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Meta-analysis comparing the perioperative efficacy of single-port versus two and multi-port video-assisted thoracoscopic surgical anatomical lung resection for lung cancer

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Abstract

Background: As a new surgical procedure for non-small cell lung cancer, single-port video-assisted thoracoscopic surgery (VATS) has lately gained popularity; nevertheless, it is unknown if single-port VATS offers any advantages over multi-portal. The study aims to assess the different impacts of using single-port VATS versus 2-port or multi-port VATS such as operation and drainage time, blood loss volume, number of resected lymph nodes, and hospital stay in lung cancer patients.

Methods: Inclusion criteria included studies from different languages that compare single-port against 2 or multi-port VATS. The outcomes of these studies were analyzed using a random-effect model and it was used to calculate the mean difference with 95 percent confidence intervals to quantify the impact of different surgical techniques on clinical parameters.

Results: Single or Uni-portal video-assisted thoracoscopic surgery results in significantly lower drainage time after surgery compared with 2-port ($P = .03$) and multi-port ($P < .001$) VATS. In contrast to the resection of lymph nodes, there was no significant difference between uni-port and 2-port ($P = .49$) or multiport ($P = .29$) VATS. While operation time, blood loss, complications, and hospital stay were significantly lower in uni-port compared with multi-port VATS ($P = .04$, $P = .002$, $P < .001$, respectively), but not with 2-port VATS ($P = .44$, 0.06, $P = .13$). There were no significant differences between uni-port and multi-port VATS regarding conversion rate, mortality, and staging.

Conclusion: Single or Uni-portal video-assisted thoracoscopic surgery has high efficacy and lower side effects compared with multi-port regarding the perioperative outcomes. Two-port VATS has similar results with uni-port in several parameters.

Abbreviations: CI = confidence interval, MD = mean difference, M-VATS = multi-portal video-assisted thoracoscopic surgery, U-VATS = Uni-portal video-assisted thoracoscopic surgery, VATS = video-assisted thoracoscopic surgery.

Keywords: hospital stay, lung cancer, operation time, Uniport, video-assisted thoracoscopic surgery

1. Introduction

Small cell lung carcinoma and non-small cell lung carcinoma are the 2 main categories of lung cancer based on their growth and dissemination patterns. Surgery, radiotherapy, chemotherapy, and targeted therapy are all viable alternatives for treating lung cancer.[1] For individuals with early-stage lung cancer, a complete surgical resection has the potential to be curative, whereas the long-term prognosis remains dismal for those with metastases. Segmentectomy and video-assisted thoracoscopic surgery (VATS) are only 2 examples of the many surgical procedures that have undergone rapid evolution and advancement in recent decades.[2]

Most commonly, 1 observation hole and 2 to 3 operation holes are used[3] while performing a VATS incision. Single utility port thoracoscopic surgery has reduced the number of incisions required for VATS from multiple incisions to 2 incisions, thanks to advances in laparoscopic instrumentation.[4] Single-port VATS lobectomy was originally described by Gonzalez-Rivas et al in the early months of 2011,x[5] and this work was the first of its kind to be published anywhere in the world. In recent years, single-port VATS has been created, and its minimum invasiveness and ease of operation make it attractive.[6] Single-port VATS lobectomy is just as safe and effective as triple-port VATS in both randomized controlled trials and cohort studies.[7,8] Prospective randomized controlled trials[9–11] have confirmed that VATS is superior to standard thoracotomy in terms of mortality rate, postoperative discomfort, and quality of life. Multi-portal video-assisted

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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thoracoscopic surgery (M-VATS) was the standard method of performing VATS, and it required making 3 or 4 tiny incisions in the patient's chest wall. Uni-portal video-assisted thoracic surgery (U-VATS) is a relatively recent development in the field of thoracic surgery. Rocco et al originally reported on uni-portal minimally invasive surgery in 2004, and since then it has swiftly evolved to include more sophisticated thoracic procedures, such as lobectomy, segmentectomy, and even bronchial or pulmonary angioplasty.[12] Numerous articles have already been written about the potential of the U-VATS strategy for treating lung neoplasm. In several studies,[13] researchers found no distinction between the 2 methods in terms of the most important intra- and postoperative outcomes. Although some of these trials have shown potential benefits of the U-VATS technique, such as decreased blood loss during surgery, a shorter hospital stay, and less discomfort thereafter,[14–16] the outcomes of these investigations were very inconsistent. For instance, Lin et al suggested that U-VATS greatly increased operation time in comparison to the M-VATS approach,[6] whereas Bourdages-Pageau et al believed that operation time was significantly reduced in the U-VATS group.[17] Uni-portal VATS has been shown to either shorten or lengthen hospital stays.[18,19] There has been no definitive study comparing the clinical efficacy of U-VATS with M-VATS.

The study aims to assess the different impacts of using single-port VATS versus 2-port or multi-port VATS on clinical outcomes such as operation and drainage time, blood loss volume, number of resected lymph nodes, and hospital stay for lung cancer patients.

2. Method

2.1. Study design

Current meta-analyses of clinical studies were included in the epidemiological declaration[20] and had a set study protocol. For data collection and analysis, a wide variety of databases were consulted, including OVID, PubMed, Cochrane Library, Embase, and Google Scholar.

2.2. Data pooling

Retrospective studies focusing on the assessment of the impact of different VATS techniques using uni-portal or 2 and multi-portal on the perioperative outcomes were used to analyze the consequences of various outcomes. Regardless of language, only human-related studies were involved. There was no restriction on the sample size of recruited studies. Non-interventional studies such as reviews, editorials, or letters were excluded from the current meta-analysis. The whole study identification process is illustrated in Figure 1.

2.3. Eligibility and Inclusion

Analyzing the impact of different VATS techniques on perioperative outcomes in lung cancer patients was used to construct a summary.

Sensitivity analysis comprised only papers reporting the impact of interventions on operation time, drainage time, number of lymph nodes resected, the volume of blood loss during surgery, and hospital stay. The interventional groups were

