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SYSTEMATIC REVIEW

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Comparison of non-intubated and intubated video-assisted thoracoscopic surgery for perioperative complications—a systematic review and meta-analysis

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Abstract

Background Non-intubated video-assisted thoracic surgery (NIVATS) avoids lung injury and intubation-related complications from mechanical ventilation, but the intraoperative safety and postoperative recovery quality of NIVATS remain controversial. Consequently, we systematically assessed the viability and safety of non-intubated video-assisted thoracic surgery (NIVATS) in comparison to intubated video-assisted thoracic surgery (IVATS). These findings provide evidence for optimizing anesthetic and surgical decision-making.

Methods PubMed, Web of Science, Embase, Cochrane Library, OVID, and Google Scholar were queried from their establishment until October 2024. We included eligible studies that compared non-intubated anesthesia with intubated anesthesia for video-assisted thoracoscopic surgery for thoracic conditions. Following the evaluation of bias risk in these randomized controlled trials (RCTs), a meta-analysis was conducted using Review Manager (Manager 5.4).

Results Nineteen randomized controlled trials were incorporated into the study. NIVATS demonstrated a reduced length of hospital stay, feeding time, and chest-tube dwell time compared to intubated methods. IVATS groups, hypoxemia exhibited a reduced incidence, but perioperative cough and perioperative arrhythmias revealed no statistically significant differences between IVATS and NIVATS groups. The NIVATS groups exhibited a significantly reduced risk compared to the IVATS groups for postoperative pulmonary complications (PPCs), postoperative nausea and vomiting (PONV), and sore throat.

Conclusions NIVATS avoid complications associated with intubation and are able to accelerate patient recovery to a certain extent. Although NIVATS carries intraoperative safety risks, careful patient selection can mitigate these risks.

Keywords Thoracic surgery, Non-intubated anesthesia, Length of hospital stay, PPCs, Meta-analysis, VATS

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Introduction

Since Carlens introduced double-lumen endotracheal intubation general anesthesia in 1949, it is considered the gold standard for thoracic anesthesia in the field of thoracic surgery [1]. Lung isolation, surgical field exposure, and surgical process facilitation can all be accomplished with one-lung ventilation (OLV). However, there are noticeable side effects from intubated general anesthesia with OLV, such as postoperative sore throat, hoarseness, ventilator-related problems, nausea and vomiting, and decreased lung function [2, 3].

Recently, the'Enhanced Recovery After Surgery'(ERAS) approach has gained significant prominence, and non-intubated video-assisted thoracic surgery (NIVATS) has been more widely used. IVATS reduces the risks from intubating the trachea and the post-operative effects of muscle relaxants, allowing post-operative improvement in breathing functions and airway clearance and limiting the incidence of post-operative complications [4, 5]. This anesthesia has been successfully employed in video-assisted thoracic surgery (VATS) procedures, such as alveolar resection [6, 7], thoracic sympathectomy [8, 9], pulmonary nodule resection [10, 11], mediastinal tumor resection [12, 13], and pleural biopsy [14]. This procedure reduces airway complications and conforms to the modern approach of rapid rehabilitation surgery [15, 16].

Although NIVATS offers advantages over IVATS, it carries risks such as mediastinal flutter, intraoperative cough, hypercapnia, and hypoxemia. These challenges require precise surgical and anesthetic management [3, 15, 17]. Currently, high-quality, multicentre studies assessing the safety and efficacy of NIVATS remain limited, and it remains uncertain whether the efficacy of NIVATS is equivalent to or superior to that of IVATS. This meta-analysis evaluated the incidence of complications, quality of postoperative recovery, and duration of hospital stay to ascertain the benefits of NIVATS on overall patient recovery. Additionally, it examined intraoperative cough, hypoxemia, and heart rate arrhythmia to assess the feasibility and safety of NIVATS. These studies are important indicators of perioperative safety for the treatment of various thoracic diseases and evidence for optimizing anesthetic and surgical decision-making.

Material and methods

This study was reported under PRISMA [18]. This meta-analysis has been entered into PROSPERO (PROSPERO). Number of registrations: CRD42024620928.

Search strategy

PubMed, Web of Science, Embase, Cochrane Library, OVID, and Google Scholar were queried from their establishment until October 2024. We combined the phrases'non-intubated,"non-tracheal intubation,"awake,'or'wake,'or'spontaneous respiration,'or'spontaneous,'or'tubeless'with'video-assisted thoracoscopic surgery'in conjunction with corresponding Medical Subject Headings (MeSH) terms. A supplementary manual search was conducted on the reference indexes of acquired review papers and primary studies, as well as conference abstracts. All results were analyzed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Now, using PubMed as an example, the specific search strategy is as follows:

Search	PUBMED
#1	((((((((((((((((((Surgeries, Video-Assisted Thoracic[Title/Abstract]) OR (Surgery, Video-Assisted Thoracic[Title/Abstract])) OR (Thoracic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracic Surgery, Video Assisted[Title/Abstract])) OR (Video-Assisted Thoracic Surgeries[Title/Abstract])) OR (Surgery, Thoracic, Video-Assisted[Title/Abstract])) OR (VATS[Title/Abstract])) OR (VATSs[Title/Abstract])) OR (Video-Assisted Thoracic Surgery[Title/Abstract])) OR (Video Assisted Thoracic Surgery[Title/Abstract])) OR (Video-Assisted Thoracoscopic Surgery[Title/Abstract])) OR (Surgeries, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Surgery, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Thoracoscopic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracoscopic Surgery, Video-Assisted[Title/Abstract])) OR (Video-Assisted Thoracoscopic Surgeries[Title/Abstract])) OR (Video Assisted Thoracoscopic Surgery[Title/Abstract])) OR ("Thoracic Surgery, Video-Assisted"[Mesh])
#2	((((((non-intubated[Title/Abstract]) OR (non-tracheal intubation[Title/Abstract])) OR (awake[Title/Abstract])) OR (wake[Title/Abstract])) OR (spontaneous respiration[Title/Abstract])) OR (spontaneous[Title/Abstract])) OR (tubeless[Title/Abstract])
#3	#1 AND #2

Inclusion criteria

(1) Comparisons between NIVATS and IVATS; (2) all patients who underwent identical surgical procedures, excluding intubation, anesthesia, or ventilation; (3) a randomized controlled trial (RCT) was used as the experimental design; (4) sufficient data were accessible for the computation of weighted mean differences (WMD) or risk ratios (RR).

