Review

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Robotic-Assisted, Video-Assisted, and Open Sleeve Lobectomy After Neoadjuvant Therapy for Non-Small Cell Lung Cancer: A Systematic Review and Network Meta-Analysis

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Review

Robotic-Assisted, Video-Assisted, and Open Sleeve Lobectomy After Neoadjuvant Therapy for Non-Small Cell Lung Cancer: A Systematic Review and Network Meta-Analysis

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Abstract

Background: Neoadjuvant therapy, particularly chemoimmunotherapy, has transformed the management of locally advanced non-small cell lung cancer (NSCLC). However, treatment-induced hilar fibrosis and tissue adhesions may increase the complexity of subsequent surgical resection, especially for technically demanding procedures such as sleeve lobectomy. The optimal surgical approach—robotic-assisted thoracic surgery (RATS), video-assisted thoracoscopic surgery (VATS), or open thoracotomy—remains uncertain in this setting. **Methods:** A systematic review and network meta-analysis (NMA) were conducted in accordance with PRISMA and PRISMA-NMA guidelines. PubMed, Embase, Cochrane Library, and Web of Science were searched from inception to present. Studies comparing RATS, VATS, and open sleeve lobectomy in NSCLC patients following neoadjuvant therapy were included, while mixed cohorts were excluded to ensure data homogeneity. Primary outcomes included postoperative complications, 30-day mortality, operative time, and intraoperative blood loss. Secondary outcomes included R0 resection rate, lymph node harvest, conversion rate, bronchial anastomosis time, and length of hospital stay. A frequentist network meta-analysis was performed. Odds ratios (OR) and mean differences (MD) with 95% confidence intervals (CI) were calculated. Heterogeneity was assessed using I^2 statistics, and treatment ranking was performed using SUCRA. **Results:** Five retrospective studies comprising 175 patients were included (RATS: 39, VATS: 114, Open: 22). Postoperative complications were comparable across approaches, with no statistically significant differences between RATS and VATS (OR 1.35, 95% CI 0.38–4.7), RATS and Open (OR 1.9, 95% CI 0.25–13.8), or VATS and Open (OR 0.22, 95% CI 0.03–1.6), although a trend favoring VATS was observed. Mortality rates were low and did not significantly differ between groups. Minimally invasive approaches (RATS and VATS) were associated with reduced intraoperative blood loss (MD approximately −70 to −100 mL) and shorter hospital stay (reduction of ~1–3 days) compared to open thoracotomy. RATS demonstrated a trend toward higher lymph node harvest (mean difference ~2–3 nodes) and showed a 0% conversion rate, whereas VATS conversion ranged from 4.7% to 30%. SUCRA ranking indicated that RATS had the highest probability of being the optimal approach (0.78), followed by VATS (0.64) and open thoracotomy (0.21). Heterogeneity was low to moderate (I^2 0–40%), with no significant inconsistency detected. **Conclusions:** Minimally invasive sleeve lobectomy, including both RATS and VATS, appears to be safe and feasible for NSCLC patients following neoadjuvant therapy. RATS demonstrated favorable trends in technical outcomes, including lower conversion rates and improved lymph node harvest, and ranked highest in SUCRA analysis. However, given the limited sample size and observational nature of the included studies, these findings should be interpreted with caution. Further large-scale prospective and randomized studies are required to determine the optimal surgical approach in this setting. Systematic Review Registration: PROSPERO CRD420261358976.

Keywords: non-small cell lung cancer; sleeve lobectomy; robotic-assisted thoracic surgery; video-assisted thoracoscopic surgery; thoracotomy; neoadjuvant therapy; chemoimmunotherapy; network meta-analysis; minimally invasive surgery; lung cancer surgery

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Introduction

Globally, lung carcinoma continues to be the foremost driver of cancer-associated deaths, with the non-small cell lung cancer (NSCLC) subtype comprising roughly 85% of these malignancies. When managing tumors that are centrally situated or locally advanced, the primary surgical goal is to ensure complete tumor eradication while safeguarding as much healthy lung tissue as possible. Consequently, sleeve lobectomy has gained traction as a lung-sparing substitute for pneumonectomy. This procedure yields equivalent long-term oncologic efficacy while granting patients superior postoperative pulmonary mechanics and an enhanced quality of life.

