneumonia, (D) hoarseness, (E) air leakage and (F) arrhythmia. CI, confidence interval; OR, odds ratio.

Particularly, NIVATS was markedly associated with a reduced incidence of postoperative adverse reactions such as sore throat and pneumonia. This could be due to the fact that patients in the NIVATS group were able to breathe spontaneously without the need for tracheal intubation or mechanical ventilation, thereby avoiding intubation-related complications and general anesthesia-related complications.

Previous studies have suggested that NIVATS performed under local or regional anesthesia can attenuate inflammatory responses, as evidenced by reduced levels of inflammatory cytokines, such as tumor necrosis factor-α and C-reactive protein, modulation of lymphocyte activity, and reduced stress hormone release (44). These effects could partially explain the improved postoperative recovery and lower complication rates observed in the NIVATS group.

In terms of long-term outcomes, the pooled analysis showed an association between NIVATS and improved survival compared with IVATS. This finding was consistent with the results of a retrospective study by Zheng *et al* (15), suggesting that patients who underwent self-ventilated VATS lobectomy had significantly improved overall survival and disease-free survival compared with those who underwent mechanically ventilated thoracoscopic surgery and open lobectomy. Greater reliance on regional anesthesia and reduced opioid use postoperatively have been proposed as potential contributing factors (45,46). However, recent studies have shown inconsistent findings. Two propensity score-matching studies by Wang *et al* (21) and Chen *et al* (30) reported that patients who underwent NIVATS achieved comparable local control, disease-free and overall survival to those who were treated with IVATS. These discrepancies could be attributed

Table II. Summary of complications.

Complication	NIVATS, %	IVATS, %
Re-intubation	4.33	-
Conversion to thoracotomy	0.69	0.60
Total complications	15.79	23.13
Sore throat	6.20	26.03
Hoarseness	1.22	3.72
Pneumonia	3.47	5.95
Air leakage	8.50	10.17
Arrhythmia	3.13	3.96

NIVATS, non-intubated video-assisted thoracic surgery; IVATS, intubated video-assisted thoracic surgery.

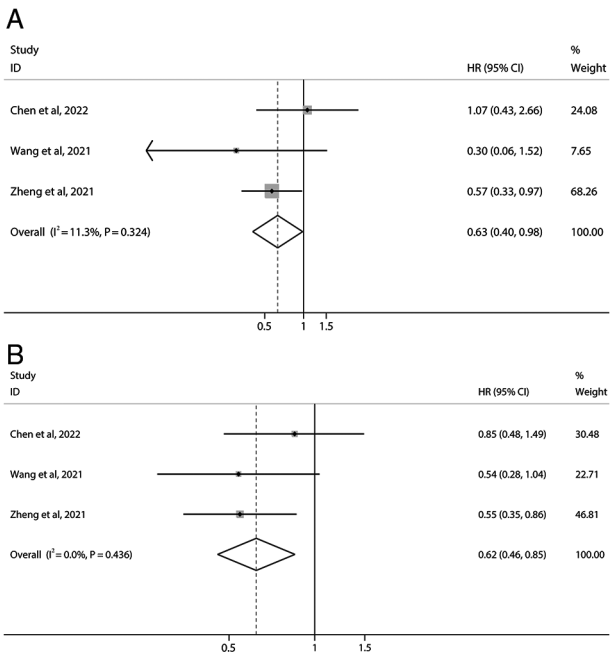

Figure 5. Forest plots of oncological outcomes for non-intubated video-assisted thoracoscopic surgery vs. control group. (A) Overall survival and (B) recurrence-free survival. HR, hazard ratio; CI, confidence interval.

to differences in patient selection, tumor characteristics, surgical approaches and techniques, which could affect the balance of prognostic factors between groups. Overall, NIVATS was associated with improved survival in limited observational evidence; however, causality cannot be inferred.

Although NIVATS offers advantages in postoperative recovery, potential intraoperative safety risks warrant higher attention. A meta-analysis of 19 RCTs suggested that NIVATS could be associated with a higher incidence of intraoperative hypoxemia compared with IVATS. However, this risk could be mitigated through careful patient selection and intraoperative crisis resource management (47). Additionally, a PSM study reported a 7.7% conversion rate to intubation in the NIVATS group due to surgical difficulties, along with markedly elevated peak end-tidal CO_2 levels (24). In addition to hypoxemia and hypercapnia, the present pooled descriptive data showed a re-intubation rate of 4.33% in NIVATS patients, highlighting the need for preparedness to convert to intubation during NIVATS procedures. To minimize these risks, careful patient selection is essential. Contraindications to NIVATS could include difficult airway, morbid obesity (BMI >30), extensive pleural adhesions, severe cardiopulmonary dysfunction and complex surgical procedures (40).

