

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

Yuan Li, MD^a, Tianyang Dai, MD^{a,*}

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.

^a Department of Thoracic Surgery, The Affiliated Hospital of Southwest Medical University, Sichuan, China.

^{*} Correspondence: Tianyang Dai, Department of Thoracic Surgery, The Affiliated Hospital Of Southwest Medical University, Sichuan 646000, China (e-mail: Daitianyang_sci@outlook.com).

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

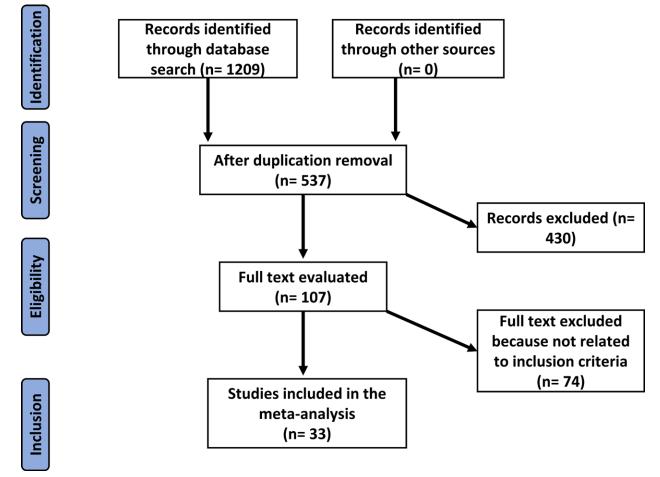


Figure 1. Schematic diagram of the study procedure.

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 ' #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.

4	Single	-port VA	IS	Two-	oort VA	IS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Chang et al.2016	143.8	28.9	29	161.1	43.5	57	12.4%	-17.30 [-32.73, -1.87]	2016	
Dai et al.2016	184.9	39.5	63	177.7	58.2	63	11.5%	7.20 [-10.17, 24.57]	2016	
French et al.2016	154	24.44	50	146	42.22	50	13.2%	8.00 [-5.52, 21.52]	2016	+
Lin et al.2016	132.3	13.2	21	105.4	12.5	46	15.9%	26.90 [20.20, 33.60]	2016	
Han et al.2017	189	62	167	195	75	58	9.8%	-6.00 [-27.47, 15.47]	2017	
/Vang et al.2017	154.88	31.31	73	163.91	49.72	86	13.5%	-9.03 [-21.76, 3.70]	2017	
Liu et al.2019	89	18.5	166	79	20.83	162	16.5%	10.00 [5.73, 14.27]	2019	-
Tian et al.2021	159.59	65.19	38	156.63	69.86	43	7.2%	2.96 [-26.46, 32.38]	2021	
Total (95% CI)			607			565	100.0%	4.06 [-6.33, 14.46]		
Heterogeneity: Tau ² =	165.55; (Chi² = 47	7.32, df	= 7 (P < 0	0.00001); l ² = 8	5%			
Test for overall effect										-50 -25 0 25 50 Single-port VATS Two-port VATS