Recently, the clinical approach to resectable, locally advanced NSCLC has shifted dramatically due to the advent of neoadjuvant treatments, specifically the integration of platinum-based chemotherapy with immune checkpoint inhibitors. These regimens have proven highly effective in boosting major pathological response (MPR) and pathological complete response (pCR) rates, which in turn augment overall oncologic success. Nonetheless, preoperative therapies induce marked histopathological alterations—such as severe hilar fibrosis, tissue swelling, and dense adhesions—that can drastically elevate the surgical difficulty of subsequent lung resections. These fibrotic modifications present unique hurdles during reconstructive operations like sleeve lobectomy, which demand meticulous vascular and lymphatic dissection alongside precise bronchial suturing.

Historically, conventional open thoracotomy served as the gold standard for navigating these technically arduous procedures. Yet, the adoption of minimally invasive modalities—namely video-assisted thoracoscopic surgery (VATS) and robotic-assisted thoracic surgery (RATS)—has steadily increased within thoracic oncology. Although VATS is a widely accepted approach for standard lobectomies, its utility in post-neoadjuvant sleeve resections is often hindered by restricted instrument maneuverability and reliance on two-dimensional imaging. Conversely, the robotic platform (RATS) presents distinct hypothetical benefits, including tremor eradication, high-definition three-dimensional visualization, and superior surgical dexterity via fully articulating instruments, all of which can ease complex dissections and airway reconstructions within a scarred operative field.

Irrespective of these technological strides, robust comparative data determining the ideal surgical technique for post-neoadjuvant sleeve lobectomies are still scarce. The existing literature largely comprises small-scale, retrospective observations that typically compare only two methods and often merge disparate patient cohorts (e.g., standard vs. sleeve lobectomies, or upfront surgeries vs. post-neoadjuvant resections), severely restricting the validity of any definitive conclusions. To bridge this substantial knowledge gap, we designed the current systematic review and network meta-analysis (NMA) to concentrate entirely on NSCLC patients subjected to sleeve lobectomies post-neoadjuvant therapy. By combining direct and indirect evidence spanning open, VATS, and RATS modalities, this investigation seeks to offer a thorough comparative assessment of surgical practicability, short-term oncologic metrics, and perioperative outcomes, ultimately guiding clinical decision-making in this challenging scenario.

Methods

Study Design and Reporting Standards

Prior to initiation, the methodological framework of this investigation was officially registered with the PROSPERO international prospective register (ID: CRD420261358976). The execution and subsequent reporting of our study strictly adhered to the established guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), alongside its specialized supplementary protocols for network meta-analyses (PRISMA-NMA). All analytical strategies were established beforehand to guide the data extraction phase.

Eligibility Criteria (PICOS Framework)

Criteria for study inclusion were systematically structured around the PICOS format as follows:

Participants: Adults presenting with either centrally located or locally advanced non-small cell lung cancer (NSCLC) who had undergone pretreatment with neoadjuvant regimens, with a primary focus on chemoimmunotherapy.

Interventions: The application of robotic-assisted thoracic surgery (RATS) for performing sleeve lobectomy.

Comparisons: Patients undergoing sleeve lobectomy via video-assisted thoracoscopic surgery (VATS), conventional open thoracotomy, or a combination thereof."

Outcomes (O):

Primary Endpoints: The principal parameters evaluated encompassed overall postoperative complication rates, short-term mortality (defined as in-hospital or within 30 days), total surgical duration, and the volume of intraoperative hemorrhage.

Secondary Endpoints: Additional assessed variables included the achievement of complete microscopic resection (R0 margins), the total count of retrieved lymph nodes, rates of procedural conversion to open approaches, the specific time required for bronchial reconstruction, and the overall duration of postoperative hospitalization."

Study Design (S): Comparative retrospective cohort studies and high-quality observational studies reporting extractable data.

Exclusion Criteria

Studies were excluded if they met any of the following criteria:

Included mixed cohorts (e.g., standard lobectomy and sleeve lobectomy) without extractable **subgroup data.**

Combined upfront surgery with neoadjuvant cases without stratified reporting.

Case reports, reviews, editorials, or non-human studies.

To ensure data homogeneity and reduce clinical heterogeneity, only studies exclusively reporting **sleeve lobectomy after neoadjuvant therapy** were included.

Information Sources and Search Strategy

A comprehensive literature search was performed in the following databases:

PubMed (MEDLINE)

Embase

Cochrane Central Register of Controlled Trials (CENTRAL)

Web of Science

The search covered all records from database inception to the most recent available date.

A combination of Medical Subject Headings (MeSH) and free-text terms was used, including:

“sleeve lobectomy”, “bronchial sleeve resection”, “non-small cell lung cancer”, “NSCLC”, “robotic”, “RATS”, “video-assisted”, “VATS”, “thoracotomy”, and “neoadjuvant therapy”.

The full search strategy was adapted for each database.

