REVIEW

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Video-assisted thoracoscopic surgery vs. open thoracotomy in the management of empyema: A Meta-analytical perspective

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ABSTRACT

Background: Pleural empyema is a serious condition requiring surgical intervention in advanced stages. This systematic review and meta-analysis compared the outcomes of video-assisted thoracoscopic surgery (VATS) and open thoracotomy in the management of pleural empyema.

Method: After performing a systematic search on electronic databases, 15 studies were included with a total of 1,795 patients.

Result: The results demonstrated that VATS was associated with significantly shorter chest tube duration (MD: −2.68 days, 95% CI: −4.22 to −1.13, $p < 0.001$), reduced rates of prolonged air leak (OR: 0.44, 95% CI: 0.26 to 0.74, $p = 0.001$), and lower total complications (OR: 0.62, 95% CI: 0.44 to 0.87, $p = 0.006$). Mortality, reoperation rates, and recurrence rates were comparable between VATS and open thoracotomy, indicating similar efficacy for long-term disease resolution. In conclusion, this analysis highlights the advantages of VATS as a minimally invasive approach, particularly in reducing postoperative morbidity and complications.

Conclusion: Open thoracotomy remains crucial for complex or advanced cases requiring extensive decortication. The findings underscore the importance of individualized surgical decision-making based on disease stage and patient characteristics.

Keywords: *Empyema, Minimally invasive surgery, Open thoracotomy, Video-assisted thoracoscopic surgery*.
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INTRODUCTION

Pleural empyema, a serious condition characterized by the accumulation of pus within the pleural cavity, poses significant morbidity and mortality risks worldwide.[1] Prompt and effective management is critical to prevent complications such as chronic infection, respiratory failure, and systemic sepsis. Surgical intervention remains a cornerstone of treatment, particularly in patients with advanced empyema where conservative measures such as antibiotics and drainage are insufficient.[2] The evolution of surgical techniques has introduced minimally invasive approaches, notably video-assisted thoracoscopic surgery (VATS), as an alternative to traditional open thoracotomy. VATS, with its ability to provide adequate visualization and access to the pleural cavity, has gained traction due to purported benefits, including reduced postoperative pain, shorter hospital stays, and faster recovery.[3] However, open thoracotomy continues to be the standard approach for complex or advanced cases, offering direct access and the ability to perform extensive debridement or decortication when necessary.[4]

Despite the increasing adoption of VATS, there remains ongoing debate about its efficacy and safety compared to open thoracotomy, particularly in patients with advanced empyema (Stage II and III). Key clinical questions center around differences in operative outcomes, postoperative complications, recurrence rates, and overall mortality. Existing literature provides mixed findings, with some studies favoring VATS for its minimally invasive nature and others advocating open thoracotomy for its comprehensive surgical access. This study aims to provide a thorough analysis comparing VATS and open thoracotomy for the surgical management of pleural empyema. By synthesizing data from multiple studies, this research aims to highlight the strengths and weaknesses of each surgical approach, offering useful insights to guide clinical decisions and improve treatment guidelines.

METHODS

Study Design

This study was conducted as a systematic review and meta-analysis to compare the outcomes of video-assisted thoracoscopic surgery (VATS) and open thoracotomy in the management of pleural empyema. The study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[5]

Search Strategy

A comprehensive literature search was performed using the PubMed and ScienceDirect databases to identify relevant studies. The search was conducted until September 2024. The following search terms and Boolean operators were used: "empyema" OR "pleural empyema" OR "thoracic empyema" AND ("VATS" OR "video-assisted thoracoscopic surgery") AND ("thoracotomy" OR "open thoracotomy"). We did not apply any restrictions on language or publication year, and all studies meeting the inclusion criteria, regardless of publication year, were considered for inclusion. Reference lists of included studies were also reviewed to identify additional relevant articles.