Exclusion criteria

(1) Absence of comparison between NIVATS and IVATS; (2) Patients who were intubated and those who were not

were operated on differently; (3) Reviews, editorials, letters, case reports, expert opinions, and animal studies; (4) Inability to extract relevant data.

Study selection

The literatures were evaluated and eliminated utilizing the literature administration program Endnote. Two investigators first checked the literature titles for duplicates, non-randomized controlled trials, conference papers, protocols, review articles, and correspondence. After that, two researchers looked over the literature abstracts to establish inclusion and exclusion standards. Ultimately, the residual materials were thoroughly reviewed by two investigators and subsequently recognized for inclusion. Throughout the procedure, two researchers separately evaluated the papers and subsequently contrasted the remaining studies; if they concurred, the studies were included, while disagreements were the responsibility of a third researcher.

Data extraction

Data collection for study enrolment, the standardized eight-item data extraction form was used in the following categories: (1) author, (2) country, (3) year of publication, (4) type of surgery, (5) mean age, (6) sample size, (7) details of the intervention, (8) outcome.

Potential for risk of bias

The quality of the randomized controlled trials was assessed using the Cochrane Collaboration's risk of bias assessment technique, with all items categorized as'low risk,''uncertain,'or'high risk' [19].

Analyzing data

Review Manager (Manager 5.4) was used for the meta-analysis. Statistical heterogeneity was evaluated using Higgins I^2, which reflects the proportion of total variation among the trials. A fixed-effect model (Mantel–Haenszel method) was employed to aggregate homogeneous studies where the I^2 was below 50%; alternatively, a random-effects model (DerSimonian-Laird) was adopted and is considered to have high heterogeneity. The potential for publication bias was analyzed by running a funnel plot, with asymmetry analyzed via Begg's test and Egger's test; $p < 0.05$ indicates publication bias, while $p > 0.05$ indicates no significant publication bias. Statistical significance was established when the p-value fell below 0.05.

Results

Basic characteristics of included trials

Figure 1 illustrates a flowchart outlining the process of selecting eligible studies based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. From the electronic database, a total of 5014 documents were acquired, along with 3 items identified by manual search. Subsequent to the elimination of duplication, 2831 papers were screened using titles and abstracts, resulting in 2434 being excluded. A comprehensive evaluation of 397 documents was conducted, leading to the exclusion of 378 documents for reasons including non-randomized controlled trials, conference papers, inadequate data, and non-adherence to designated interventions in this study. Consequently, 19 documents were ultimately involved in this analysis (Fig. 1). Table 1 presents fundamental features about the involved trials, comprising 2,222 patients, with 1,102 in the NIVATS group and 1,120 in the IVATS group. We performed a GRADE (Grade of Recommendations Assessment, Development and Evaluation) assessment, and the specific results are in Table S4 of the Supplementary Materials.

Quality assessment

The risk of bias was assessed using the risk of bias assessment methodology endorsed through the Cochrane system. The majority of the research featured in the publication defined randomization procedures, allocation concealment, blinding, and data integrity. Figure 2 displays the quality assessment outcomes of these selected papers.

Publication bias and sensitivity analysis

The funnel plots showed symmetrical distributions for the majority of outcomes (Supplementary Figs). Findings from Begg's test and Egger's test further validated the nonexistence of publication bias among the final outcomes. The specific consequences are detailed in Supplementary Material, Table S3. A sensitivity analysis demonstrated the reliable stability of the majority of our outputs (Supplementary Figs.).

Meta-analysis results

Postoperative recovery

(1) Hospital stay and subgroup analysis A total of 16 articles reported the length of hospital stay, which included 1904 patients in the analysis. Heterogeneity analyses indicated significant variability in length of hospital stay ($p = 0$, $I^2 = 93\%$), necessitating the adoption of random effects models for the analysis. The result revealed that the NIVATS group spent significantly less time in the hospital compared to those being treated with IVATS (WMD: −1.09; 95% CI, −1.56 to −0.62; $p = 0$; Fig. 3). We performed subgroup analyses to identify sources of heterogeneity, examining factors such as type of surgery, oxygen administration mode, and local