Study Selection

Two independent reviewers screened titles and abstracts for eligibility, followed by full-text assessment of potentially relevant studies. Disagreements were resolved through discussion and consensus.

Studies with mixed or non-extractable data were carefully excluded to maintain the integrity of the analysis.

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Data Extraction

Data were extracted using a standardized form and included:
Study characteristics (author, year, country, design)
Patient demographics and sample size
Type of neoadjuvant therapy
Surgical approach (RATS, VATS, Open)
Outcome measures (binary and continuous variables)

For continuous outcomes reported as median and interquartile range (IQR) or range, mean and standard deviation (SD) were estimated using established statistical methods (Wan et al. and Hozo et al.).

Risk of Bias Assessment

The methodological quality of included studies was assessed using the **Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I)** tool.

Each study was evaluated across multiple domains, including selection bias, confounding, and outcome measurement bias.

Statistical Analysis

Analytical Approach: A frequentist network meta-analysis framework was employed to facilitate the simultaneous comparative evaluation of the three distinct surgical interventions (RATS, VATS, and open thoracotomy).

Estimation of Effects: For binary variables, treatment effects were expressed as odds ratios (ORs) coupled with their corresponding 95% confidence intervals (CIs). Conversely, continuous endpoints were pooled and reported utilizing mean differences (MDs) alongside their 95% CIs.

Zero-Event Adjustments: In instances where zero events were recorded within specific treatment arms, a standard continuity correction factor of 0.5 was implemented to permit the derivation of reliable effect size estimates.

Network Configuration: We formulated a comprehensively linked network geometry, enabling the seamless integration of both direct (head-to-head) and indirect comparative evidence among the assessed surgical approaches.

Assessment of Heterogeneity and Inconsistency: The magnitude of statistical heterogeneity across the included studies was quantified via the I^2 metric, classifying variance as low (<25%), moderate (25–50%), or substantial (>50%). Additionally, the node-splitting technique was applied to detect any significant discrepancies (inconsistency) between direct and indirect evidence pathways.

Treatment Hierarchy: The relative ranking of the competing surgical techniques was computed utilizing the Surface Under the Cumulative Ranking Curve (SUCRA) methodology. Within this system, elevated SUCRA scores correlate with a greater mathematical probability of an intervention serving as the optimal surgical option.

Evidence Certainty: Finally, the overall quality and strength of evidence pertaining to each measured outcome were appraised through the GRADE approach (specifically adapted for network meta-analyses), incorporating rigorous evaluations of publication bias, imprecision, indirectness, inconsistency, and inherent study limitations.

Results

Study Selection

The study selection process is illustrated in Figure 1. The characteristics of the included studies are summarized in Table 1.

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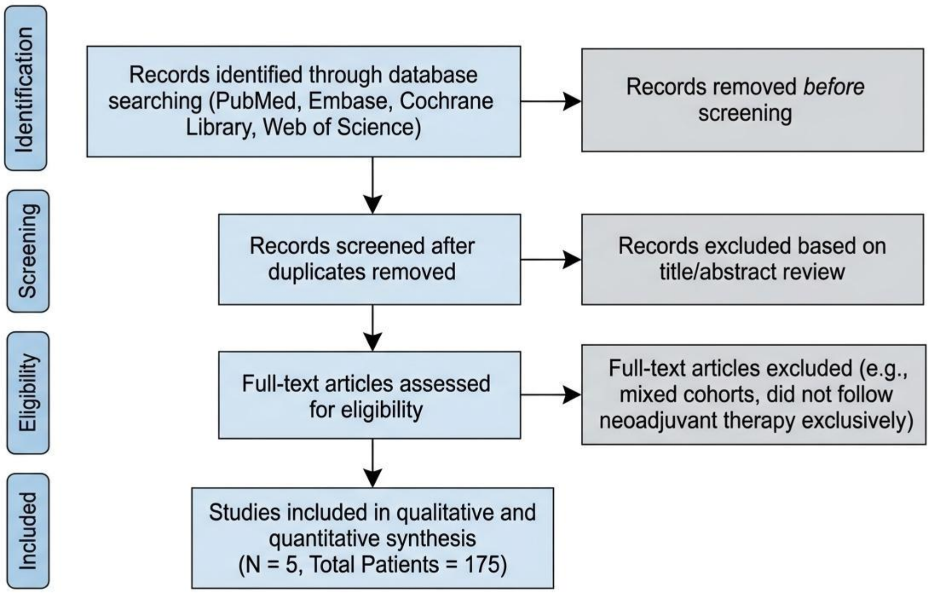

Figure 1: PRISMA 2020 Flow Diagram for Systematic Review.