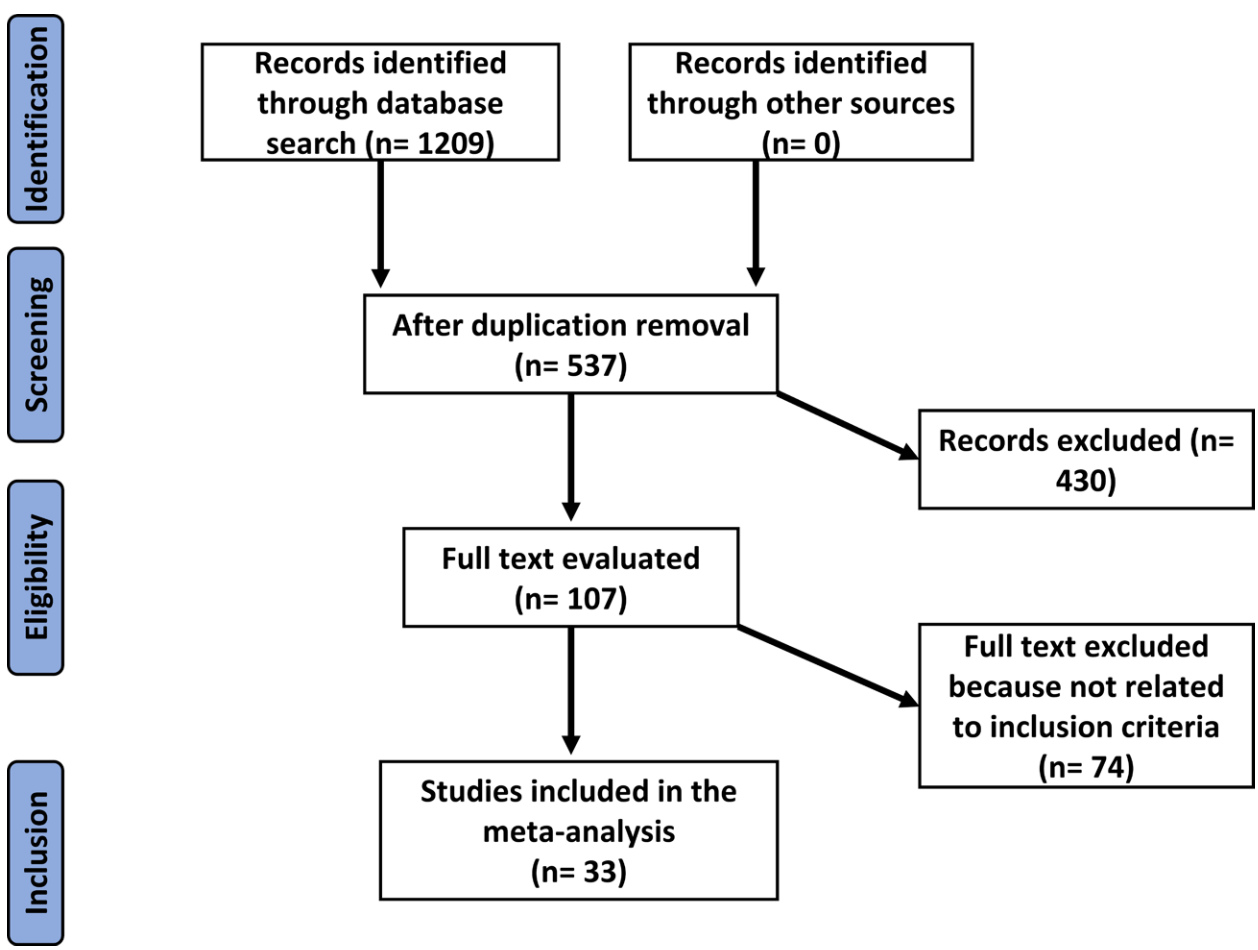

Figure 1. Schematic diagram of the study procedure.

Table 1

Search strategy for each database.

Database	Search strategy
Pubmed	#1 "Single-port VATs"[MeSH Terms] OR "Two-port VATS"[All Fields] #2 "Lung cancer"[MeSH Terms] OR "multiport"[All Fields] #3 #1 AND #2
OVID	#1 " Single-port VATs "[All fields] OR " Two-port VATS "[All Fields] #2 " Lung cancer "[All fields] OR " multiport "[All Fields] #3 #1 AND #2
Google Scholar	#1 " Single-port VATs " OR " Two-port VATS " #2 " Lung cancer " OR " multiport " #3 #1 AND #2
Embase	' Single-port VATs/exp OR Two-port VATS ' #2 " Lung cancer '/exp OR ' multiport ' #3 #1 AND #2
Cochrane library	(Single-port VATs):ti,ab,kw (Two-port VATS):ti,ab,kw (Word variations have been searched) #2 (' Lung cancer):ti,ab,kw OR (multiport):ti,ab,kw (Word variations have been searched) #3 #1 AND #2

ti,ab,kw = terms in either title or abstract or keyword fields, exp = exploded indexing term, VATS = video-assisted thoracoscopic surgery.

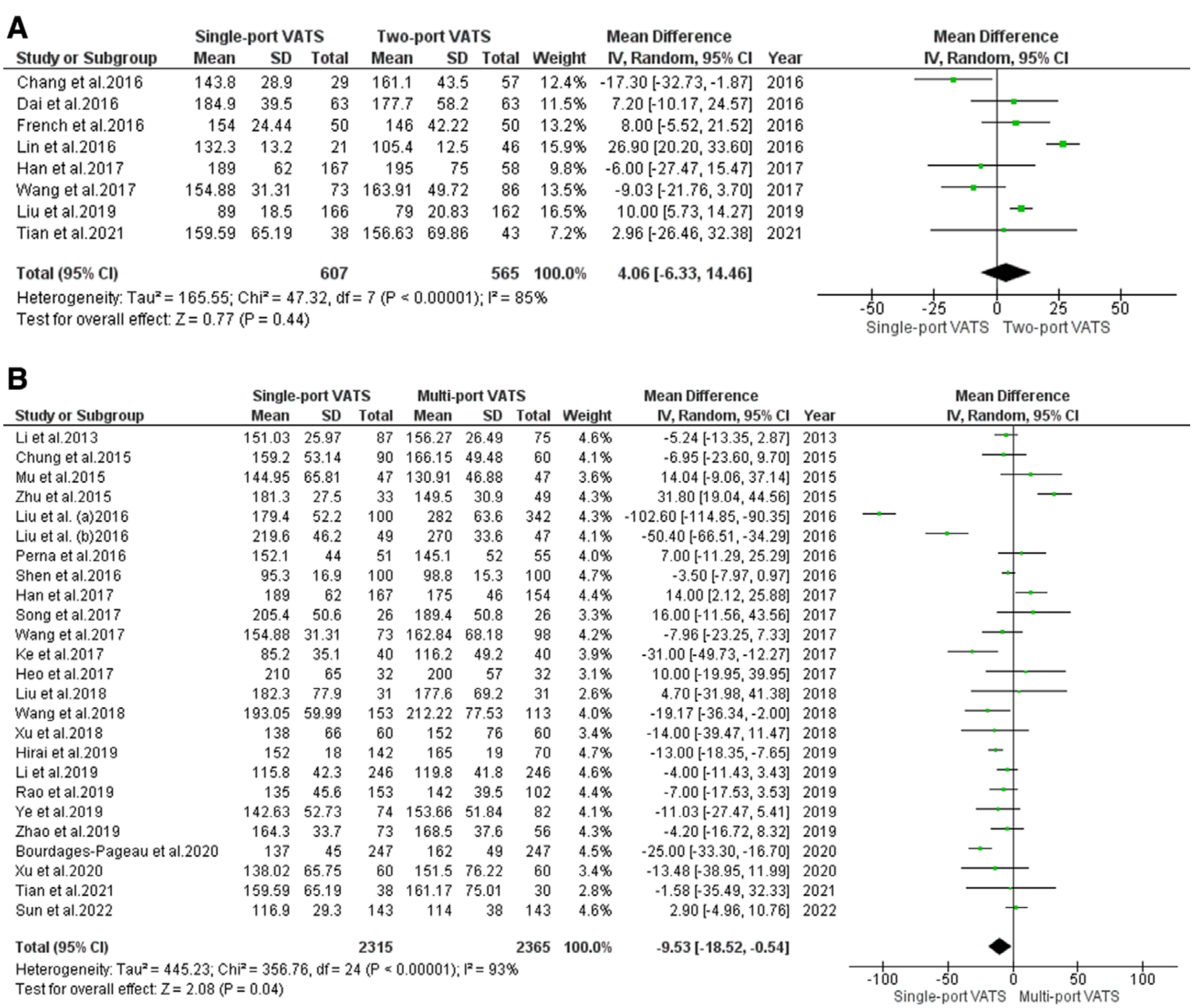

Figure 2. Forest plot showing the impact of uni-port versus 2-port VATS (a) and uni-port versus multi-port VATS (b) on operation time. VATS = video-assisted thoracoscopic surgery.

compared to a range of subject types for subclass and sensitivity analysis.