Inclusion and Exclusion Criteria

Studies were included if they: (1) Reported outcomes of patients undergoing VATS or open thoracotomy for the treatment of pleural empyema; (2) Included adult patients with empyema (Stage II or III); (3) Provided data on at least one of the outcomes of interest. Studies were excluded if they were: (1) case reports, conference abstracts, or reviews without original data; (2) Focused on pediatric populations; (3) Lacked sufficient detail on surgical outcomes or study methodology.

Outcomes of interest

The outcomes assessed in this study included mortality, which was defined as all-cause death occurring during the postoperative period or within 30 days after surgery. Chest tube duration refers to the total number of days the chest tube remained in place postoperatively. A prolonged air leak was defined as an air leak persisting for five or more days following surgery. Total complications encompassed any postoperative adverse event reported in the studies, including infections, bleeding, and other complications. Reoperation was characterized as the need for additional surgical intervention after the initial procedure. Lastly, recurrence refers to the re-accumulation of pleural empyema requiring further medical or surgical intervention.

Data Extraction

Two independent reviewers extracted data from the included studies. The following parameters were collected: study characteristics (author, year of publication, sample size); patient demographics (age, gender); clinical characteristics (empyema stage, comorbidities); and surgical outcomes, including complications, mortality, length of chest tube duration, and recurrence rates.

Disagreements between reviewers were resolved through consensus or by consulting a third reviewer.

Statistical Analysis

All statistical analyses were performed using RevMan 5.4.1 software. For continuous outcomes, mean differences (MDs) with 95% confidence intervals (CIs) were calculated. For dichotomous outcomes, odds ratios (ORs) or risk ratios (RRs) with 95% CIs were computed. We used a random-effects model, and heterogeneity among studies was assessed using the I^2 statistic. Publication bias was evaluated using funnel plots.

RESULTS

Study Selection

The initial database search identified 2,272 studies, with 1,031 duplicate records removed before screening. After title and abstract screening, 274 studies were assessed for eligibility. Among these, 171 reports were not retrieved, and 103 studies underwent full-text review. Following exclusions for irrelevant interventions, incomplete data, and insufficient outcome reporting, 15 studies were included in the final systematic review and meta-analysis.[6–18] The PRISMA flow diagram details the study selection process (Figure 1).

Study Characteristics and Quality Assessment

The included studies comprised both retrospective and prospective designs, with sample sizes of 1017 patients for the VATS group and 778 patients for the open thoracotomy group. The mean age of participants varied from 31.1 to 61.3 years across studies. Most studies included patients with advanced empyema (Stage II and III), with detailed staging reported in several studies. The baseline characteristics of the included studies are summarized in Table 1, which highlights the study design, population, mean age, and empyema stage distribution for each survey. Key characteristics and quality assessments of the included studies are summarized in Table 1. The Newcastle-Ottawa Scale (NOS) scores ranged from 7 to 8, indicating overall moderate to high methodological quality (Table 2).

Outcomes

Six studies reported on mortality rates. The pooled analysis revealed no significant difference between VATS and open thoracotomy (Odds Ratio [OR]: 0.81, 95% Confidence Interval [CI]: 0.23 to 2.77, $p = 0.73$), with moderate heterogeneity ($I^2 = 56\%$). Chest tube duration was significantly shorter in the VATS group compared to open thoracotomy (Mean Difference [MD]: −2.68 days, 95% CI: −4.22 to −1.13, $p < 0.001$). High heterogeneity was observed ($I^2 = 81\%$). Prolonged air leak (≥5 days) was less common in the VATS group (OR: 0.44, 95% CI: 0.26 to 0.74, $p = 0.001$), with low heterogeneity ($I^2 = 0\%$). Total complications were significantly lower in the VATS group compared to open thoracotomy (OR: 0.62, 95% CI: 0.44 to 0.87, $p = 0.006$), with no heterogeneity ($I^2 = 0\%$). Reoperation rates did not differ significantly between the two groups (OR: 0.37, 95% CI: 0.11 to 1.22, $p = 0.10$), with no heterogeneity ($I^2 = 0\%$). The recurrence rates were comparable between VATS and open thoracotomy (OR: 1.02, 95% CI: 0.33 to 3.16, $p = 0.99$), with low heterogeneity ($I^2 = 22\%$). The forest plots of study outcomes are provided in Figure 2.