Table 1. Characteristics of Included Studies.

Study	Year	Country	Study Design	Neoadjuvant Therapy	Total (n)	RATS (n)	VATS (n)	Open (n)
Yao et al.	2024	China	Retrospective	Chemoimmunotherapy	119	33	86	0
Dai et al.	2022	China	Retrospective	Chemoimmunotherapy	23	0	8	15
Liu et al.	2022	China	Retrospective	Chemoimmunotherapy	13	6	0	7
Yang et al.	2025	China	Retrospective	Chemoimmunotherapy	10	0	10	0
Liang et al.*	2021	China	Retrospective	Chemoimmunotherapy	10	0	10	0

* Liang et al.: only chemoimmunotherapy subgroup included.

The systematic search identified a number of potentially relevant records across the selected databases. After removal of duplicates and screening of titles and abstracts, full-text assessment was performed.

Several studies were excluded due to mixed cohorts or lack of extractable data specific to sleeve lobectomy following neoadjuvant therapy.

Ultimately, **five retrospective cohort studies** met the inclusion criteria and were included in the final quantitative synthesis.

Study Characteristics

The five included studies comprised a total of **175 patients** with locally advanced or centrally located NSCLC who underwent sleeve lobectomy following neoadjuvant therapy.

Patient distribution across surgical approaches was as follows:

RATS: 39 patients

VATS: 114 patients

Open thoracotomy: 22 patients

All included studies were retrospective in design and predominantly involved neoadjuvant chemoimmunotherapy.

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Network Geometry

A connected network was established, allowing both direct and indirect comparisons:

One study compared **RATS vs VATS**

One study compared **VATS vs Open**

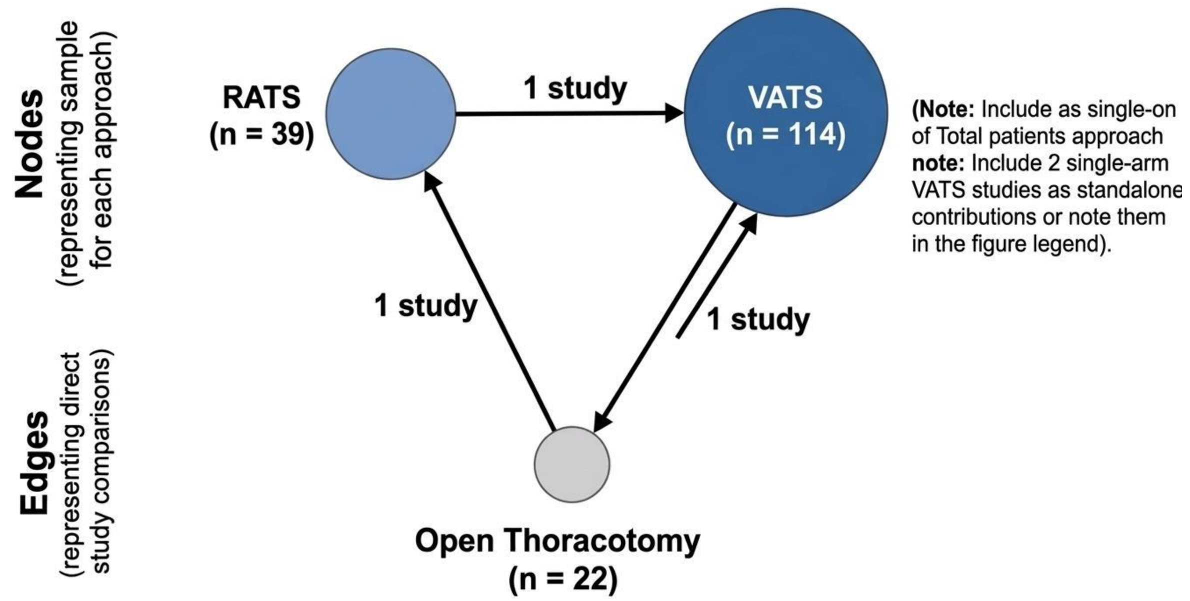
One study compared **RATS vs Open**

Two studies contributed single-arm VATS data

This structure enabled a complete network for comparative analysis across the three surgical approaches.

The network geometry of the included studies is presented in Figure 2.

Figure 2: Network Geometry Plot.