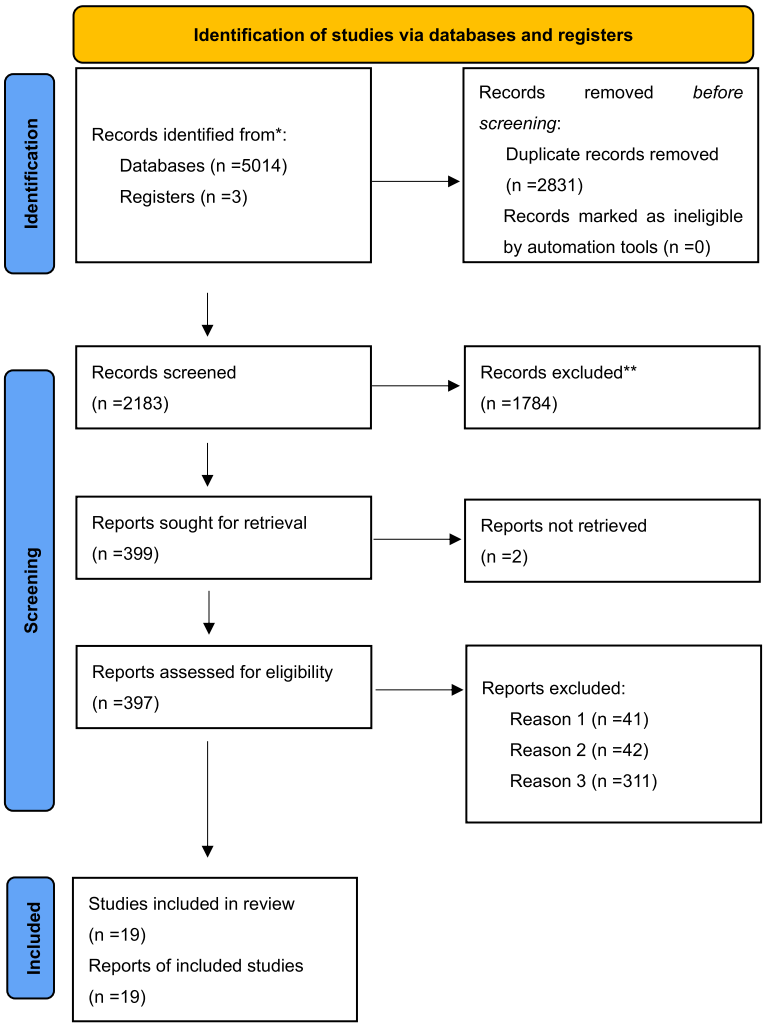

Fig. 1 PRISMA flow diagram

anaesthesia type. We determined that operation type did not contribute to heterogeneity by doing subgroup analyses, which revealed that both uniportal VATS (WMD: −1.32; 95% CI, −2.27 to −0.37; $p = 0.07$) and VATS (WMD: −0.88; 95% CI, −1.35 to −0.40; $p = 0.0003$) were statistically significant for length of hospital stay. We discovered that two oxygen administration modes, laryngeal mask airway (LMA) (WMD: −1.07; 95% CI, −1.86 to −0.29; $p = 0.007$) and Mask (WMD: −1.02; 95% CI, −1.38 to −0.67; $p = 0$), showed statistically significant differences, indicating that the oxygen administration mode was not a source of heterogeneity. Nevertheless, in the subgroup analysis of local anesthesia type, we discovered that two types, thoracic paravertebral block (TPVB) (WMD: −1.02; 95% CI, −1.97 to −0.06; $p = 0.04$) and thoracic epidural anesthesia (TEA) (WMD: −0.93; 95% CI, −1.29 to −0.56; $p = 0$), were statistically significant, while the category labeled'Other'(WMD: −1.16; 95% CI, −4.33 to 1.10; $p = 0.244$) was not statistically significant, suggesting that the type of local anesthesia may influence heterogeneity (Supplementary Figs.).

(2) Feeding time, chest-tube dwell time, first ambulation time and VAS The analysis of feeding time ($p = 0$, $I^2 = 94\%$), chest-tube dwell time ($p = 0$, $I^2 = 70\%$), and first ambulation time ($p = 0$, $I^2 = 97\%$) revealed that both feeding time (WMD: −4.46; 95% CI, −6.79 to −2.14; $p = 0.0002$; Fig. 4) and chest-tube dwell time (WMD: −0.34; 95% CI, −0.61 to −0.07; $p = 0.01$) were markedly shortened in the NIVATS group in comparison to the IVATS group, while no statistically significant difference was noted about the first ambulation time (WMD: −3.42; 95% CI, −7.50 to 0.65; $p = 0.1$) between the two groups. There are 11 studies with 1,146 patients reporting VAS ($p = 0.05$, $I^2 = 47\%$), which demonstrated the NIVATS group had a significantly lower VATS group (WMD: −0.18; 95%

Table 1 Studies included in the meta-analysis

Author	Country	Year	Type of surgery	Age(mean + SD)	Total/male/female	Intervention	Control	Outcomes
Xiangang Kong [3]	China	2024	uniportal VATS	I:58(13) C:58(9.3)	I:35/16/19 C:35/17/18	LMA + TPVB	DLT	⑥⑦⑬⑭
Lingfei Wang [20]	China	2024	uniportal VATS	I:51.7(7.7) C:51.9(6.4)	I:60/24/36 C:60/18/42	LMA + TPVB	DLT	①②③④⑤⑥⑦⑧⑩⑪⑫⑭
YongFeng Zheng [21]	China	2023	uniportal VATS	I:47.2(11.7) C:46.17(10.25)	I:29/15/14 C:30/14/16	LMA + TPVB	DLT	①②③④⑤⑨⑫⑬⑭
Thomas Galetin [17]	Germany	2023	VATS	I:67(12) C:67(12)	I:50/NA C:57/NA	Mask + TEA	DLT	①③④⑨⑪
Yu Huang [15]	China	2022	VATS	I:67(12) C:67(12)	I:30/14/16 C:30/10/20	LMA + TPVB	DLT	①④⑤⑦⑧⑨⑩⑫⑭
Jun Liu [16]	China	2022	uniportal VATS	I:22.6(6.8) C:23.1(7.6)	I:162/152/10 C:163/155/8	LMA + other	DLT	①②③⑤⑥⑧⑨⑩⑪⑫⑭
Chengya Huang [22]	China	2022	VATS	I:49(14.1) C:50(13.3)	I:109/15/94 C:108/20/88	LMA + TPVB	DLT	①④⑥⑦⑧⑨⑪⑫⑬⑭
Mohamed Rabeea [23]	Egypt	2022	uniportal VATS	I:33.4(8.8) C:36(10.1)	I:30/16/14 C:30/20/10	LMA + TEA	DLT	①③④⑨
Wei Wei [24]	China	2020	VATS	I:3(2.2) C:4(1.5)	I:29/9/20 C:29/12/17	LMA + TPVB	Blocker	②⑤⑥⑨⑫⑭
Xiaobing Xiang [25]	China	2020	uniportal VATS	I:48.3(4.2) C:46.3(4.5)	I:40/23/17 C:40/25/15	LMA + TPVB LMA + other	DLT	①⑨⑪⑫⑭
Celalettin Kocatürk [26]	Turkey	2019	uniportal VATS	I:55.1(17.2) C:52.2(15.7)	I:145/93/52 C:148/108/40	Mask + other	DLT	③⑨
Jinwook Hwang [27]	Korea	2018	uniportal VATS	NA	I:20/20/0 C:21/18/3	Mask + other	DLT	③⑨⑫
Fei Cui [28]	China	2016	VATS	I:22.1(7.2) C:26.5(9.5)	I:89/56/33 C:82/43/39	Mask + TEA	DLT	①②⑨⑪
Jun Liu [29]	China	2014	VATS	NA	I:167/NA C:180/NA	Mask + TEA	DLT	①②⑧⑪
Eugenio Pompeo [30]	Italy	2013	uniportal VATS	I:67(12) C:67(10)	I:20/13/7 C:20/10/10	Mask + TEA	DLT	①③⑨
Federico Tacconi [31]	Italy	2010	VATS	I:48(1.5) C:48.5(14.8)	I:11/7/4 C:10/6/4	Mask + TEA	DLT	①⑨
Gianluca Vanni [32]	Italy	2010	VATS	I:57(8.1) C:52(10.3)	I:25/15/10 C:25/16/9	Mask + TEA	DLT	①⑨
Eugenio Pompeo [11]	Italy	2007	VATS	I:28(14) C:26(11)	I:21/17/4 C:22/17/5	Mask + TEA	DLT	①③⑨
Eugenio Pompeo [10]	Italy	2004	VATS	I:60(17) C:63.5(5.2)	I:30/20/10 C:30/21/9	Mask + TEA	DLT	①③⑨