Heterogeneity and Publication Bias

Heterogeneity was moderate to high for some outcomes, such as chest tube duration ($I^2 = 81\%$) and mortality ($I^2 = 56\%$). Funnel plots for each outcome were visually inspected, with no significant evidence of publication bias identified (Figure 3).

DISCUSSION

This systematic review and meta-analysis provide a comprehensive comparison of video-assisted thoracoscopic surgery (VATS) and open thoracotomy for

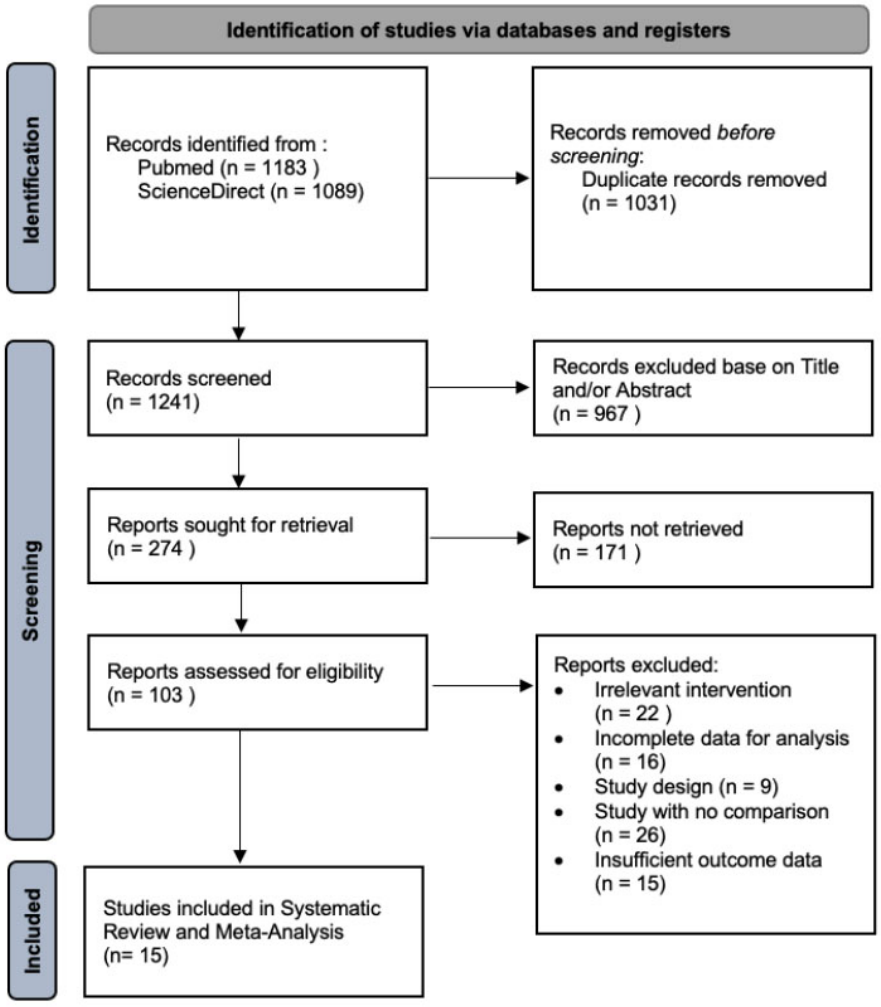

Figure 1. PRISMA flow diagram.

the management of pleural empyema, highlighting their respective strengths and limitations across key clinical outcomes. The findings contribute to the ongoing debate regarding the optimal surgical approach for this challenging condition. Our analysis demonstrated several important findings across the outcomes evaluated. No significant differences in mortality were observed between VATS and open thoracotomy. This finding suggests that both approaches are effective in managing life-threatening infections associated with pleural empyema. Thoracotomy, with its larger incisions, provides direct access for extensive decortication, particularly in complex or advanced cases. While it carries a higher risk of complications and prolonged recovery, it remains equally effective in resolving life-threatening empyema.