The following inclusion criteria have to be completed for an article to be considered for inclusion in the meta-analysis:

1. The allowed studies could be either retrospective, prospective, or cohort studies.
2. The target intervention population consisted of individuals with lung cancer undergoing thoracic surgery using VATS.
3. The intervention regimen of the included studies was to compare the perioperative outcomes for U-VATS against either 2-port or multi-port VATS.

The exclusion criteria were:

1. Studies that failed to identify the perioperative outcomes for different interventions.
2. Review articles, letters, books, and book chapters were also excluded from the current study.
3. Studies were excluded if they are not focusing on the impact of comparison outcomes.

2.4. Identification

According to the PICOS principle, a protocol of search strategies was developed[21] and defined as follows: P (population) Lung cancer subjects; I (intervention/exposure): thoracic surgery using VATS; C (comparison): surgical techniques. O (outcome): operation time, drainage time, blood loss, lymph resection, complications, conversion rate, mortality, staging, and hospital stay; S (study design): Cohort studies.[22]

Using the keywords and associated phrases listed in Table 1 (Search strategies for different databases), we conducted a complete search of the PubMed, OVID, Cochrane Library, Embase, and Google Scholar databases until August 2022. There was a review of the titles and abstracts of all the publications that had been collated into a reference managing software, and any research that did not link the different VAST techniques with perioperative outcomes was excluded. The 2 authors (Y.L. and T. D.) act as reviewers for the identification of suitable studies.

2.5. Screening

According to the following criteria, data were trimmed down to include: study and subject-related features in a standard format; the sir name of the first author; the period of the study the year of publication; the country of the study; and the design of the study; the population type recruited in the studies; the total number of subjects; qualitative and quantitative evaluation method, demographic data; clinical and treatment characteristics; information source; outcome evaluation; and statistical analysis.[23] Each study was assessed for bias, and the methodological quality of the chosen studies was evaluated by 2 writers in a blinded fashion.

The Newcastle-Ottawa Scale (NOS), a quality and bias assessment tool developed specifically for observational research, was used to do just that. The NOS examines the

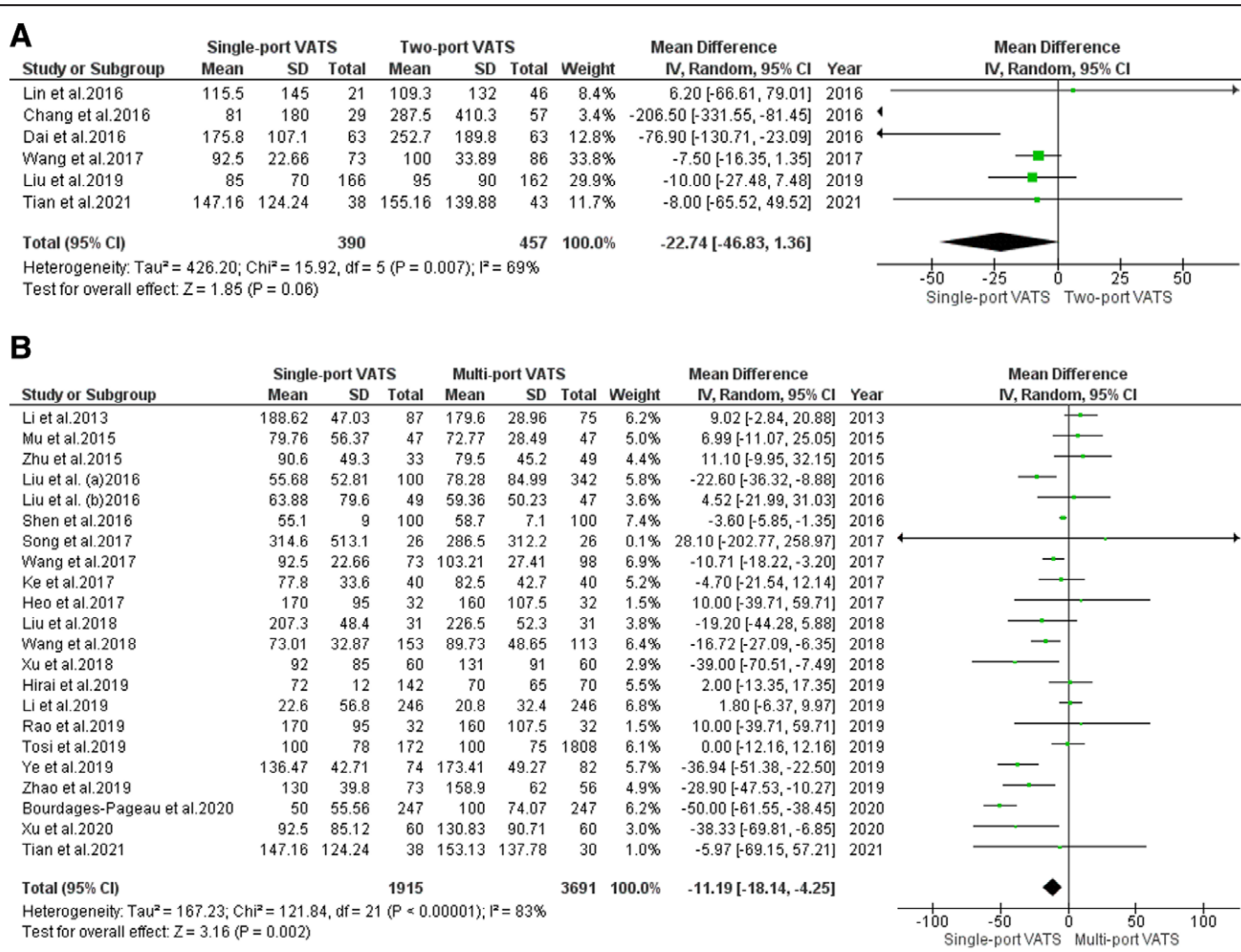

Figure 3. Forest plot showing the impact of uni-port versus 2-port VATS (a) and uni-port versus multi-port VATS (b) on blood loss during operation. VATS = video-assisted thoracoscopic surgery.

sample, the comparability of cases and controls, and the exposure in observational studies. This scale can be used to assign values between 0 and 9. Studies with a rating of 7 to 9 stars are of the highest quality and have the lowest risk of bias compared to those with a rating of 4. Studies with a quality and bias risk rating between 4 and 6 stars are considered to be of moderate quality. Each study was given a methodological evaluation by 2 reviewers.