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D										
	-	-port V/			port VA			Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Li et al.2013	151.03	25.97	87	156.27	26.49	75	4.6%	-5.24 [-13.35, 2.87]	2013	
Chung et al.2015	159.2	53.14	90	166.15	49.48	60	4.1%	-6.95 [-23.60, 9.70]	2015	
Mu et al.2015	144.95	65.81	47	130.91	46.88	47	3.6%	14.04 [-9.06, 37.14]	2015	+
Zhu et al.2015	181.3	27.5	33	149.5	30.9	49	4.3%	31.80 (19.04, 44.56)	2015	
Liu et al. (a)2016	179.4	52.2	100	282	63.6	342	4.3%	-102.60 [-114.85, -90.35]	2016	<u> </u>
Liu et al. (b)2016	219.6	46.2	49	270	33.6	47	4.1%	-50.40 [-66.51, -34.29]	2016	_ —
Perna et al.2016	152.1	44	51	145.1	52	55	4.0%	7.00 [-11.29, 25.29]	2016	-+
Shen et al.2016	95.3	16.9	100	98.8	15.3	100	4.7%	-3.50 [-7.97, 0.97]	2016	-1
Han et al.2017	189	62	167	175	46	154	4.4%	14.00 [2.12, 25.88]	2017	
Song et al.2017	205.4	50.6	26	189.4	50.8	26	3.3%	16.00 [-11.56, 43.56]	2017	+
Wang et al.2017	154.88	31.31	73	162.84	68.18	98	4.2%	-7.96 [-23.25, 7.33]	2017	+
Ke et al.2017	85.2	35.1	40	116.2	49.2	40	3.9%	-31.00 [-49.73, -12.27]	2017	
Heo et al.2017	210	65	32	200	57	32	3.1%	10.00 [-19.95, 39.95]	2017	
Liu et al.2018	182.3	77.9	31	177.6	69.2	31	2.6%	4.70 [-31.98, 41.38]	2018	
Wang et al.2018	193.05	59.99	153	212.22	77.53	113	4.0%	-19.17 [-36.34, -2.00]	2018	
Xu et al.2018	138	66	60	152	76	60	3.4%	-14.00 [-39.47, 11.47]	2018	
Hirai et al.2019	152	18	142	165	19	70	4.7%	-13.00 [-18.35, -7.65]	2019	-
Li et al.2019	115.8	42.3	246	119.8	41.8	246	4.6%	-4.00 [-11.43, 3.43]	2019	
Rao et al.2019	135	45.6	153	142	39.5	102	4.4%	-7.00 [-17.53, 3.53]	2019	-++
Ye et al.2019	142.63	52.73	74	153.66	51.84	82	4.1%	-11.03 [-27.47, 5.41]	2019	
Zhao et al.2019	164.3	33.7	73	168.5	37.6	56	4.3%	-4.20 [-16.72, 8.32]	2019	
Bourdages-Pageau et al.2020	137	45	247	162	49	247	4.5%	-25.00 [-33.30, -16.70]	2020	
Xu et al.2020	138.02	65.75	60	151.5	76.22	60	3.4%	-13.48 [-38.95, 11.99]	2020	
Tian et al.2021	159.59		38	161.17	75.01	30	2.8%	-1.58 [-35.49, 32.33]	2021	
Sun et al.2022	116.9	29.3	143	114	38	143	4.6%	2.90 [-4.96, 10.76]	2022	+
Total (95% CI)			2315			2365	100.0%	-9.53 [-18.52, -0.54]		•
Heterogeneity: Tau ² = 445.23; C	hi² = 356.1	76. df = 2	24 (P <	0.00001)	; I ² = 93'	%				
Test for overall effect: Z = 2.08 (F			- •							-100 -50 0 50 100
										Single-port VATS Multi-port VATS

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:

- The allowed studies could be either retrospective, prospective, or cohort studies.
- 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

	Single	e-port VA	IS		port VAT			Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Lin et al.2016	115.5	145	21	109.3	132	46	8.4%	6.20 [-66.61, 79.01]	2016	
Chang et al.2016	81	180	29	287.5	410.3	57	3.4%	-206.50 [-331.55, -81.45]	2016 <	(
Dai et al.2016	175.8	107.1	63	252.7	189.8	63	12.8%	-76.90 [-130.71, -23.09]	2016 4	•
Wang et al.2017	92.5	22.66	73	100	33.89	86	33.8%	-7.50 [-16.35, 1.35]	2017	
Liu et al.2019	85	70	166	95	90	162	29.9%	-10.00 [-27.48, 7.48]	2019	
Tian et al.2021	147.16	124.24	38	155.16	139.88	43	11.7%	-8.00 [-65.52, 49.52]	2021	
Total (95% CI)			390			457	100.0 %	-22.74 [-46.83, 1.36]		
Heterogeneity: Tau ² =	= 426.20: 0	Chi ² = 15.	92. df =	5(P = 0.	007); $ ^2 =$	69%			-	
Test for overall effect				- (//					-50 -25 Ó 25 50 Sinale-port VATS Two-port VATS