This comparable efficacy in managing severe infections ensures that mortality rates between the two techniques remain similar when performed by experienced surgeons. VATS was associated with significantly shorter chest tube duration compared to open thoracotomy. This result suggests that VATS, as a minimally invasive technique, may promote faster postoperative recovery by reducing the extent of pleural disruption and inflammation. From a surgical perspective, the reduced tissue trauma and smaller incision size in VATS lead to less exudative response in the pleural cavity, which likely accounts for the shorter chest tube duration. The mean reduction of 2.68 days is clinically meaningful, particularly in reducing hospital stays and associated healthcare costs. Patients undergoing VATS experienced significantly fewer cases of prolonged air leak (≥5 days) compared to those undergoing open thoracotomy. This advantage may be attributed to the precision of VATS in handling lung parenchyma and sealing leaks, which can improve postoperative recovery and reduce patient discomfort.[21] The total complication rate was notably lower in the VATS group, underscoring the safety profile of minimally invasive surgery. Complications such as infections and bleeding were reduced, likely due to the less invasive nature of VATS, which involves smaller incisions and gentler tissue handling. This is in contrast to thoracotomy, which involves larger incisions and more significant tissue disruption, leading to a higher risk of complications. The comparable reoperation rates indicate that both VATS and open thoracotomy achieve similar surgical efficacy in resolving empyema, minimizing the need for additional interventions. The recurrence rates were also similar between the two approaches, highlighting their comparable long-term effectiveness in achieving disease resolution. From a theoretical perspective, recurrence may depend more on the completeness of the surgical procedure and patient-specific factors rather than the surgical approach itself. This finding reinforces that VATS, despite being less invasive, provides durable outcomes comparable to open thoracotomy.

Despite the numerous advantages of VATS highlighted in this study, it is important to acknowledge that VATS can be associated with conversion to thoracotomy in cases where the minimally invasive approach fails, particularly in advanced-stage empyema requiring extensive decortication. However, this aspect was not assessed in our analysis and warrants further investigation in future studies. Lardinois et al. demonstrated that the likelihood of conversion to thoracotomy significantly increases with delayed VATS. Specifically, for fibrinopurulent empyema, the probability of conversion rises from 22% on day 12 to 86% by day 16, indicating the challenges of performing successful minimally invasive surgery as the disease progresses.[22] Similarly, Chung et al., in a retrospective analysis of 120 VATS empyemectomies, confirmed that early referral to surgery is associated with better outcomes. Patients with symptoms lasting

Table 1. Baseline characteristic of included studies

Study	Design	Population		Age, mean (SD)		Empyema Phase (Stage)	
		VATS	Open	VATS	Open	VATS	Open
Reichert (2017)[6]	Retrospective single-center	110	107	61.3 (15.6)	54.2 (15.9)	All Stg. III	
Chan (2007)[7]	Retrospective	41	36	46.1 (14.7)	48.6 (16.0)	NR	NR
Shahin (2009)[8]	Retrospective	32	19	NR	NR	Stg. II: 36%, Stg. III: 64%	
Dokhan (2022)[9]	Prospective cohort	28	30	49.79 (7.85)	48.23 (8.44)	All Stg. III	
Banik (2021)[10]	Prospective cohort	35	35	35.2 (11.64)	37.1 (13.39)	Stg. II: 77.1%, Stg. III: 22.9%	Stg. II: 60%, Stg. III: 40%
Jindal (2020)[11]	Prospective single-center	24	27	48.21 (10.96)	42.30 (12.26)	NR	NR
Waller (2001)[12]	Prospective cohort	21	12	45.4 (4.1)	43.5 (4.1)	NR	NR
Hajjar (2016)[13]	Prospective cohort	25	12	42.72 (21.93)	36.76 (12.89)	All Stg. III	
Podbielski (2000)[14]	Retrospective	16	14	51.6 (NR)	50.9 (NR)	NR	NR
Mackinlay (1996)[15]	Retrospective	31	33	48.9 (17.6)	51.1 (17.8)	NR	NR
Cardillo (2009)[16]	Retrospective	185	123	55.8 (10.6)	57 (12.9)	Stg. II: 63.7%, Stg. III: 36.3%	Stg. II: 69.1%, Stg. III: 30.9%
Muhammad (2012)[17]	Prospective cohort	25	24	31.1 (8.99)	33 (8.80)	NR	NR
Tong (2009)[18]	Retrospective	326	94	55 (17)	53 (17)	NR	NR
Laohathai (2019)[19]	Retrospective	98	202	52.20 (16.02)	49.41 (19.19)	Stg. II: 29.59%, Stg. III: 70.41%	Stg. II: 13.37%, Stg. III: 85.64%
Hossain (2022)[20]	Cross-sectional	20	10	35 (10)	40 (10)	Mostly Stg. III	