3. Statistical analysis

The mean difference (MD) with a 95% confidence interval (CI) was calculated using a random-effect model in the current meta-analysis. All groups were analyzed using the random model due to high heterogeneity in some groups and inconsistent methodology in other groups while using the fixed models requires the confirmation of high similarity between the included study and low heterogeneity (I^2) level. The I^2 index (determined using Reviewer manager and expressed in the form of Forrest plots), a numeric value ranging from 0 to 100, was calculated (%). Percentages ranging from 0% to 25% to 50% to 75% indicated the absence of heterogeneity, as did percentages indicating low, moderate, and high heterogeneity.[24] Random effect models were used when heterogeneity is high. Subcategory analysis was performed by stratifying the initial evaluation into result categories as previously stated. Publication bias was investigated quantitatively with Begg's test and publication bias was considered present if $P > .05$.[25] To get the p-values, a test with 2 tails was used. The statistical analysis and graphs were displayed using the Reviewer Manager version 5.3 software (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) and Jamovi software 2.3 using the dichotomous model.

4. Results

Thirty-three studies published between 2013 and 2022 were included in the meta-analysis because they fit the inclusion criteria following a review of 1209 relevant studies.[6–8,17–44] Table 2 (characteristic of included studies including year, country, number of subjects, patients' characteristics, and Nos score) summarizes the findings of these investigations.

4.1. Operation time

Thirty studies (Han et al, Wang et al, Tian et al, and Liu et al, were represented twice in both analyses) including 8 studies with 1172 subjects reported data stratified according to operation time of uni-port versus 2-port VATS (Fig. 2 a), and 26 studies including 6660 subjects comparing the uniport versus multiport VATS (Fig. 2 b). Uni-port VATS was not significantly different from 2-port VATS, (MD = 4.06, 95% CI [-6.33, 14.46], P = .44 with heterogeneity I^2 = 85%). On the other hand, U-VATS resulted in lower operation time compared with multi-port, MD = -9.53, 95% CI [-18.52, -0.54], P = .04 with heterogeneity I^2 = 93%. According to Lim et al, the operation time of VATS compared with open surgery was not different statistically. Begg's test results were P = .99 for the comparison of uni-port versus

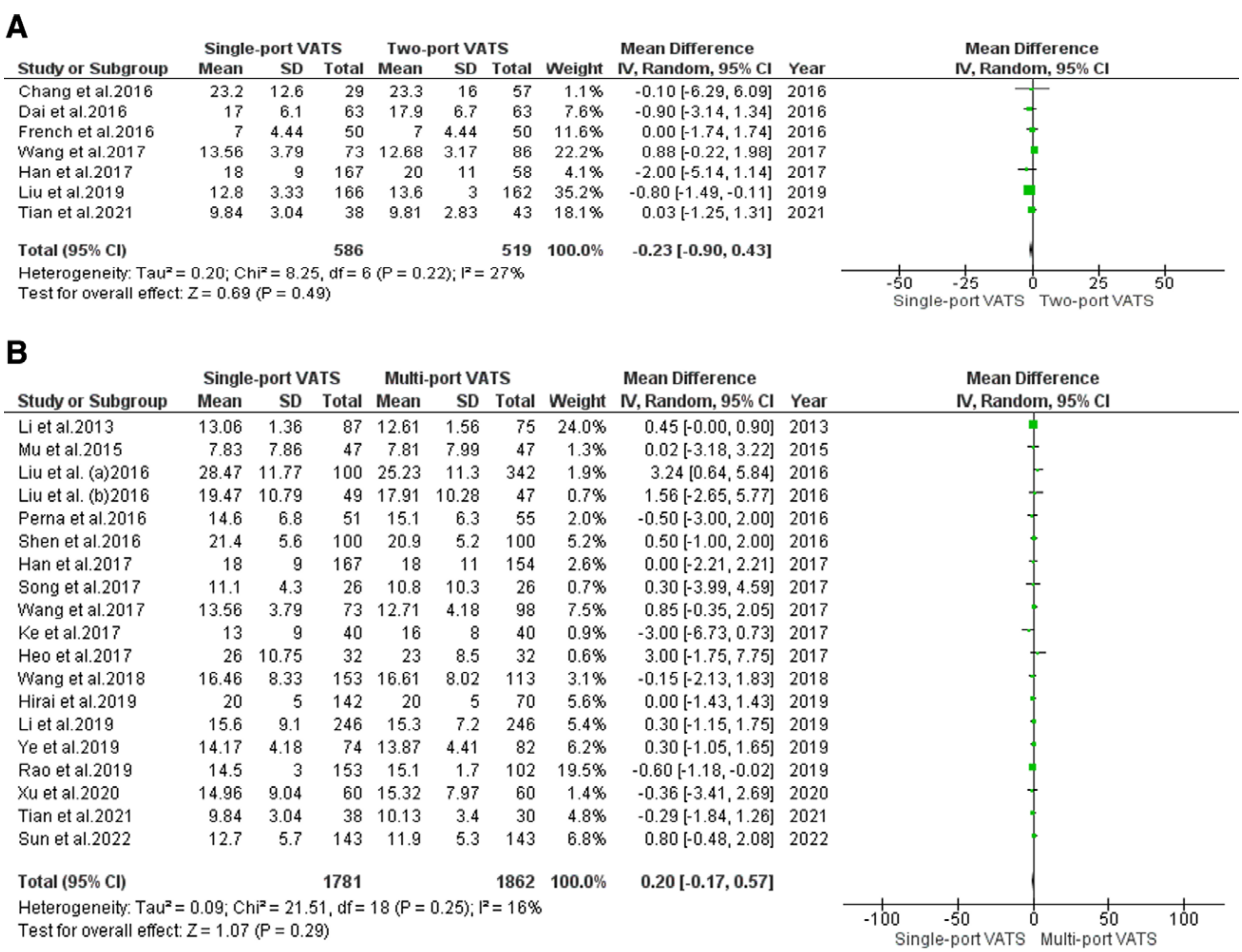

Figure 4. Forest plot showing the impact of uni-port versus 2-port VATS (a) and uni-port versus multi-port VATS (b) on resected lymph nodes. VATS = video-assisted thoracoscopic surgery.

2-port and P = .17 for the analysis of uni-port versus multi-port VATS.

4.2. Blood loss

Twenty-five studies (Wang et al, Tian et al, and Liu et al, were represented twice in both analyses) including 6 studies with 847 subjects reported data stratified according to blood loss volume of uni-port versus 2-port VATS (Fig. 3 a), and 22 studies including 5797 subjects comparing the uniport versus multi-port VATS (Fig. 3 b). Uni-port VATS was not significantly different from 2-port VATS, (MD = -22.74, 95% CI [-46.83, 1.36], P = .06 with heterogeneity I^2 = 69%). On the other hand, U-VATS resulted in lower blood loss compared with multi-port, MD = -11.19, 95% CI [-18.14, -4.25], P = .002 with heterogeneity I^2 = 83%. Begg's test results were P = .99 for the comparison of uni-port versus 2-port and P = .57 for the analysis of uni-port versus multi-port VATS.