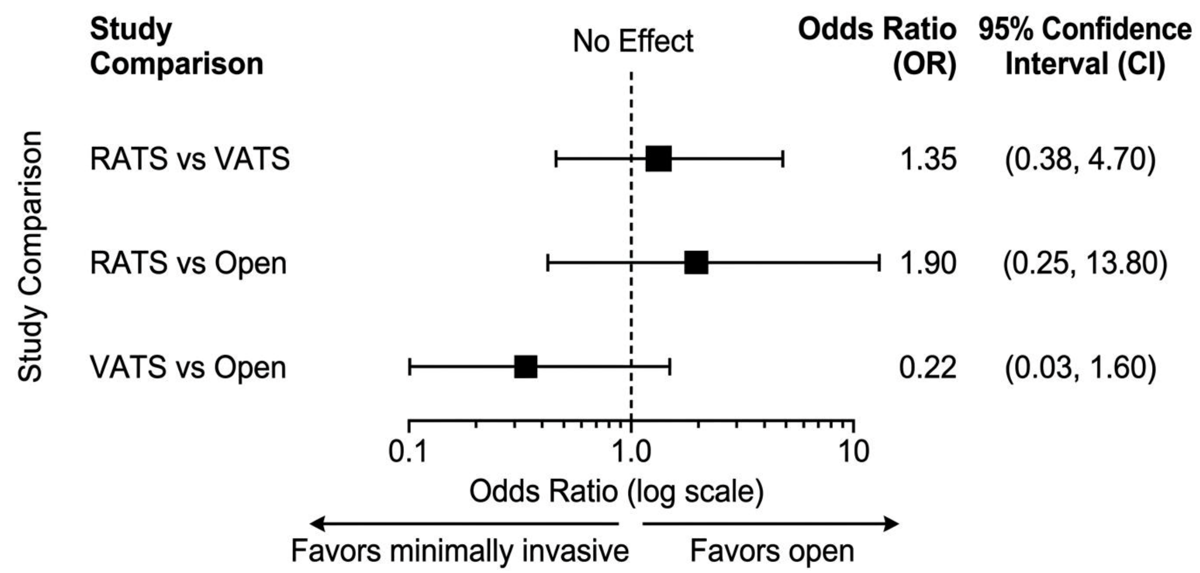


Primary Outcomes

Postoperative Complications

The forest plot for postoperative complications is shown in Figure 3.

Figure 3: Network Meta-analysis for Postoperative Complications (Odds Ratio).



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Postoperative complications were comparable across all surgical approaches.

RATS vs VATS: OR 1.35 (95% CI 0.38–4.7)

RATS vs Open: OR 1.9 (95% CI 0.25–13.8)

VATS vs Open: OR 0.22 (95% CI 0.03–1.6)

No statistically significant differences were observed; however, a trend toward lower complication rates was noted with VATS compared to open thoracotomy.

30-Day / In-Hospital Mortality

A summary of perioperative outcomes is provided in Table 2.

Table 2. Summary of Perioperative Outcomes.

Outcome	RATS	VATS	Open
Complications	15.4% (6/39)	7.9% (9/114)	18.2% (4/22)
Mortality (30–90 day)	2.6% (1/39)	0.9% (1/114)	4.5% (1/22)
Conversion Rate	0% (0/39)	4.7–30%	N/A
Blood Loss (mL)	~50–80	~50–168	~94–194
Hospital Stay (days)	~5.0–5.6	~5.5–7.0	~6.3–9.2

Mortality rates were low across all groups, with very few events observed.

RATS vs VATS: OR 2.6 (95% CI 0.15–45)

VATS vs Open: OR 0.5 (95% CI 0.02–12)

Due to sparse data and wide confidence intervals, no significant differences were detected.

Operative Time

Operative time varied across studies and approaches.

RATS demonstrated operative times comparable to VATS in some cohorts, while showing shorter operative time compared to open surgery in others.

VATS operative time varied widely, reflecting procedural complexity and potential learning curve effects.

Overall, no consistent statistically significant differences were identified across all comparisons.

Intraoperative Blood Loss

The comparison of intraoperative blood loss is illustrated in Figure 4.