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	_	e-port VA			port VAT			Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
.i et al.2013	188.62	47.03	87	179.6	28.96	75	6.2%	9.02 [-2.84, 20.88]	2013	+
/lu et al.2015	79.76	56.37	47	72.77	28.49	47	5.0%	6.99 [-11.07, 25.05]	2015	- -
Zhu et al.2015	90.6	49.3	33	79.5	45.2	49	4.4%	11.10 [-9.95, 32.15]	2015	+
.iu et al. (a) 2016	55.68	52.81	100	78.28	84.99	342	5.8%	-22.60 [-36.32, -8.88]	2016	_ —
.iu et al. (b)2016	63.88	79.6	49	59.36	50.23	47	3.6%	4.52 [-21.99, 31.03]	2016	
Shen et al.2016	55.1	9	100	58.7	7.1	100	7.4%	-3.60 [-5.85, -1.35]	2016	-
Song et al.2017	314.6	513.1	26	286.5	312.2	26	0.1%	28.10 [-202.77, 258.97]	2017	•
Vang et al.2017	92.5	22.66	73	103.21	27.41	98	6.9%	-10.71 [-18.22, -3.20]	2017	
<e al.2017<="" et="" td=""><td>77.8</td><td>33.6</td><td>40</td><td>82.5</td><td>42.7</td><td>40</td><td>5.2%</td><td>-4.70 [-21.54, 12.14]</td><td>2017</td><td></td></e>	77.8	33.6	40	82.5	42.7	40	5.2%	-4.70 [-21.54, 12.14]	2017	
leo et al.2017	170	95	32	160	107.5	32	1.5%	10.00 [-39.71, 59.71]	2017	
iu et al.2018.	207.3	48.4	31	226.5	52.3	31	3.8%	-19.20 [-44.28, 5.88]	2018	
Vang et al.2018	73.01	32.87	153	89.73	48.65	113	6.4%	-16.72 [-27.09, -6.35]	2018	
(u et al.2018	92	85	60	131	91	60	2.9%	-39.00 [-70.51, -7.49]	2018	
Hirai et al.2019	72	12	142	70	65	70	5.5%	2.00 [-13.35, 17.35]	2019	+
.i et al.2019	22.6	56.8	246	20.8	32.4	246	6.8%	1.80 [-6.37, 9.97]	2019	+
Rao et al.2019	170	95	32	160	107.5	32	1.5%	10.00 [-39.71, 59.71]	2019	
°osi et al.2019	100	78	172	100	75	1808	6.1%	0.00 [-12.16, 12.16]	2019	
/e et al.2019	136.47	42.71	74	173.41	49.27	82	5.7%	-36.94 [-51.38, -22.50]	2019	
(hao et al.2019	130	39.8	73	158.9	62	56	4.9%	-28.90 [-47.53, -10.27]	2019	<u> </u>
Bourdages-Pageau et al.2020	50	55.56	247	100	74.07	247	6.2%	-50.00 [-61.55, -38.45]	2020	
(u et al.2020	92.5	85.12	60	130.83	90.71	60	3.0%	-38.33 [-69.81, -6.85]	2020	
ian et al.2021	147.16	124.24	38	153.13	137.78	30	1.0%	-5.97 [-69.15, 57.21]	2021	
otal (95% CI)			1915			3691	100.0%	-11.19 [-18.14, -4.25]		•
leterogeneity: Tau ² = 167.23; Cl	hi ² = 121.8	84, df = 21	1 (P < 0	00001);	²= 83%					
Test for overall effect: Z = 3.16 (F										-100 -50 Ó 50 10 Single-port VATS Multi-port VATS

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 (I2) level. The I2 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 I² = 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 I² = 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