4.3. Number of lymph nodes resected

Twenty-two studies (Han et al, Wang et al, Tian et al, and Liu et al, were represented twice in both analyses) including 7 studies with 1105 subjects reported data stratified according to the number of resected lymph nodes for uni-port versus 2-port VATS (Fig. 4 a), and 19 studies including 3643 subjects comparing the uniport versus multi-port VATS (Fig. 4 b). Uni-port VATS was not significantly different from 2-port VATS, (MD = -0.23, 95% CI [-0.90, 0.43], P = .49 with heterogeneity I^2 = 27%), or multi-port, MD = 0.20, 95% CI [-0.17, 0.57], P = .29 with heterogeneity I^2 = 16%. Begg's test results were P = .38 for the comparison of uni-port versus 2-port and P = .63 for the analysis of uni-port versus multi-port VATS.

4.4. Drainage time

Twenty-seven studies (Han et al, Wang et al, and Tian et al, were represented twice in both analyses) including 8 studies with 1172 subjects reported data stratified according to drainage time after surgery for uni-port versus 2-port VATS (Fig. 5 a), and 22 studies including 3766 subjects comparing the uniport versus multi-port VATS (Fig. 5 b). Uni-port VATS was significantly different from 2-port VATS, (MD = -0.62, 95% CI [-1.17, -0.08], P = .03 with heterogeneity I^2 = 82%), and multi-port, MD = -0.42, 95% CI [-0.66, -0.18], P < .001 with heterogeneity I^2 = 75% regarding the drainage time by expressing lower drainage time. Begg's test results were P = .006 for the comparison of uni-port versus 2-port and P = .83 for the analysis of uni-port versus multi-port VATS.

4.5. Hospital stay

Tweenty-two (Wang et al, and Tian et al, were represented twice in both analyses) including 6 studies with 821 subjects reported data stratified according to hospitalization time of uni-port versus 2-port VATS (Fig. 6 a), and 18 studies including 3369

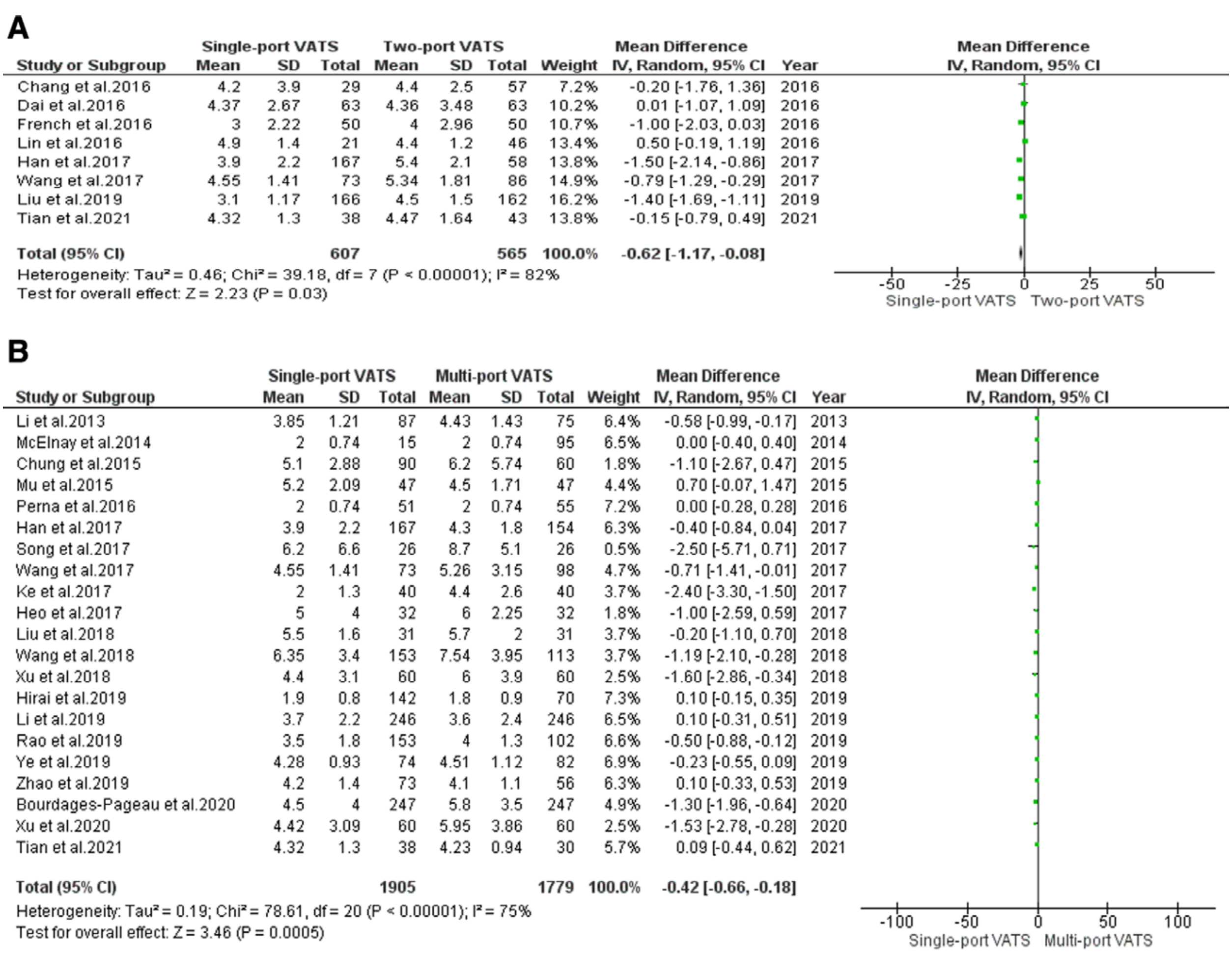

Figure 5. Forest plot showing the impact of uni-port versus 2-port VATS (a) and uni-port versus multi-port VATS (b) on drainage time. VATS = video-assisted thoracoscopic surgery.