① Hospital stay ② Feeding time ③ VAS ④ Chest-tube dwell time ⑤ First ambulation time ⑥ Hypoxemia ⑦ Perioperative cough
⑧ Perioperative arrhythmia ⑨ Surgery duration ⑩ Awakening time ⑪ PPCs ⑫ PONV ⑬ Atelectasis ⑭ Sore throat

VATS video-assisted thoracic surgery with three incisions; uniportal, *VATS* video-assisted thoracic surgery with uniportal incision, *VAS* visual analogue scale score, *DLT* double-lumen tracheal intubation, *LMA* laryngeal mask airway, *TEA* thoracic epidural anesthesia, *PPCs* postoperative pulmonary complications, *PONV* postoperative nausea and vomiting

CI, −0.33 to −0.03; $p = 0.02$; Fig. 5). Subgroup analysis in feeding time and VAS based on operation type, oxygen administration mode, and local anesthesia type; the comprehensive results are encapsulated in Supplementary Material, Table S2 (Supplementary Figs.).

Perioperative safety

(1) Hypoxemia, perioperative cough and perioperative arrhythmia Only four trials with 733 participants assessed hypoxemia ($p = 0.31$, $I^2 = 17\%$), showing a significant deviation among the NIVATS and IVATS groups, with IVATS demonstrating superior efficacy over NIVATS (RR: 1.78; 95% CI, 1.03 to 3.07; $p = 0.04$). Perioperative cough ($p = 0.005$, $I^2 = 77\%$) was documented in four investigations involving 467 patients, showed no significant variation in outcomes among the NIVATS and IVATS groups (RR: 2.58; 95% CI, 0.55 to 12.16; $p = 0.23$). Analysis of data from six studies including 1,125 patients and revealed no statistical difference in the rate of perioperative arrhythmias ($p = 0.18$, $I^2 = 36\%$) over the IVATS and NIVATS groups (RR: 0.69; 95% CI, 0.38 to 1.26; $p = 0.227$) (Supplementary Figs.).

(2) Surgery duration and awakening time.

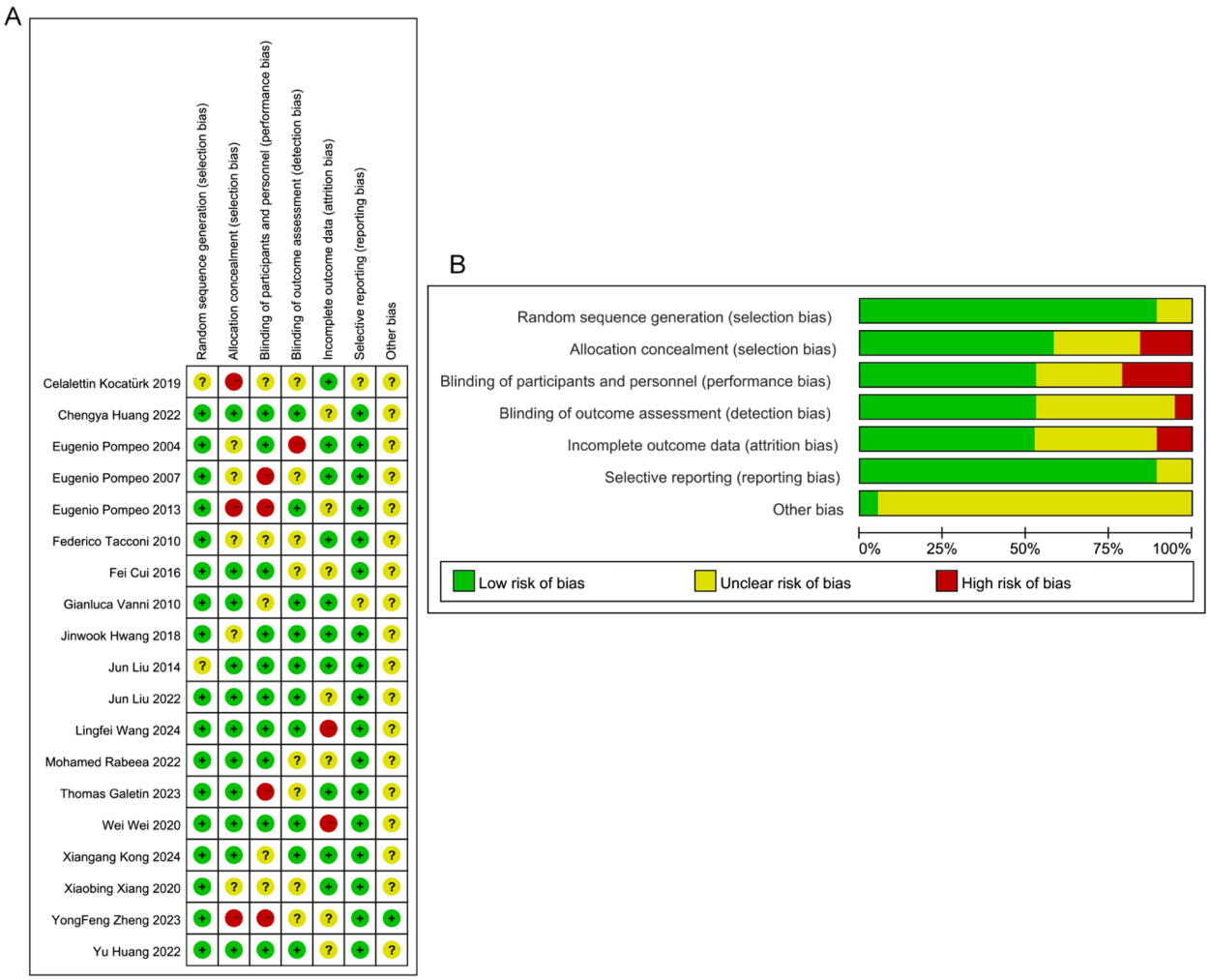

Fig. 2 Risk of bias analysis for the RCTs. **A** Risk of bias summary reviewing the authors' judgments regarding each risk of bias item for each included study. **B** Risk of bias graph reviewing the authors' judgments regarding each risk of bias item presented as percentages across all included studies. RCTs, randomized controlled trials