Study or Subgroup Mear Chang et al.2016 23.3 Dai et al.2016 13 French et al.2016 13 Wang et al.2017 13.56	12.6	Total 29 63 50	Mean 23.3 17.9	SD 16 6.7	57	Weight 1.1%	-0.10 [-6.29, 6.09]		IV, Random, 95% Cl
Daietal.2016 1 French et al.2016 3	6.1	63				1.1%	-0.10 [-6.29, 6.09]	2016	
French et al.2016			17.9	67					
	4.44	50		0.7	63	7.6%	-0.90 [-3.14, 1.34]	2016	+
/Vangetal.2017 13.56		50	7	4.44	50	11.6%	0.00 [-1.74, 1.74]	2016	+
	3.79	73	12.68	3.17	86	22.2%	0.88 [-0.22, 1.98]	2017	•
Han et al. 2017 18	; 9	167	20	11	58	4.1%	-2.00 [-5.14, 1.14]	2017	-+
Liu et al.2019 12.8	3.33	166	13.6	3	162	35.2%	-0.80 [-1.49, -0.11]	2019	•
Tian et al.2021 9.84	3.04	38	9.81	2.83	43	18.1%	0.03 [-1.25, 1.31]	2021	+
Fotal (95% CI)		586			519	100.0%	-0.23 [-0.90, 0.43]		

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	Single	e-port V	ATS	Multi	port VA	TS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD		Mean			Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Li et al.2013	13.06	1.36	87	12.61	1.56	75	24.0%	0.45 [-0.00, 0.90]	2013	•
Mu et al.2015	7.83	7.86	47	7.81	7.99	47	1.3%		2015	+
Liu et al. (a)2016	28.47	11.77	100	25.23	11.3	342	1.9%	3.24 [0.64, 5.84]	2016	~
Liu et al. (b)2016	19.47	10.79	49	17.91	10.28	47	0.7%	1.56 [-2.65, 5.77]	2016	+
Perna et al.2016	14.6	6.8	51	15.1	6.3	55	2.0%	-0.50 [-3.00, 2.00]	2016	+
Shen et al.2016	21.4	5.6	100	20.9	5.2	100	5.2%	0.50 [-1.00, 2.00]	2016	+
Han et al.2017	18	9	167	18	11	154	2.6%	0.00 [-2.21, 2.21]	2017	+
Song et al.2017	11.1	4.3	26	10.8	10.3	26	0.7%	0.30 [-3.99, 4.59]	2017	+
Wang et al.2017	13.56	3.79	73	12.71	4.18	98	7.5%	0.85 [-0.35, 2.05]	2017	ł
Ke et al.2017	13	9	40	16	8	40	0.9%	-3.00 [-6.73, 0.73]	2017	-
Heo et al.2017	26	10.75	32	23	8.5	32	0.6%	3.00 [-1.75, 7.75]	2017	+-
Wang et al.2018	16.46	8.33	153	16.61	8.02	113	3.1%	-0.15 [-2.13, 1.83]	2018	4
Hirai et al.2019	20	5	142	20	5	70	5.6%	0.00 [-1.43, 1.43]	2019	1
Li et al.2019	15.6	9.1	246	15.3	7.2	246	5.4%	0.30 [-1.15, 1.75]	2019	1
Ye et al.2019	14.17	4.18	74	13.87	4.41	82	6.2%	0.30 [-1.05, 1.65]	2019	
Rao et al.2019	14.5	3	153	15.1	1.7	102	19.5%	-0.60 [-1.18, -0.02]	2019	•
Xu et al.2020	14.96	9.04	60	15.32	7.97	60	1.4%	-0.36 [-3.41, 2.69]	2020	+
Tian et al.2021	9.84	3.04	38	10.13	3.4	30	4.8%	-0.29 [-1.84, 1.26]	2021	t t
Sun et al.2022	12.7	5.7	143	11.9	5.3	143	6.8%	0.80 [-0.48, 2.08]	2022	t
Total (95% CI)			1781			1862	100.0%	0.20 [-0.17, 0.57]		
Heterogeneity: Tau ² =	= 0.09; Cl	hi² = 21.:	51.df=	18 (P =	0.25); P	² = 16%	,			
Test for overall effect					-71					-100 -50 Ó 50 100 Single-port VATS Multi-port VATS
			č							Single-port VATS Multi-port VATS

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.