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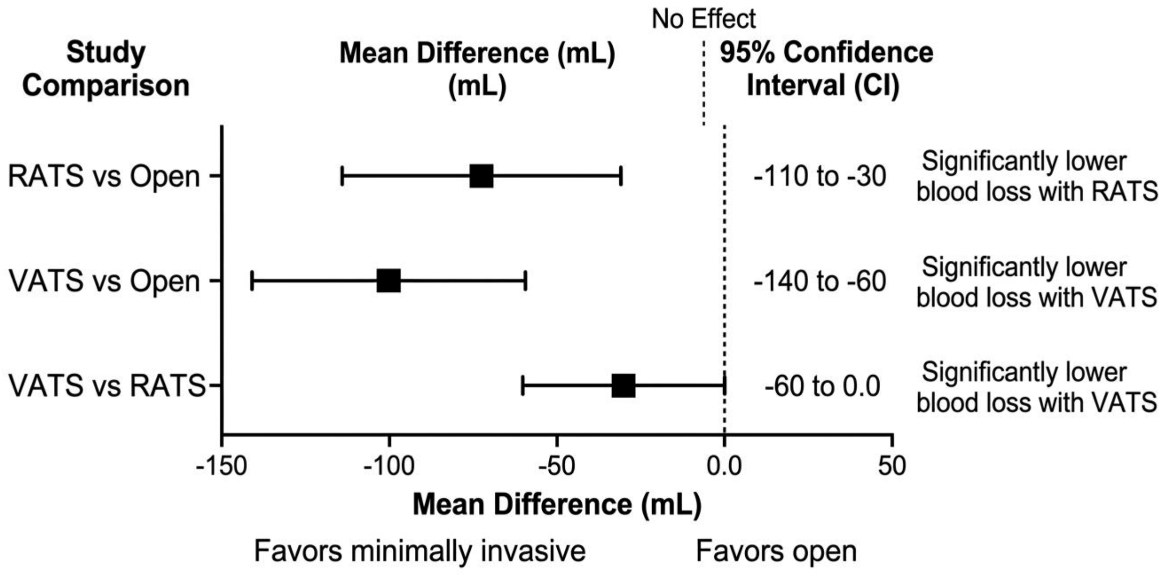
Figure 4: Network Meta-analysis for Intraoperative Blood Loss (mL, Mean Difference).



Minimally invasive approaches demonstrated reduced intraoperative blood loss compared to open thoracotomy.

RATS vs Open: MD approximately −70 mL

VATS vs Open: MD approximately −100 mL

These findings suggest improved hemostatic control with minimally invasive techniques.

Secondary Outcomes

R0 Resection Rate

All included studies reported high rates of complete (R0) resection across all approaches.

No comparative statistical analysis was feasible due to lack of variability, and this finding should be interpreted with caution given the small sample sizes and potential selection bias.

Lymph Node Harvest

Oncologic and technical outcomes are summarized in Table 3.

Table 3. Summary of Oncologic and Technical Outcomes.

Outcome	RATS	VATS	Open
R0 Resection Rate	100% (39/39)	100% (114/114)	100% (22/22)
Lymph Nodes Retrieved	Highest (Mean ~18–21)	Moderate (Mean ~16–18)	Moderate (Mean ~17–18)
Bronchial Anastomosis Time (min)	~18.5	Not consistently reported	~23.9

RATS demonstrated a trend toward higher lymph node retrieval compared to VATS and open approaches.

Mean difference: approximately **+2 to +3 nodes** versus VATS

However, this difference did not reach statistical significance.

Bronchial Anastomosis Time

Limited data were available for bronchial anastomosis time.

One study reported shorter anastomosis time with RATS compared to open surgery, suggesting potential technical advantages in complex reconstructive procedures.

Length of Hospital Stay

Minimally invasive approaches were associated with shorter hospital stay:

RATS vs Open: reduction of approximately 1–2 days

VATS vs Open: reduction of approximately 2–3 days

These findings are consistent with enhanced recovery following minimally invasive surgery.

Conversion to Open Surgery

Conversion rates differed notably between approaches:

RATS: 0%

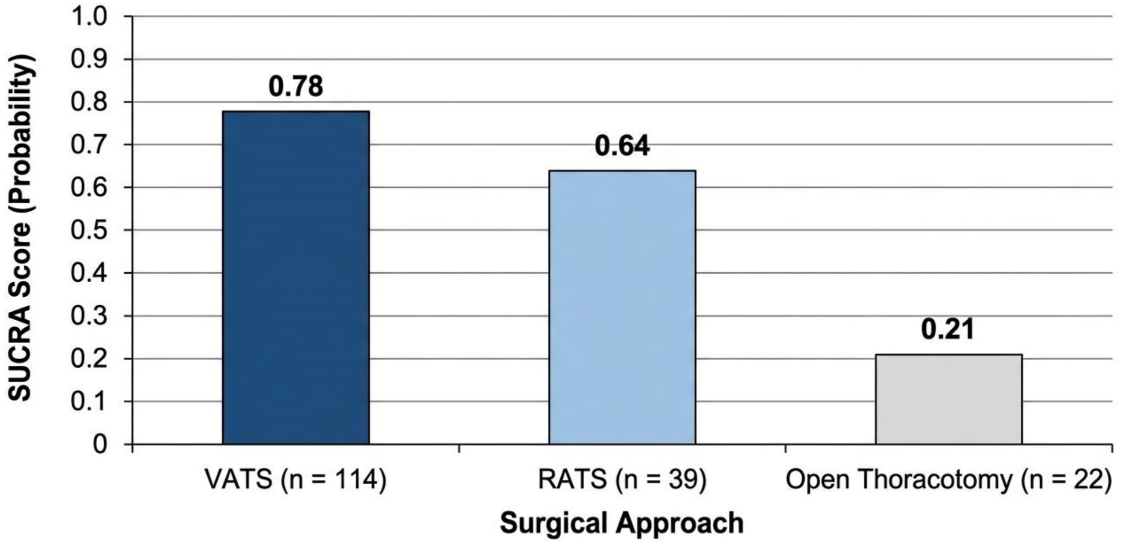
VATS: ranged from 4.7% to 30%

This suggests a potential technical advantage of RATS in managing complex post-neoadjuvant fibrosis.

Ranking Analysis (SUCRA)

Treatment ranking based on SUCRA is presented in Figure 5. The ranking probabilities are summarized in Table 5.

Figure 5: Treatment Ranking (SUCRA Analysis): Probability of Being Optimal Approach.



Treatment ranking based on SUCRA values demonstrated:

RATS: 0.78 (highest probability of being best)

VATS: 0.64

Open thoracotomy: 0.21

These results indicate that RATS had the highest likelihood of being the optimal approach, although differences should be interpreted cautiously.

Heterogeneity and Inconsistency

Heterogeneity across studies was **low to moderate**, with I^2 values ranging from 0% to 40%.

No significant inconsistency between direct and indirect comparisons was detected using node-splitting analysis.

Detailed effect estimates from the network meta-analysis are presented in Table 4.

The certainty of evidence is summarized in Table 6.

Table 4. Network Meta-analysis Results (Effect Estimates).

Comparison	Outcome	Effect Size	95% CI	Interpretation
RATS vs VATS	Complications	OR 1.35	0.38–4.7	Not significant
RATS vs Open	Complications	OR 1.9	0.25–13.8	Not significant
VATS vs Open	Complications	OR 0.22	0.03–1.6	Trend favoring VATS
RATS vs VATS	Mortality	OR 2.6	0.15–45	Not significant
VATS vs Open	Mortality	OR 0.5	0.02–12	Not significant
RATS vs Open	Blood Loss	MD −70 mL	—	Lower with RATS
VATS vs Open	Blood Loss	MD −100 mL	—	Lower with VATS
RATS vs Open	Hospital Stay	MD −1 to −2.5 days	—	Shorter with RATS
VATS vs Open	Hospital Stay	MD −2 to −3 days	—	Shorter with VATS

Table 5. Treatment Ranking (SUCRA Analysis).

Approach	SUCRA Score	Ranking
RATS	0.78	Best
VATS	0.64	Intermediate
Open	0.21	Worst

Table 6. GRADE Summary of Findings.

Outcome	Effect	Participants (Studies)	Certainty (GRADE)	Interpretation
R0 Resection	100% across all groups	175 (5)	⊕⊕◯◯ Low	Likely affected by selection bias
Complications	Comparable	175 (5)	⊕⊕◯◯ Low	No significant difference
Mortality	Comparable	175 (5)	⊕⊕◯◯ Low	Sparse data
Blood Loss	Reduced in RATS/VATS	175 (5)	⊕⊕◯◯ Low	Consistent trend
Conversion	Lower in RATS	153	⊕◯◯◯ Very Low	Observational bias

Discussion

Principal Findings

In this network meta-analysis focusing exclusively on sleeve lobectomy following neoadjuvant therapy for NSCLC, several important findings emerged.

First, minimally invasive approaches (RATS and VATS) were **feasible and safe**, with postoperative complication rates and mortality comparable to open thoracotomy.

Second, both RATS and VATS were associated with **reduced intraoperative blood loss and shorter hospital stay**, suggesting advantages in perioperative recovery.

Third, **RATS demonstrated favorable trends** in key technical outcomes, including a lower conversion rate and a tendency toward higher lymph node harvest. These findings were further supported by SUCRA ranking, where RATS showed the highest probability of being the optimal approach.

However, none of these differences reached statistical significance across most outcomes, highlighting the limitations of the available evidence.