Abbreviation: VATS= video-assisted thoracoscopic surgery, Stg.= stage, NR= not reported, SD= standard deviation

Table 2. The Newcastle-Ottawa Scale qualitative analysis of the included studies

Author	Study design	NOS Score			Total score
		Selection	Comparability	Outcome	
Reichert (2017)[6]	Retrospective	★★★	★★	★★★	8
Chan (2007)[7]	Retrospective	★★★	★★	★★	7
Shahin (2009)[8]	Retrospective	★★★	★★	★★	7
Dokhan (2022)[9]	Prospective	★★★	★★	★★	7
Banik (2021)[10]	Prospective	★★★	★★	★★★	8
Jindal (2020)[11]	Prospective	★★★	★★	★★	7
Waller (2001)[12]	Prospective	★★★	★★	★★★	8
Hajjar (2016)[13]	Prospective	★★★	★★	★★★	8
Podbielski (2000)[14]	Retrospective	★★★	★★	★★★	8
Mackinlay (1996)[15]	Retrospective	★★★	★★	★★★	8
Cardillo (2009)[16]	Retrospective	★★★	★★	★★	7
Muhammad (2012)[17]	Prospective	★★★	★★	★★★	8
Tong (2009)[18]	Retrospective	★★★	★★	★★★	8
Laohathai (2019)[19]	Retrospective	★★★	★★	★★	7
Hossain (2022)[20]	Cross-sectional	★★★	★★	★★	7

less than four weeks had significantly improved early results compared to those with symptom durations exceeding four weeks. These findings emphasize the importance of performing VATS early in the disease course, especially before the empyema progresses to an advanced stage that necessitates thoracotomy.[23] This also represents one of the limitations of our study, as we did not further analyze the specific optimal timing for VATS, which could significantly influence the success of the procedure or the likelihood of conversion to thoracotomy.

A significant strength of this study is the inclusion of a robust number of studies with high methodological quality, as evidenced by Newcastle-Ottawa Scale scores ranging from 7 to 8. Additionally, the use of predefined inclusion criteria and standardized statistical methods enhances the reliability of the results. However, the study is not without limitations. High heterogeneity was observed for some outcomes, such as chest tube duration, which may reflect variability in study populations, surgical expertise,