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 I² = 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 I² = 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). Uniport VATS was not significantly different from 2-port VATS, (MD = -0.23, 95% CI [-0.90, 0.43], P = .49 with heterogeneity I² = 27%), or multi-port, MD = 0.20, 95% CI [-0.17, 0.57], P = .29 with heterogeneity I² = 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 I² = 82%), and multi-port, MD = -0.42, 95% CI [-0.66, -0.18], *P* < .001 with heterogeneity I² = 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

	Single	-port V	ATS	Two-	ort VA	TS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Chang et al.2016	4.2	3.9	29	4.4	2.5	57	7.2%	-0.20 [-1.76, 1.36]	2016	4
Dai et al.2016	4.37	2.67	63	4.36	3.48	63	10.2%	0.01 [-1.07, 1.09]	2016	+
French et al.2016	3	2.22	50	4	2.96	50	10.7%	-1.00 [-2.03, 0.03]	2016	
Lin et al.2016	4.9	1.4	21	4.4	1.2	46	13.4%	0.50 [-0.19, 1.19]	2016	+
Han et al.2017	3.9	2.2	167	5.4	2.1	58	13.8%	-1.50 [-2.14, -0.86]	2017	-
Wang et al.2017	4.55	1.41	73	5.34	1.81	86	14.9%	-0.79 [-1.29, -0.29]	2017	
Liu et al.2019	3.1	1.17	166	4.5	1.5	162	16.2%	-1.40 [-1.69, -1.11]	2019	•
Tian et al.2021	4.32	1.3	38	4.47	1.64	43	13.8%	-0.15 [-0.79, 0.49]	2021	1
Total (95% CI)			607			565	100.0%	-0.62 [-1.17, -0.08]		
Heterogeneity: Tau ² =	0.46; Ch	i ² = 39.1	18. df=	7 (P < 0	.00001); $l^2 = 8$	2%			
Test for overall effect										-50 -25 0 25 50 Single-port VATS Two-port VATS

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-	Single	-port V	ATS	Multi-	port VA	ITS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Li et al.2013	3.85	1.21	87	4.43	1.43	75	6.4%	-0.58 [-0.99, -0.17]	2013	4
McElnay et al.2014	2	0.74	15	2	0.74	95	6.5%	0.00 [-0.40, 0.40]	2014	
Chung et al.2015	5.1	2.88	90	6.2	5.74	60	1.8%	-1.10 [-2.67, 0.47]	2015	-
Mu et al.2015	5.2	2.09	47	4.5	1.71	47	4.4%	0.70 [-0.07, 1.47]	2015	•
Perna et al.2016	2	0.74	51	2	0.74	55	7.2%	0.00 [-0.28, 0.28]	2016	
Han et al.2017	3.9	2.2	167	4.3	1.8	154	6.3%	-0.40 [-0.84, 0.04]	2017	
Song et al.2017	6.2	6.6	26	8.7	5.1	26	0.5%	-2.50 [-5.71, 0.71]	2017	-
Wang et al.2017	4.55	1.41	73	5.26	3.15	98	4.7%	-0.71 [-1.41, -0.01]	2017	1
Ke et al.2017	2	1.3	40	4.4	2.6	40	3.7%	-2.40 [-3.30, -1.50]	2017	•
Heo et al.2017	5	4	32	6	2.25	32	1.8%	-1.00 [-2.59, 0.59]	2017	4
Liu et al.2018	5.5	1.6	31	5.7	2	31	3.7%	-0.20 [-1.10, 0.70]	2018	· · · · · · · · · · · · · · · · · · ·
Wang et al.2018	6.35	3.4	153	7.54	3.95	113	3.7%	-1.19 [-2.10, -0.28]	2018	•
Xu et al.2018	4.4	3.1	60	6	3.9	60	2.5%	-1.60 [-2.86, -0.34]	2018	4
Hirai et al.2019	1.9	0.8	142	1.8	0.9	70	7.3%	0.10 [-0.15, 0.35]	2019	
Li et al.2019	3.7	2.2	246	3.6	2.4	246	6.5%	0.10 [-0.31, 0.51]	2019	
Rao et al.2019	3.5	1.8	153	4	1.3	102	6.6%	-0.50 [-0.88, -0.12]	2019	
Ye et al.2019	4.28	0.93	74	4.51	1.12	82	6.9%	-0.23 [-0.55, 0.09]	2019	
Zhao et al.2019	4.2	1.4	73	4.1	1.1	56	6.3%	0.10 [-0.33, 0.53]	2019	
Bourdages-Pageau et al.2020	4.5	4	247	5.8	3.5	247	4.9%	-1.30 [-1.96, -0.64]	2020	•
Xu et al.2020	4.42	3.09	60	5.95	3.86	60	2.5%	-1.53 [-2.78, -0.28]	2020	-
Tian et al.2021	4.32	1.3	38	4.23	0.94	30	5.7%	0.09 [-0.44, 0.62]	2021	1
Total (95% CI)			1905			1779	100.0%	-0.42 [-0.66, -0.18]		
Heterogeneity: Tau ² = 0.19; Chi ²	= 78.61.	df = 20	(P < 0.0	0001): P	²= 75%	,				
Test for overall effect: Z = 3.46 (P										-100 -50 0 50 100 Single-port VATS Multi-port VATS