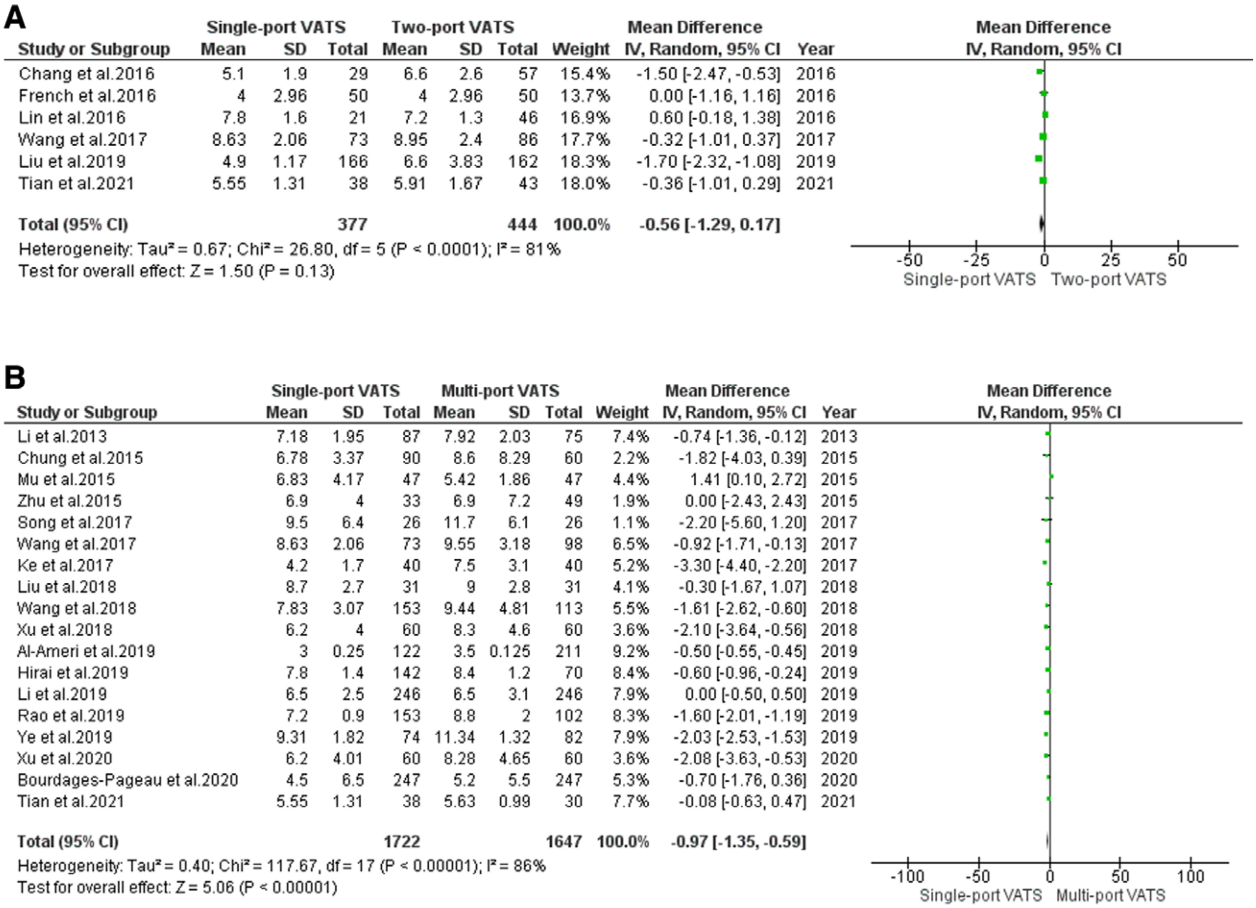

Figure 6. Forest plot showing the impact of uni-port versus 2-port VATS (a) and uni-port versus multi-port VATS (b) on Hospitalization time. VATS = video-assisted thoracoscopic surgery.

subjects comparing the uniport versus multi-port VATS (Fig. 6 b). Uni-port VATS was not significantly different from 2-port VATS, (MD = -0.56, 95% CI [-1.29, 0.17], $P = .13$ with heterogeneity $I^2 = 81\%$). On the other hand, U-VATS resulted in lower hospitalization time compared with multi-port, MD = -0.97, 95% CI [-1.35, -0.59], $P < .001$ with heterogeneity $I^2 = 93\%$. Begg's test results were $P = .47$ for the comparison of uni-port versus 2-port and $P = .94$ for the analysis of uni-port versus multi-port VATS.

There was no significant difference in outcomes related to conversion rate and mortality between uni-for VATS and multi-port. On the other hand, uni-portal VATS resulted in significantly ($P = .009$) fewer complications compared with multi-port VATS, with heterogeneity $I^2 = 0$ as shown in Figure 7. Regarding staging of the tumor, the histological and pathological staging of the tumor for both groups showed no significant difference between adenocarcinoma or squamous cell carcinoma between uni-portal and multi-portal VATs. In addition, there was no significant difference between both groups regarding stages I, II, or III as shown in Figure 8.

It was not possible to assess the impact of individual characteristics like ethnicity or gender on the comparison results because no data on these variables had been analyzed in the study. In addition, publication bias has been assessed using Begg's test which showed a non-significant bias for included analysis groups except for the analysis of drainage time between uniport and 2-port VATS.

The risk of bias assessment was evaluated using NOS as shown in table 2. Twenty-eight studies have a score between 7 and 9 which reflects a low risk of bias and high methodological quality, while only 4 studies showed a moderate risk of bias by achieving scores ranging from 4 to 6 points.

5. Discussion

A total of 32 studies were recruited for the current analysis for analyzing the impact of different VATS techniques (uni, 2, and multi-port) on the perioperative outcomes.

The use of single-port VATS in lung cancer surgery became a common practice, but its efficacy and safety compared with traditional multi-port surgeries remain the main practical question that needs deep investigation and analysis of all available studies focusing on this clinical area.

The current meta-analysis showed that single or U-VATS results in significantly lower drainage time after surgery compared with 2-port ($P = .03$) and multi-port ($P < .001$) VATS. In contrast to the resection of lymph nodes, there was no significant difference between uni-port and 2-port ($P = .49$) or multiport ($P = .29$) VATS. While operation time, blood loss, and hospital stay were significantly lower in uni-port compared with multi-port VATS ($P = .04$, $P = .002$, $P < .001$, respectively), but not with 2-port VATS ($P = .44$, 0.06, $P = .13$). In addition, the uni-portal VATS showed a fewer complication degree compared with the multi-portal. On the other hand, conversion rate and mortality post-surgery showed no significant difference between both groups. While different surgical techniques investigated in the current study showed no significant impact on the pathological staging of the tumor.

Compared to open thoracotomy, VATS surgery for early-stage lung cancer was linked with less pain, more air leaks,