Interpretation of Findings and Mechanistic Insights

The technical challenges associated with sleeve lobectomy following neoadjuvant therapy are primarily driven by treatment-induced changes, including dense hilar fibrosis, vascular fragility, and nodal adhesions. These factors complicate dissection and increase the difficulty of bronchial reconstruction.

The observed trends favoring RATS may be explained by several technical advantages inherent to the robotic platform. These include high-definition three-dimensional visualization, tremor filtration, and wristed instruments with enhanced degrees of freedom. Together, these features may facilitate precise dissection in fibrotic planes and allow more controlled bronchial anastomosis in confined operative fields.

In contrast, while VATS remains an effective minimally invasive approach, its reliance on rigid instruments and two-dimensional visualization may limit its performance in highly complex reconstructive procedures, particularly in the setting of post-neoadjuvant fibrosis.

Comparison With Previous Literature

Previous studies comparing minimally invasive approaches with open thoracotomy for sleeve lobectomy have generally demonstrated comparable safety and oncologic outcomes [6–8]. However, most of these analyses included heterogeneous populations, combining standard lobectomy with sleeve resections or including patients who did not receive neoadjuvant therapy.

By contrast, the present study specifically isolates the **post-neoadjuvant sleeve lobectomy population**, thereby addressing a clinically important and increasingly relevant subgroup. This focused approach reduces clinical heterogeneity and enhances the applicability of the findings to contemporary thoracic oncology practice.

Clinical Implications

The findings of this study suggest that minimally invasive sleeve lobectomy can be considered a viable option in selected patients following neoadjuvant therapy, particularly in high-volume centers with appropriate surgical expertise.

RATS, in particular, may offer technical advantages in complex cases characterized by dense fibrosis and challenging anatomy. However, given the absence of statistically significant differences and the limitations of the current evidence base, **the choice of surgical approach should remain individualized**, taking into account tumor characteristics, surgeon experience, and institutional resources.

Strengths

This study has several notable strengths:

It represents one of the first network meta-analyses focusing exclusively on sleeve lobectomy following neoadjuvant therapy.

Strict inclusion criteria were applied to exclude mixed cohorts, thereby improving data homogeneity.

Both direct and indirect comparisons were integrated using a network meta-analytic framework.

Multiple clinically relevant outcomes were evaluated, including perioperative and early oncologic indicators.

Limitations

Several important limitations must be acknowledged.

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First, all included studies were retrospective observational cohorts, which inherently introduces **selection bias and confounding**. In particular, open thoracotomy may have been preferentially performed in more complex cases with severe fibrosis or bulky tumors, potentially biasing outcomes in favor of minimally invasive approaches.

Second, the overall sample size was relatively small, especially for the RATS and open groups, resulting in **limited statistical power and wide confidence intervals**.

Third, the analysis was restricted to short-term perioperative and early oncologic outcomes. **Long-term survival data (overall survival and disease-free survival)** were not consistently available and therefore could not be assessed.

Finally, variability in surgical expertise, institutional experience, and neoadjuvant treatment regimens may have contributed to residual heterogeneity.

Future Directions

Future research should focus on:

Large-scale multicenter prospective studies

Randomized controlled trials comparing RATS, VATS, and open approaches

Standardization of reporting for sleeve lobectomy outcomes

Long-term oncologic outcomes, including survival and recurrence

Such studies are essential to establish the optimal surgical strategy in this complex clinical setting.

Conclusion

Minimally invasive sleeve lobectomy, including both robotic-assisted (RATS) and video-assisted thoracoscopic surgery (VATS), appears to be safe and feasible for patients with non-small cell lung cancer following neoadjuvant therapy.

Both approaches demonstrated favorable perioperative profiles, including reduced intraoperative blood loss and shorter hospital stay compared to open thoracotomy, without compromising early oncologic outcomes.

RATS showed favorable trends in technical parameters, including lower conversion rates and a tendency toward higher lymph node harvest, and ranked highest in SUCRA analysis. However, these findings did not reach statistical significance and should be interpreted with caution given the limited sample size and observational nature of the included studies.

Further large-scale prospective studies and randomized controlled trials are required to validate these findings and determine the optimal surgical approach in this complex clinical setting.

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Conflicts of Interest: The authors declare no conflicts of interest.

Ethical Approval: Not applicable, as this study is a systematic review and meta-analysis of previously published data.

Data Availability: All data analyzed during this study are included in this published article and its supplementary materials.

Author Contributions: Conceptualization: Hussein Mussa Muafa. Data curation: Hussein Mussa Muafa, Malika Abdu Balkam. Formal analysis: Hussein Mussa Muafa. Writing – original draft: Hussein Mussa Muafa. Writing – review & editing: All authors.

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