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.

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•	Single	-port V	ATS	Two-p	oort VA	IS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% Cl
Chang et al.2016	5.1	1.9	29	6.6	2.6	57	15.4%	-1.50 [-2.47, -0.53]	2016	-
French et al.2016	4	2.96	50	4	2.96	50	13.7%	0.00 [-1.16, 1.16]	2016	+
Lin et al.2016	7.8	1.6	21	7.2	1.3	46	16.9%	0.60 [-0.18, 1.38]	2016	•
Wang et al.2017	8.63	2.06	73	8.95	2.4	86	17.7%	-0.32 [-1.01, 0.37]	2017	•
Liu et al.2019	4.9	1.17	166	6.6	3.83	162	18.3%	-1.70 [-2.32, -1.08]	2019	-
Tian et al.2021	5.55	1.31	38	5.91	1.67	43	18.0%	-0.36 [-1.01, 0.29]	2021	1
Total (95% CI)			377			444	100.0%	-0.56 [-1.29, 0.17]		
Heterogeneity: Tau ² = Test for overall effect:				5 (P < 0	.0001)	; I² = 81	%		-	-50 -25 0 25 50 Single-port VATS Two-port VATS

5	Single	-port V/	ATS	Multi	port VA	TS		Mean Difference		Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	Year	IV, Random, 95% CI
Li et al.2013	7.18	1.95	87	7.92	2.03	75	7.4%	-0.74 [-1.36, -0.12]	2013	
Chung et al.2015	6.78	3.37	90	8.6	8.29	60	2.2%	-1.82 [-4.03, 0.39]	2015	~
Mu et al.2015	6.83	4.17	47	5.42	1.86	47	4.4%	1.41 [0.10, 2.72]	2015	
Zhu et al.2015	6.9	4	33	6.9	7.2	49	1.9%	0.00 [-2.43, 2.43]	2015	+
Song et al.2017	9.5	6.4	26	11.7	6.1	26	1.1%	-2.20 [-5.60, 1.20]	2017	-
Wang et al.2017	8.63	2.06	73	9.55	3.18	98	6.5%	-0.92 [-1.71, -0.13]	2017	-
Ke et al.2017	4.2	1.7	40	7.5	3.1	40	5.2%	-3.30 [-4.40, -2.20]	2017	•
Liu et al.2018	8.7	2.7	31	9	2.8	31	4.1%	-0.30 [-1.67, 1.07]	2018	+
Wang et al.2018	7.83	3.07	153	9.44	4.81	113	5.5%	-1.61 [-2.62, -0.60]	2018	1
Xu et al.2018	6.2	4	60	8.3	4.6	60	3.6%	-2.10 [-3.64, -0.56]	2018	-
Al-Ameri et al.2019	3	0.25	122	3.5	0.125	211	9.2%	-0.50 [-0.55, -0.45]	2019	
Hirai et al.2019	7.8	1.4	142	8.4	1.2	70	8.4%	-0.60 [-0.96, -0.24]	2019	-
Li et al.2019	6.5	2.5	246	6.5	3.1	246	7.9%	0.00 [-0.50, 0.50]	2019	1
Rao et al.2019	7.2	0.9	153	8.8	2	102	8.3%	-1.60 [-2.01, -1.19]	2019	-
Ye et al.2019	9.31	1.82	74	11.34	1.32	82	7.9%	-2.03 [-2.53, -1.53]	2019	•
Xu et al.2020	6.2	4.01	60	8.28	4.65	60	3.6%	-2.08 [-3.63, -0.53]	2020	-
Bourdages-Pageau et al.2020	4.5	6.5	247	5.2	5.5	247	5.3%	-0.70 [-1.76, 0.36]	2020	•
Tian et al.2021	5.55	1.31	38	5.63	0.99	30	7.7%	-0.08 [-0.63, 0.47]	2021	1
Total (95% CI)			1722			1647	100.0%	-0.97 [-1.35, -0.59]		
Heterogeneity: Tau ² = 0.40; Chi ²	= 117.67	, df = 17	(P < 0.	00001);	l² = 869	%		. , ,		-100 -50 0 50 10
Test for overall effect: $Z = 5.06$ (F	° < 0.0000	01)								Single-port VATS Multi-port VATS

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 I² = 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 I² = 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 multiport. On the other hand, uni-portal VATS resulted in significantly (P = .009) fewer complications compared with multi-port VATS, with heterogeneity I² = 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,