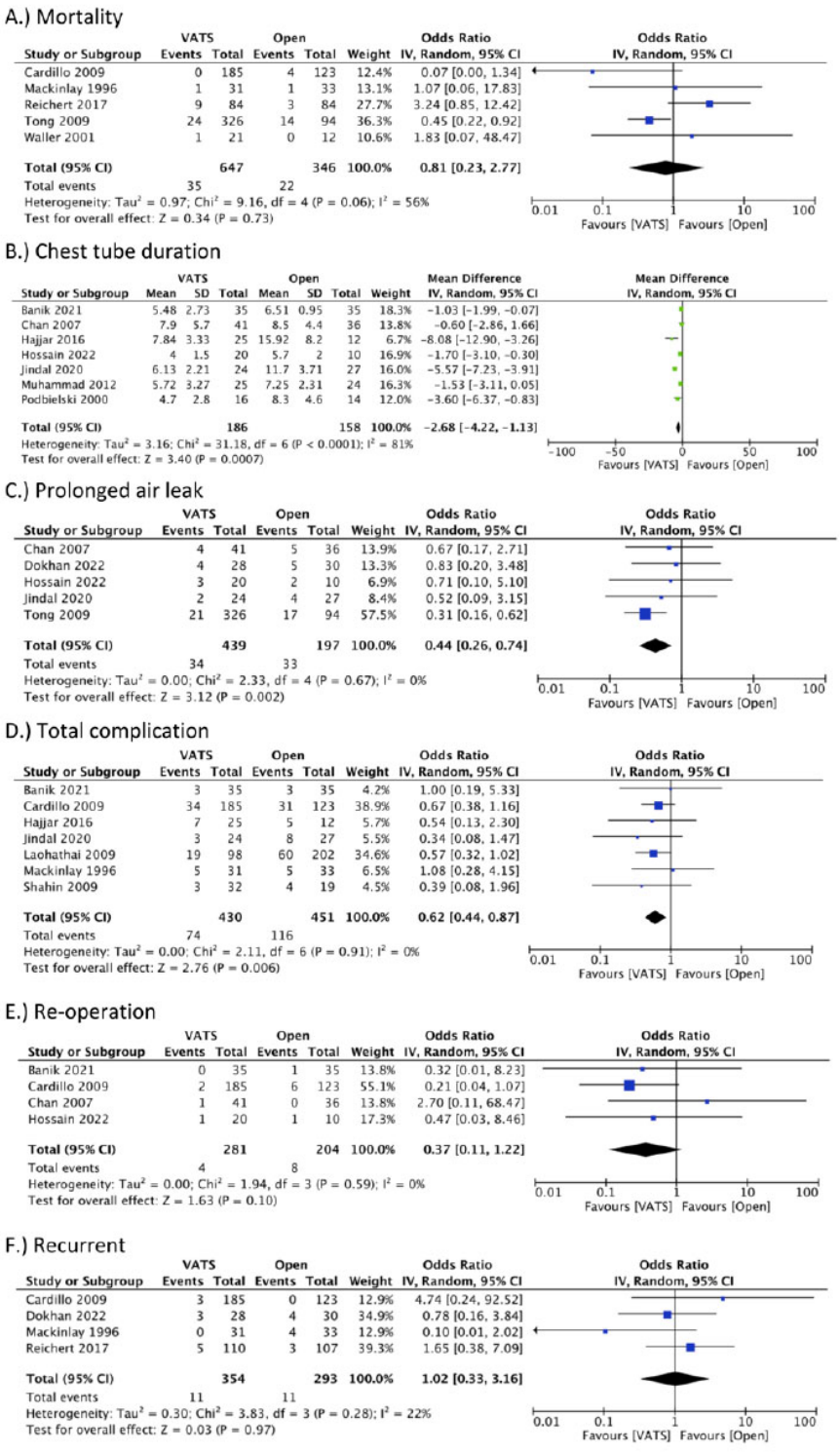

Figure 2. Forest plots of outcomes comparing VATS vs. Open thoracotomy.

and reporting standards. Furthermore, the inclusion of retrospective studies introduces potential bias, and the absence of patient-level data limits the ability to perform subgroup analyses (e.g., based on empyema stage or comorbidities). Another limitation is the lack of analysis regarding the specific timing of VATS and its influence on outcomes. While evidence suggests that early VATS is associated with better success rates and lower conversion to thoracotomy, this study did not examine the optimal timing for VATS, which could have provided critical insights into the timing-dependent efficacy of the procedure. Addressing this in future research may help guide clinical decisions on the timing of surgical intervention.

CONCLUSION

The superior outcomes associated with VATS in terms of postoperative recovery and complication rates suggest that it should be considered the preferred approach for most patients with pleural empyema, particularly in early-stage disease. The shorter chest tube duration and lower rates of prolonged air leaks and complications are significant advantages that can improve patient comfort, reduce hospital stays, and lower healthcare costs. However, open thoracotomy remains an indispensable option for complex or advanced cases where extensive decortication is required. These results emphasize the need for individualized decision-making based on patient characteristics, disease stage, and surgical expertise.