Seventeen studies including 1,771 patients indicated that the surgery duration ($p = 0$, $I^2 = 77\%$) was considerably less in the NIVATS group in comparison to the IVATS group (WMD: −2.33; 95% CI, −3.73 to −0.92; $p = 0.001$ Fig. 6). Subgroup analysis in accordance with operation type, oxygen administration mode, and local anesthesia type; the detailed results are summarized in Supplementary Material, Table S2 (Supplementary Figs.). Four trials with 722 people evaluated awakening time ($p = 0$, $I^2 = 93\%$), demonstrating a considerable disparity between the NIVATS and IVATS groups, with the NIVATS group exhibiting a markedly faster recovery than the VATS group (WMD: −7.97; 95% CI, −11.97 to −3.97; $p = 0$) (Supplementary Figs.).

Postoperative complications

Seven trials involving 1,171 patients revealed the PPCs ($p = 0.05$, $I^2 = 50\%$), demonstrating that the NIVATS group had a much lower risk than the IVATS group (RR: 0.48; 95% CI, 0.27 to 0.87; $p = 0.01$; Fig. 7). The incidence of PONV ($p = 0.76$, $I^2 = 0\%$) and sore throat ($p = 0.54$, $I^2 = 0\%$) with the NIVATS group was greatly fewer than in the IVATS group (RR: 0.59; 95% CI, 0.44 to 0.80; $p = 0.00006$) (RR: 0.37; 95% CI, 0.25 to 0.54; $p = 0$); nevertheless, atelectasis ($p = 0.54$, $I^2 = 0\%$) exhibited no statistically significant variations among the two groups (RR: 0.42; 95% CI, 0.16 to 1.10; $p = 0.08$). Full meta-analysis results are detailed in supplementary material (Supplementary Material, Table S1) (Supplementary Figs.).