A	Single-port	t VATs	Multi-port	VATs		Odds Ratio		Odds Ratio
Study or Subgroup	Events	Total	Events		Weight	M-H, Random, 95% Cl	Year	M-H, Random, 95% CI
Zhu et al.2015	0	33	0	49		Not estimable	2015	
Chung et al.2015	32	90	0	60	6.4%	67.22 [4.02, 1123.36]	2015	
Chang et al.2016	1	29	1	57	6.4%	2.00 [0.12, 33.18]	2016	
French et al.2016	1	50	1	50	6.4%	1.00 [0.06, 16.44]	2016	
Shen et al.2016	1	100	2	100	7.6%	0.49 [0.04, 5.55]	2016	
Han et al.2017	11	167	12	154	15.0%	0.83 [0.36, 1.95]	2017	
Heo et al.2017	8	32	0	32	6.1%	22.55 [1.24, 409.83]	2017	
Ke et al.2017	0	40	0	40		Not estimable	2017	
Hirai et al.2019	4	142	10	70	13.2%	0.17 [0.05, 0.58]	2019	
Li et al.2019	2	246	2	246	9.4%	1.00 [0.14, 7.16]	2019	
Bourdages-Pageau et al.2020	11	247	18	247	15.4%	0.59 [0.27, 1.28]	2020	
Tian et al.2021	1	38	2	30	7.5%	0.38 [0.03, 4.39]	2021	
Sun et al.2022	1	143	1	143	6.5%	1.00 [0.06, 16.14]	2022	
Total (95% CI)		1357		1278	100.0 %	1.04 [0.43, 2.53]		+
Total events	73		49					
Heterogeneity: Tau ² = 1.19; Chi ² Test for overall effect: Z = 0.08 (P		10 (P = 0).002); l ² = 6	4%				0.001 0.1 1 10 100 Single-port VATs Multi-port VATs
3	Single-port		Multi-port			Odds Ratio		Odds Ratio
Study or Subgroup	Events	Total	Events			M-H, Random, 95% Cl	Year	M-H, Random, 95% Cl
Li et al.2013	18	87	21	75	5.5%	0.67 [0.33, 1.38]	2013	-+
Zhu et al.2015	3	33	5	49	1.3%	0.88 [0.20, 3.96]	2015	
Chung et al.2015	18	90	17	60	4.9%	0.63 [0.29, 1.36]	2015	-++
French et al.2016	4	63	6	63	1.7%	0.64 [0.17, 2.40]	2016	
Shen et al.2016	7	29	15	57	2.7%	0.89 [0.32, 2.51]	2016	
Liu et al. (b) 2016	19	50	18	50	4.3%	1.09 [0.48, 2.45]	2016	+
Dai et al.2016	4	100	7	100	1.8%	0.55 [0.16, 1.95]	2016	
Chang et al.2016	3	49	8	47	1.5%	0.32 [0.08, 1.28]	2016	
Song et al.2017	4	26	3	26	1.1%	1.39 [0.28, 6.95]	2017	