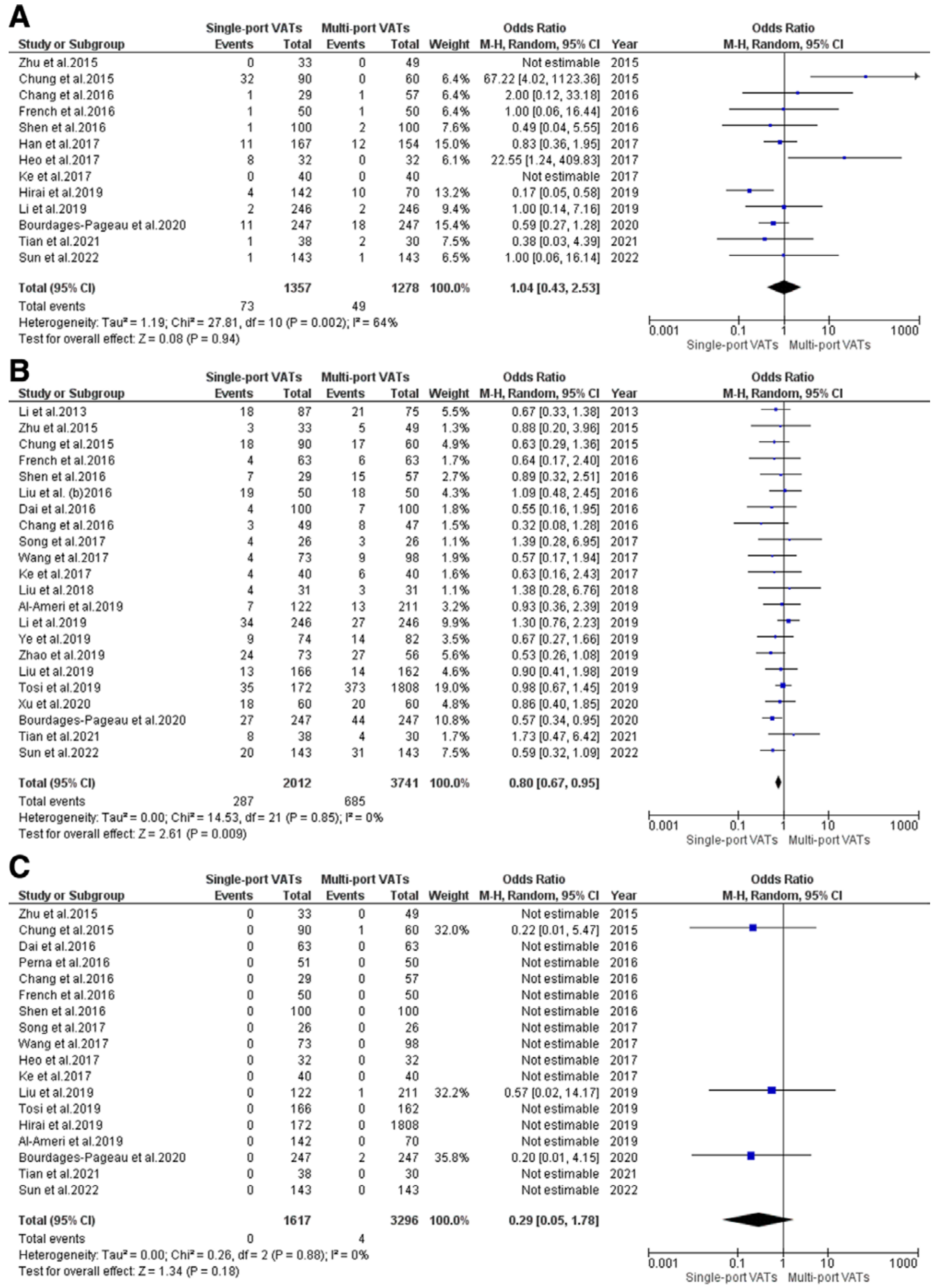

Figure 7. Forest plot showing the impact of uni-port versus multi-port VATS on conversion rate (a), complications (b), and mortality (c). VATS = video-assisted thoracoscopic surgery.

and bleeding, but overall fewer in-hospital problems, resulting in a shorter hospital stay without compromising oncologic resection.[44]

Very few clinical studies have reported on the long-term effects of U-VATS. Han et al[30] found no statistically significant difference in recurrence-free survival or overall survival between the single-incision, 2-incision, and 3-incision groups. It is worth noting that a 2016 study by Borro et al found significantly worse long-term survival in the U-VATS group compared with the M-VATS group. Using a stratified analysis, Borro revealed that patients with non-small cell lung carcinoma who underwent U-VATS had a significantly decreased survival rate regardless of tumor size (T2) or stage (I). In addition, Borro found a higher mortality rate associated with the U-VATS method.[47] Long-term consequences have not been well studied, hence a meta-analysis cannot be conducted.

As surgical oncologists, we place primary importance on achieving the best possible oncologic outcomes for our patients.[48] It is never acceptable to undertake surgery if doing so will endanger the patient's life in the long run. Thoracic surgeons should be wary of enthusiastically adopting this revolutionary method without adequately choosing suitable patients with lung cancer, even though it is arbitrary to conclude that U-VATS result in lower long-term outcomes based on only 1 trial.

The main theoretical drawback of U-VATS is that patients may have a lengthier operation time due to the small incision, restricted intercostal space, and inevitable considerable

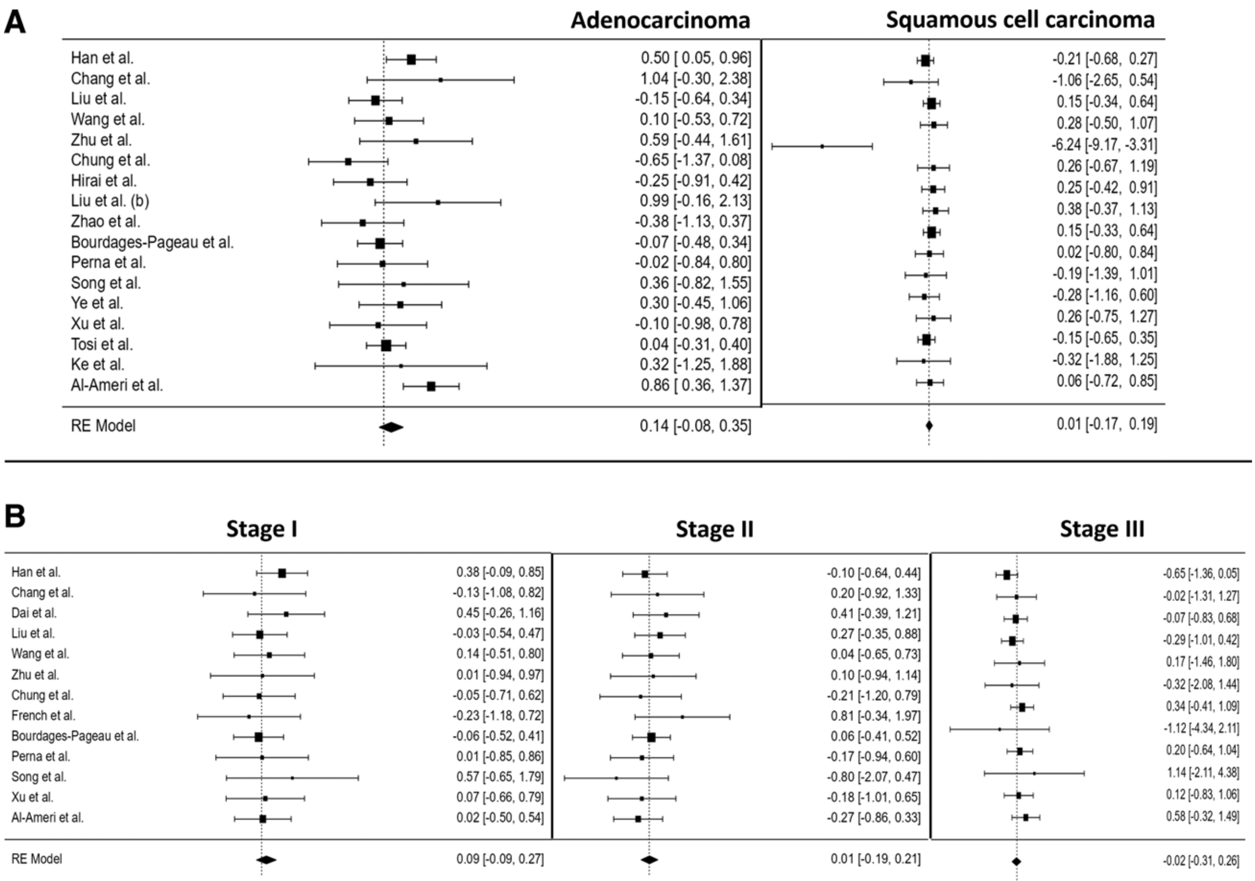

Figure 8. Forest plot showing the impact of uni-port versus multi-port VATS on histological staging (a) and pathological staging (b). VATS = video-assisted thoracoscopic surgery.

interference between the thoracoscope and the equipment.[49] On the other hand, the current meta-analysis showed that single-port VATS is linked to a shorter surgical time compared with multi-port VATS and has no significant difference in comparison with 2-port surgery. One probable explanation for this is that, like thoracotomy, direct vision can be obtained with a single-port thoracoscopic method. Due to the challenges of doing thoracic surgery through a single intracostal space, more experienced surgeons were assigned to execute the procedures in the single-port VATS group, whereas less experienced surgeons were assigned to perform the procedures in the 2 or multi-port VATS.