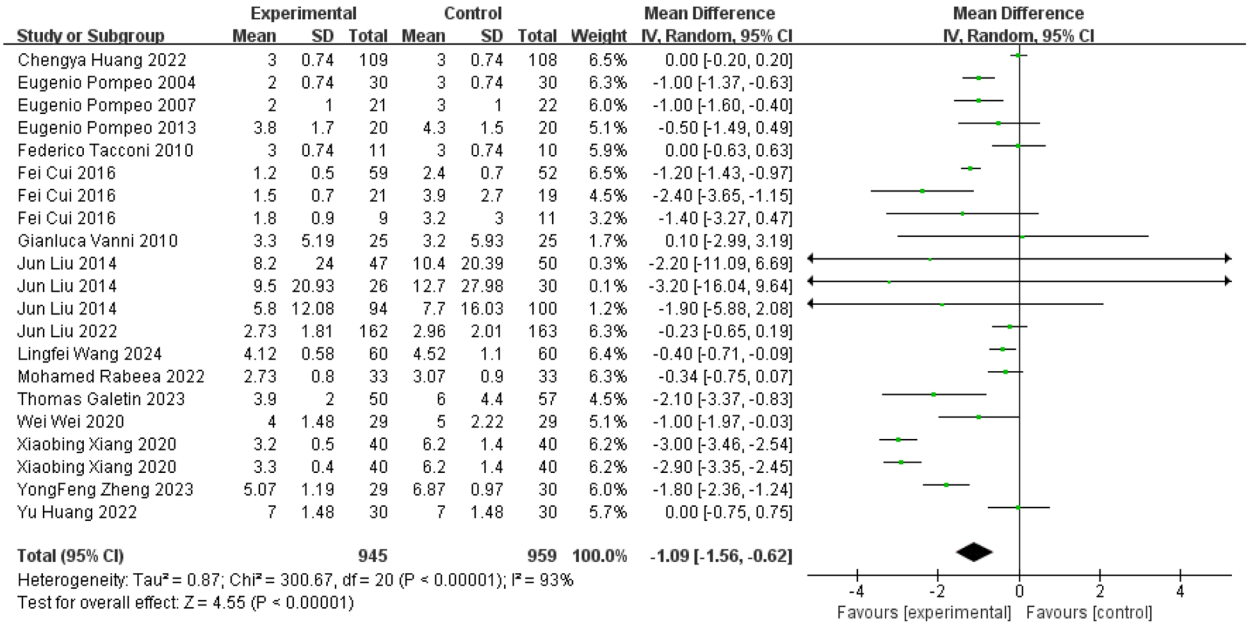

Fig. 3 Forest plot of the length of hospital stay

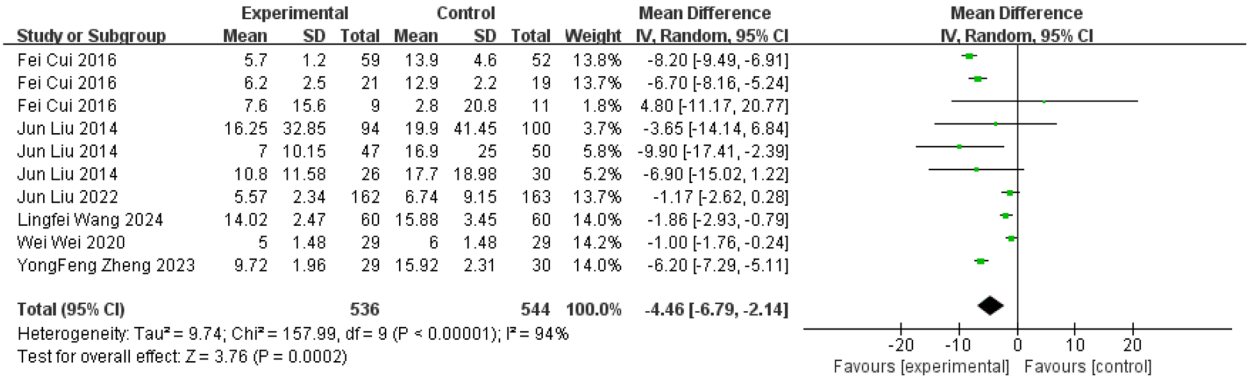

Fig. 4 Forest plot of feeding time

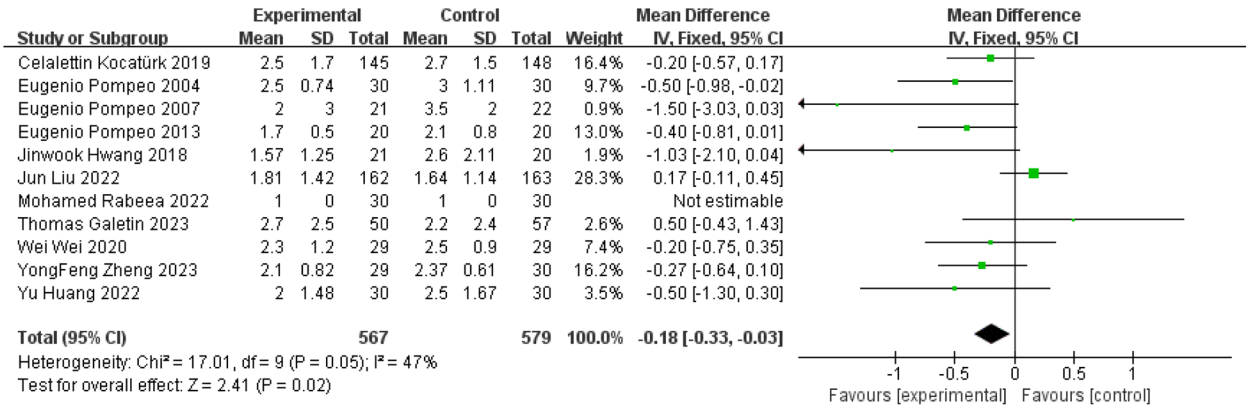

Fig. 5 Forest plot of VAS

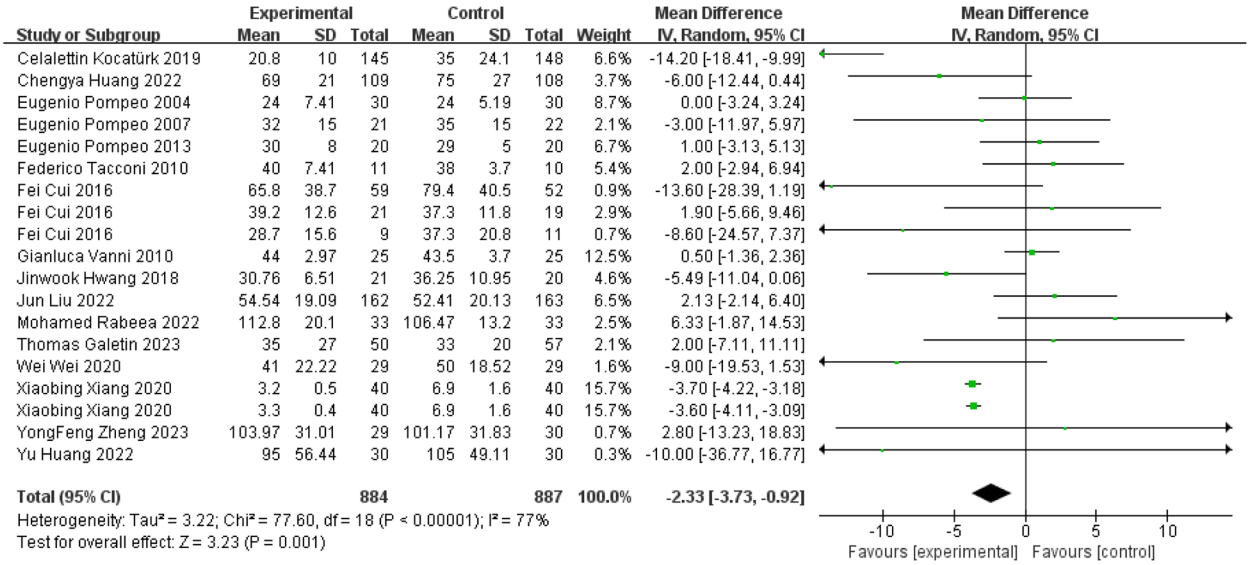

Fig. 6 Forest plot of surgery duration

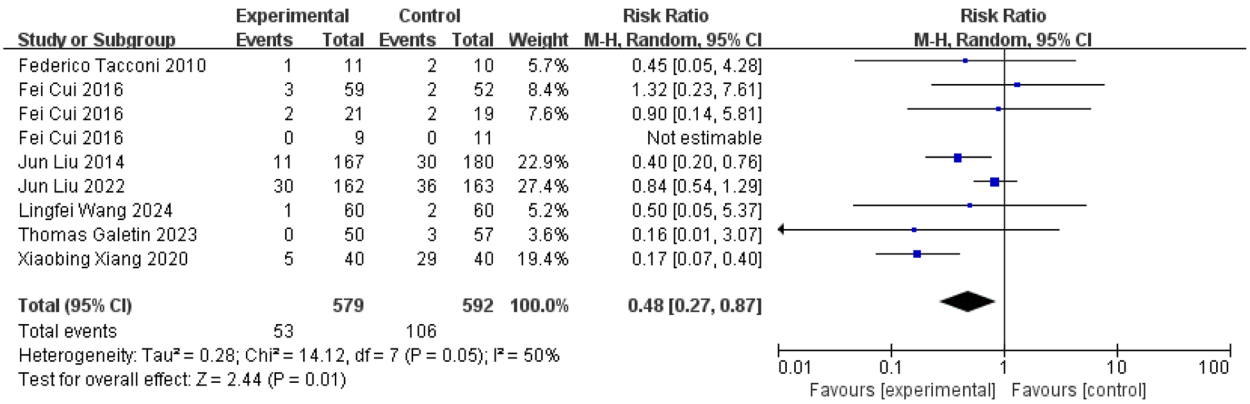

Fig. 7 Forest plot of PPCs

Discussion

Growth in the number of patients is reaping the advantages of Enhanced Recovery After Surgery (ERAS). In 2018, the ERAS Society, in collaboration with the European Society of Thoracic Surgeons (ESTS), recommended that minimally invasive surgery, early ambulation, and high-quality perioperative anesthetic management are critical components for achieving ERAS in thoracic surgery patients [20, 33]. The advancement of minimally invasive surgery has imposed new requirements on anesthetic procedures and management. Since 2004, Pompeo et al. initially documented the execution of VATS while maintaining spontaneous respiration [10], nonetheless, numerous disputes regarding anesthesia management persist. Previous meta-analyses have addressed NIVATS and IVATS [12–16]; however, more relevant studies have emerged over time. This meta-analysis encompasses 19 randomized controlled trials involving 2,222 patients, offering a thorough comparison of the two anesthesia modalities to enhance patient-specific surgical protocols and anesthesia practices in clinical settings. We compared not only postoperative recovery data but also metrics related to intraoperative patient safety and the quality of medical care.

Length of hospital stay was estimated in 16 of the 19 randomized controlled trials included in this meta-analysis. A hospital stay is regarded as a favorable clinical outcome and is crucial to enhancing recovery, resulting from a combination of variables [10, 30, 32, 34, 35]. The analysis of the random effects model showed that the length of hospital stay for the patients in the NIVATS group was shorter than that for the patients in the IVATS group.

We endeavored to investigate the sources of heterogeneity by subgroup analyses categorized by operation type, oxygen administration mode, and local anesthesia type; nonetheless, the heterogeneity among trials was substantial, the local anesthesia type being a source of heterogeneity. Liu et al. (2022) indicated that intercostal incision local anesthesia did not yield a statistically significant difference in duration of hospital stay between NIVATS and IVATS, and Xiang et al. (2020) noted that intercostal nerve block was the predominant local anesthesia technique for a cohort of 40 patients. The findings demonstrated that the intercostal nerve block cohort necessitated a higher dosage of Remifentanil and experienced an extended recovery duration relative to the paravertebral nerve block [16, 25]. The research indicates that the opioid consumption in the NIVATS group was less than in the IVATS group [20, 24, 25]. It is widely recognized that minimizing opioid usage facilitates the prompt restoration of gastrointestinal function and diminishes the occurrence of nociceptive hypersensitivity in patients, thereby indirectly impacting the duration of hospitalization [36–38]. The discharge of patients from the hospital may be contingent upon a subjective evaluation of their recovery, attributable to the diversity of diseases and surgical procedures examined, the limited sample sizes, and the absence of a cohesive surgical team. Consequently, additional extensive investigations are needed to corroborate the findings of this meta-analysis.