DISCLOSURE

Conflict of Interest

The authors declare no conflicts of interest and have no affiliations or relationships with any industries.

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Authors Contribution

IWS conceptualized the study design, supervised data collection, and led the drafting of the manuscript. PFKP performed the systematic literature review, conducted data analysis, and contributed to manuscript preparation. KPY assisted with result interpretation, critically revised the manuscript for intellectual content, and ensured methodological rigor. IKAPH provided clinical insights, supported the analysis of surgical outcomes, and reviewed the final draft for approval. All authors have read and approved the final version of the manuscript and agree to be accountable for its accuracy and integrity.

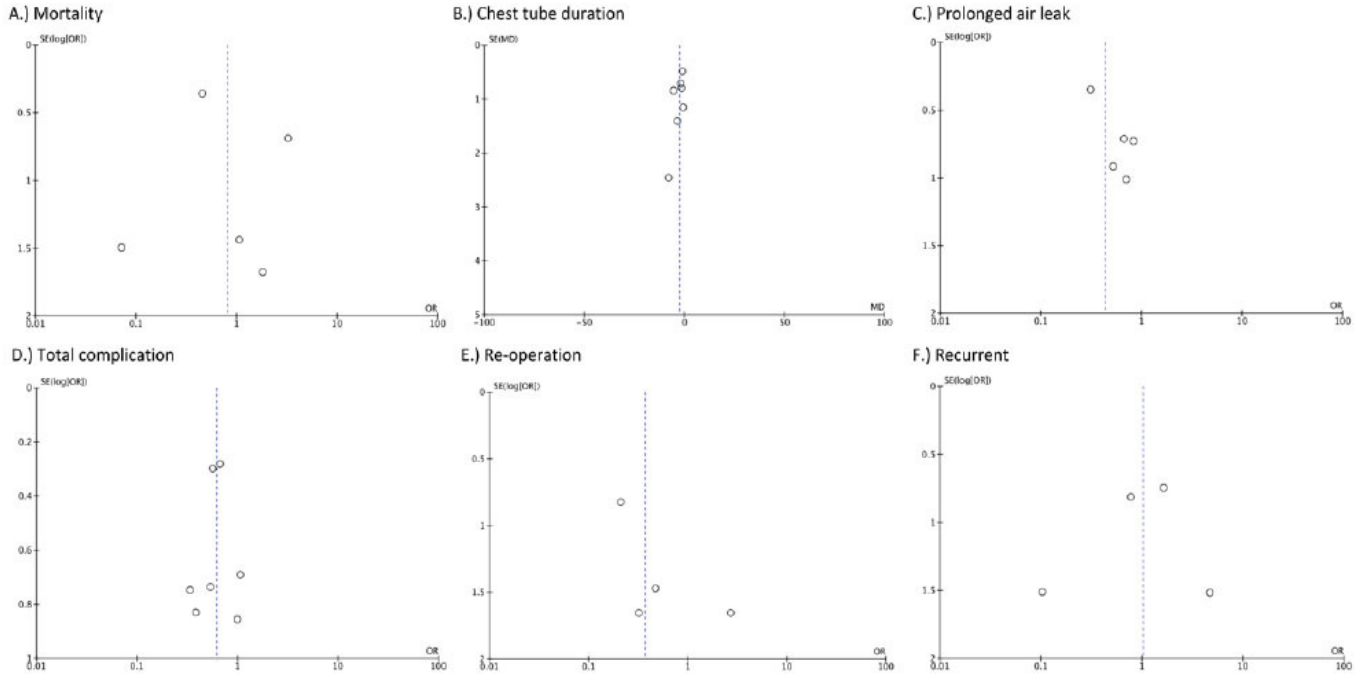

Figure 3. Funnel plots of outcomes comparing VATS vs. Open thoracotomy.

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