When Dr Gonzalez-Rivas first reported the first uni-portal VATS lobectomy in 2011,[5] it was followed by gradual improvements in the technique's utility and dependability up until now.[50] Less wound surface area means less postoperative pain, less time in the hospital, and better respiratory preservation, all of which aid in recovery from uni-portal surgery compared to standard VATS.[51] There is mounting proof that uni-portal VATS segmentectomies are more challenging than lobectomies and have a steeper learning curve. The operating time and blood loss have frequently been utilized as benchmarks for the surgical experience and skill improvement learning curve. Tian et al,[38] hypothesized that the early stages of mono portal VATS segmentectomy were more challenging, difficult, and time-consuming because of our center's experience and measurements.

6. Limitations

This study may have been skewed by the exclusion of so many trials from the meta-analysis. However, our meta-analysis excluded studies since they did not meet the inclusion criteria. In addition, some of the included studies have not evaluated the impact of race on the represented outcomes. There is no way to tell if the results are due to ethnicity. Some of the included studies have moderate methodology quality as evaluated by the NOS score. Variables such as nutritional status are not considered by included studies which may have a role in the presented outcomes. may have skewed the results. A study's results could be biased if there are unpublished articles and uncollected data.

7. Conclusions

Single or U-VATS has high efficacy and lower side effects compared with multi-port regarding the perioperative outcomes. 2-port VATS has similar results with uni-port in several parameters. However future clinical multicenter studies are needed to make a more sensible conclusion.

Author contributions

Conceptualization: Tianyang Dai, Yuan Li.
Data curation: Tianyang Dai, Yuan Li.
Formal analysis: Tianyang Dai, Yuan Li.
Investigation: Tianyang Dai
Methodology: Tianyang Dai, Yuan Li.
Software: Tianyang Dai, Yuan Li.
Visualization: Yuan Li.
Writing – original draft: Tianyang Dai, Yuan Li.
Writing – review & editing: Tianyang Dai, Yuan Li.

Table 2

Characteristic of included studies.

Study	year	country	First interventional group type	Second interventional group type	First interventional group (n)	Second interventional group (n)	Total number of subjects	Type of studies	NOs
Han et al[30]	2017	South Korea	single-port VATS	Two-port VATS	167	58	225	Retrospective	7
Han et al[30]	2017	South Korea	single-port VATS	Three-port VATS	167	154	321	Retrospective	7
Chang et al[26]	2016	China Taiwan	single-port VATS	Two-port VATS	29	57	86	Retrospective	7
Dai et al[28]	2016	China	single-port VATS	Two-port VATS	63	63	126	Retrospective	7
Lin et al[6]	2016	China	single-port VATS	Two-port VATS	21	46	67	Retrospective	7
Liu et al[20]	2019	China	single-port VATS	Two-port VATS	166	162	328	Retrospective	8
Wang et al[7]	2017	China	single-port VATS	Three-port VATS	73	98	171	Retrospective	8
Wang et al[7]	2017	China	single-port VATS	Two-port VATS	73	86	159	Retrospective	8
Tian et al[38]	2021	China	single-port VATS	Two-port VATS	38	43	81	Retrospective	8
Tian et al[38]	2021	China	single-port VATS	Three-port VATS	38	30	68	Retrospective	8
Zhu et al[43]	2015	China	single-port VATS	Three-port VATS	33	49	82	Retrospective	8
Chung et al[27]	2015	South Korea	single-port VATS	Multy-port VATS	90	60	150	Retrospective	7
Hirai et al[32]	2019	Japan	single-port VATS	Multy-port VATS	142	70	212	Retrospective	7
Liu et al[35]	2016	China	single-port VATS	Multy-port VATS	100	342	442	Retrospective	7
Liu et al[35]	2016	China	single-port VATS	Multy-port VATS (Segmentectomy)	49	47	96	Retrospective	7
Zhao et al[42]	2019	China	single-port VATS	Multy-port VATS	73	56	129	Retrospective	7
Liu et al[36]	2018	China	single-port VATS	Three-port VATS	31	31	62	RCT	4
French et al[29]	2016	Canada	single-port VATS	Two-port VATS	50	50	100	Retrospective	7
Bourdages-Pageau et al[17]	2020	Canada	single-port VATS	Multy-port VATS	247	247	494	Retrospective	8
Heo et al[31]	2017	Korea	single-port VATS	Multy-port VATS	32	32	64	Retrospective	7
Li et al[34]	2019	China	single-port VATS	Multy-port VATS	246	246	492	Retrospective	8
Mu et al[18]	2015	China	single & two-port VATS	Three-port VATS	47	47	94	Retrospective	8
Perna et al[22]	2016	Spain	single-port VATS	Multy-port VATS	51	55	106	RCT	8
Shen et al[37]	2016	China	single-port VATS	Multy-port VATS	100	100	200	Retrospective	7
Song et al[24]	2017	South Korea	single-port VATS	Two-port VATS	26	26	52	Retrospective	7
Sun et al[25]	2022	China	single-port VATS	Three-port VATS	143	143	286	Retrospective	7
Ye et al[8]	2019	China	single-port VATS	Three-port VATS	74	82	156	RCT	5
Li et al[45]	2013	China	single-port VATS	Three-port VATS	87	75	162	Retrospective	7
Rao et al[23]	2019	China	single-port VATS	Three-port VATS	153	102	255	Retrospective	7
Xu et al[40]	2018	China	single-port VATS	Three-port VATS	60	60	120	Retrospective	6
Tosi et al[39]	2019	Italy	single-port VATS	Three-port VATS	172	1808	1980	Retrospective	6
Xu et al[41]	2020	China	single-port VATS	Three-port VATS	60	60	120	Retrospective	7
Ke et al[33]	2017	China	single-port VATS	Three-port VATS	40	40	80	Retrospective	7
Wang et al[46]	2018	China	single-port VATS	Three-port VATS	153	113	266	Retrospective	7
McElnay et al[21]	2014	UK	single-port VATS	Multy-port VATS	15	95	110	Retrospective	7
Al-Ameri et al[19]	2019	Sweden	single-port VATS	Multy-port VATS	122	211	333	Retrospective	7
Lim et al[44]	2022	UK	VATS	Open surgery	247	255	502	RCT	8

RCT = randomized clinical trial, VATS = video-assisted thoracoscopic surgery.

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