The NIVATS group exhibited superior postoperative analgesia, demonstrating a shorter feeding time and chest-tube dwell time [23]. Subgroup analysis showed that TEA performed better than TPVB, intercostal nerve block, and incision infiltration anesthesia in terms of feeding time, and subgroup analysis of VAS also showed that patients who underwent TEA had lower VAS scores, which may indicate that TEA has a better analgesic effect and patients can eat earlier after surgery, but the correlation still needs to be further studied. Timely dietary support and effective postoperative analgesia are crucial components for patients' effective execution of Enhanced Recovery After Surgery (ERAS) [39, 40].

Unsafe airways (abnormal oxygenation, transition to intubation, etc.), suboptimal surgical circumstances (unanticipated body movement/coughing, inadequate lung collapse, etc.), and the emergence of intraoperative arrhythmias are significant issues when employing NI-SV methods in VATS [3]. As these conditions may expose the surgeon to risks of lung injury, life-threatening cardiac perforation, or hemorrhage, as well as persistent intraoperative hypoxemia accompanied by severe arrhythmias [15, 16, 20, 22]. Intubation is deemed necessary. NIVATS conversion to single-lumen intubation of the endotracheal tube + bronchial blocker or double-lumen endotracheal intubation in the lateral position is essential [16, 41]. Chen et al. documented a 10% transition to intubated single-lung breathing attributable to chronic hypoxemia, inadequate epidural anesthesia, bleeding from pleural adhesions, and incomplete fissures [12]. Guo Z et al. noted that 2.1% of patients required conversion to intubated one-lung ventilation due to severe mediastinal movement [6]. This meta-analysis found that whereas the NIVATS group had a heightened risk of hypoxemia, there was no corresponding increase in intraoperative cough and arrhythmias. Evidence indicates that paravertebral nerve block or epidural anesthetic effectively diminishes intraoperative cough in patients, and the incorporation of an ipsilateral vagus nerve block enhances efficacy further [3, 15, 22, 24, 42].

Intraoperative crisis resource management is crucial in NIVATS, including training anesthesiologists in lateral position intubation techniques before surgery, surgical teams being proficient in all types of minor and major VATS surgery, developing an emergency protocol, and depending on the trust among the surgical, anesthetic, and nursing teams. The primary challenge in establishing a non-intubated program necessitates rigorous and appropriate patient selection based on their pathologies, as well as their physical and psychological characteristics [41]. To mitigate intraoperative risks in NIVATS, it is essential for anesthesiologists to manage the procedure well, for surgeons to enhance their surgical skills, and for careful patient selection to be conducted, as these factors significantly influence intraoperative safety. The meta-analysis conducted by Xue et al. suggested that increased selection of patients correlates with enhanced superiority [42, 43]. Consequently, to mitigate the risk of emergency intubation and associated difficulties, it is essential to identify the appropriate patient for INVATS, particularly during the initial stages of the learning process.