Several meta-analyses have compared NIVATS with IVATS for thoracic surgery (47-53). A previously published Chinese-language meta-analysis reported perioperative advantages of NIVATS for thoracoscopic lobectomy; however, the review focused on short-term endpoints, included mixed surgical types and did not assess long-term oncological outcomes or procedure-specific safety indicators such as re-intubation and conversion-to-thoracotomy rates (53). Although the present perioperative findings are broadly consistent with the previous report, the present study extends the evidence in several important respects. First, overall survival and recurrence-free survival were systematically evaluated, which were not assessed in previous meta-analyses. Second, NIVATS-specific safety indicators, including re-intubation and conversion-to-thoracotomy rates, were investigated which have not been quantitatively analyzed in previous reviews. Third, a detailed breakdown of postoperative complications, distinguishing intubation-related events from pulmonary and cardiovascular events, was performed rather than reporting a single aggregated 'airway complications' endpoint. Fourth, most previous analyses included mixed thoracic procedures (such as bullectomy, wedge resection or sympathectomy) rather than focusing specifically on lung cancer, and some were limited by small sample sizes from early studies. By contrast, the present study focused exclusively on lobectomy for lung cancer and incorporated 18 studies, offering more comprehensive and specific evidence for this common procedure. Fifth, detailed subgroup analyses by anesthesia technique (facemask vs. laryngeal mask) were performed, which were not extensively explored in prior reviews or meta-analyses.

NIVATS is a viable option for strictly selected patients undergoing thoracic surgery, with confirmed feasibility, safety and effectiveness under spontaneous ventilation. However, complete evaluation systems and practice guidelines are urgently needed. Future large-scale, multicenter, prospective studies are warranted to further confirm long-term outcomes. Since an increasing number of medical centers adopt NIVATS, its surgical indications can gradually expand, thus potentially benefiting a larger number of patients.

The present study has several limitations. First, the majority of the included studies were retrospective and the number of RCTs was limited, which could have introduced selection and information bias. Therefore, further high-quality RCTs are needed to validate these findings. Second, the overall sample size was relatively small, and most studies were carried out at single centers, potentially leading to publication bias and overestimated effect sizes. Third, differences in the anesthetic techniques used for NIVATS, in combination with differences in patient characteristics, likely contributed to heterogeneity in several outcomes. Fourth, survival analyses were based on only three studies, the majority of which were observational, limiting the ability to draw causal inferences regarding long-term outcomes. Due

to the limited number of studies, more detailed subgroup and sensitivity analyses could not be performed. The small number of studies also precluded definitive conclusions, and future, large-scale RCTs are needed to confirm these findings. Fifth, substantial heterogeneity persisted in several outcomes, including anesthesia waking time and feeding time despite subgroup analyses by anesthesia technique and study design, thus suggesting that additional unmeasured factors could contribute to variability, such as differences in institutional ERAS protocols, variations in surgical expertise and learning curves, and heterogeneity in patient selection criteria across studies. Sixth, learning curve and center expertise bias may affect the outcomes, as experience with NIVATS varies across studies, and centers with greater expertise may overestimate its benefits. Additionally, patient selection constraints inherent in the primary studies, such as differences in inclusion and exclusion criteria may introduce heterogeneity, as selection criteria were not uniformly reported. These factors should be considered when interpreting the findings. Despite these limitations, the present study applied rigorous inclusion and exclusion criteria to comprehensively analyze the available evidence on non-intubated anesthesia thoracoscopic lobectomy, providing valuable insights to support clinical decision-making.

Overall, compared with IVATS, NIVATS in patients undergoing thoracoscopic lobectomy showed advantages in perioperative outcomes and fewer postoperative complications. Preliminary evidence also suggested improved overall survival and recurrence-free survival, although these findings require further confirmation. Within the ERAS framework, NIVATS appears to be a safe and technically feasible alternative for patients undergoing thoracoscopic lobectomy in appropriately selected cases. Large-scale, multicenter RCTs with long-term oncological follow-up are warranted to validate these findings and inform clinical decision-making.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

LH performed data curation, methodology, visualization and wrote the original draft. YZ conceptualized the present study, performed the data curation, formal analysis, methodology and reviewed and edited the manuscript. LH and YZ confirm the authenticity of all the raw data. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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