NIVSTA typically refrains from utilizing muscle relaxants, thus circumventing their sequelae, which encompass extended muscle recovery duration, compromised respiratory musculature, inadequate ventilatory capacity, and diminished effective ventilation, resulting in reduced awakening time for patients [16]. The surgical duration was reduced in the NIVATS cohort; however, the heterogeneity was great, likely attributable to the many operations conducted within the same surgical approach and the inconsistency in the surgical team's expertise, necessitating further investigations to substantiate this meta-analysis [26, 27, 31]. A subgroup analysis of the duration of surgery showed that uniportal VATS surgery took less time, possibly because uniportal VATS was mostly used for simple procedures such as bullae resection and wedge

resection of pulmonary nodules; the use of LMA for oxygen delivery was more conducive to the surgery, possibly because the LMA is safer than mask oxygenation, and the anesthetist can sedate and analgesine the patient more, which is more conducive to surgical operations. However, the intraoperative anesthetic doses and the depth of sedation and analgesia in the two groups were not compared, and more research is needed to explore this in the future.

Simultaneously, mechanical ventilation for one-lung ventilation (OLV) may lead to detrimental effects, including ventilator-associated pneumonia, mechanical ventilation-induced lung injury, and re-expansion pulmonary injury [44]. Moreover, postoperative pulmonary complications (PPCs) frequently occur following IVATS, resulting in patient discomfort, significantly hindering postoperative recovery, escalating healthcare expenses, and extending the duration of hospital stays [45]. The incidence of postoperative pulmonary complications (PPCs) in thoracic surgical patients (14–59%) exceeds that of other major surgical procedures [11, 12, 46]. Literature indicates that experienced anesthesiologists collaborating with proficient surgeons might diminish PPCS, potentially linked to accurate respiratory parameters and reduced mechanical ventilation duration [20, 27]. While NIVATS presents potential intraoperative safety risks, it has been associated with lower levels of inflammatory cytokines. TNF-α is a pivotal inflammatory cytokine predominantly synthesized by activated monocytes/macrophages, capable of inducing cytotoxicity and inhibiting tumor cells, enhancing neutrophil phagocytosis, combating infections, inducing fever, and facilitating cellular proliferation and differentiation. The NIVATS group had decreased levels of TNF-α and serum hsCRP, indicating that non-intubated patients can alleviate not only the discomfort associated with intubation post-surgery (sore throat) but also mitigate airway inflammation and systemic inflammatory response [21, 29]. PONV not only affects the speed of postoperative recovery but also the patient's comfort throughout the perioperative period. The happening of PONV in the NIVATS group was significantly lower, which may be related to the reduced intraoperative opioid use in the NIVATS group [47]. Thoracic surgery must not solely attain ERAS; simultaneously, anticipated outcomes include a reduced cognitive load, increased patient satisfaction, and a heightened usage rate of existing healthcare services [37].

Through the analysis of the above indicators, NIVATS and IVATS are fully explained. Firstly, this meta-analysis evaluated the incidence of complications, quality of postoperative recovery, and duration of hospital stay to ascertain the benefits of NIVATS on overall patient recovery. Secondly, it examined intraoperative cough, hypoxemia, and heart rate arrhythmia to assess the feasibility and safety of NIVATS for treating various thoracic diseases during the perioperative period, thereby optimizing anesthetic and surgical decision-making. Finally, it examined PONV and sore throat in the assessment of patients' perioperative comfort.

This meta-analysis has some limitations. Firstly, this study focuses on three aspects: postoperative recovery, perioperative safety, and postoperative complications. Due to the NIVATS'careful patient selection and the potential safety risks associated with perioperative management, it may increase the management difficulty for the anesthesia team and require more equipment support. However, because there is limited data on intraoperative management, intraoperative management was not analyzed. Thomas Galetin et al. (2023) noted that anesthesiologists and surgeons are more satisfied with general anesthesia. Secondly, the majority of the randomized controlled trials (RCTs) focused solely on short-term outcomes, neglecting to report long-term recurrence and mortality rates. Future meta-analyses should incorporate a broader range of literature to enhance the credibility of the results, and future research should include long-term outcomes such as recurrence rates and mortality to further validate NIVATS'safety and feasibility. Finally, certain indicators exhibited significant heterogeneity, potentially undermining our analytical strength despite employing a random-effects model.

Conclusions

This meta-analysis demonstrated that NIVATS reduced feeding time, chest tube stay, and hospital stay compared with IVATS; it also reduced intubation-related complications, mitigated gastrointestinal discomfort and postoperative pharyngeal, and lowered the patient's postoperative VAS score. Therefore, NIVATS contributes to rapid recovery to a certain extent. NVATS elevate the occurrence of intraoperative hypoxemia, and although intraoperative crisis resource management and careful patient selection possibly can mitigate intraoperative safety risks, intraoperative management still needs to be further explored and supported by data. In conclusion, NIVATS is pursuing an"overall minimally invasive strategy"and"ERAS,"proving to be a safe and technically viable anesthesia technique; nevertheless, further research is necessary to compare the two systems in long-term clinical prognosis.

Abbreviations

VATS	Video-assisted thoracic surgery
NIVATS	Non-intubated video-assisted thoracic surgery
IVATS	Intubated video-assisted thoracic surgery
RCTs	Randomized controlled trials
PPCs	Postoperative pulmonary complications

PONV	Post-operative nausea and vomiting
VAS	Visual analogue scale
ERAS	Enhanced recovery after surgery
TPVB	Thoracic paravertebral nerve block
OLV	One-lung ventilation
LMA	Laryngeal mask airway
TEA	Thoracic epidural anesthesia
DLT	Double-lumen tracheal intubation
CI	Confidence intervals
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
WMD	Weighted mean difference
SMD	Standardized mean difference

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

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Authors' contributions
D.Z., J.W., Y.Y., J.L., and L.C. participated in the design, collection of data, statistical analysis and completion of the manuscript. R.P., Z.L., Y.L., W.D., J.W., B. H., Z. G. and J. G.assisted in data collection and statistical analysis. All the authors have read and approved the final draft.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
The project was exempted from an ethical opinion by the Ethics Committee of Qujing First People's Hospital: Kunming Medical University Affiliated Qujing Hospital since it is a systematic review of the literature.
Not applicable.

Competing interests
The authors declare no competing interests.

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