Wang et al.2017	4	73	9	98	1.9%	0.57 [0.17, 1.94]	2017	
Ke et al.2017	4	40	6	40	1.6%	0.63 [0.16, 2.43]	2017	
Liu et al. 2018	4	31	š	31	1.1%	1.38 [0.28, 6.76]	2018	
Al-Ameri et al.2019	7	122	13	211	3.2%	0.93 [0.36, 2.39]	2019	
Li et al.2019	34	246	27	246	9.9%	1.30 [0.76, 2.23]		
Ye et al.2019	9	74	14	82	3.5%	0.67 [0.27, 1.66]		
Zhao et al.2019	24	73	27	56	5.6%	0.53 [0.26, 1.08]	2019	
Liu et al.2019	13	166	14	162	4.6%	0.90 [0.41, 1.98]		
Tosi et al.2019	35	172	373	1808	4.0%	0.98 [0.67, 1.45]	2019	1
	18							
Xu et al.2020	18	60 247	20	60 247	4.8%	0.86 [0.40, 1.85]	2020	
Bourdages-Pageau et al.2020			44		10.8%	0.57 [0.34, 0.95]	2020	
Tian et al.2021 Sun et al.2022	8 20	38 143	4 31	30 143	1.7% 7.5%	1.73 (0.47, 6.42) 0.59 (0.32, 1.09)	2021 2022	
Total (95% CI)		2012		3741	100.0%	0.80 [0.67, 0.95]		•
Total events	287		685					
Heterogeneity: Tau ² = 0.00; Chi ² Test for overall effect: Z = 2.61 (P		21 (P = 0).85); I² = 0%	6				0.001 0.1 1 10 1000 Single-port VATs Multi-port VATs
0	Single-port	IVATe	Multi-port	VATe		Odds Ratio		Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl	Year	M-H, Random, 95% Cl
Zhu et al.2015	0	33	0	49		Not estimable	2015	
Chung et al.2015	0	90	1	49	32.0%	0.22 [0.01, 5.47]	2015	
Dai et al.2016	0	90 63	0	63	32.070	Not estimable	2015	-
Perna et al.2016	0	51	0	50		Not estimable	2016	
	0	29	0	57		Not estimable	2016	
Chang et al.2016 French et al.2016	0	29	0	50				
French et al.2016 Shen et al.2016	0	50 100	0	50 100		Not estimable Not estimable	2016	
							2016	
Song et al.2017	0	26	0	26		Not estimable	A-0.1.1	
Wang et al.2017	0	73	0	98		Not estimable	2017	
Heo et al.2017	0	32	0	32		Not estimable	2017	
Ke et al.2017	0	40	0	40	00.00	Not estimable	2017	
Liu et al.2019	0	122	1	211	32.2%	0.57 [0.02, 14.17]		
T	0	166	0	162		Not estimable		
	0	172	0	1808		Not estimable		
Hirai et al.2019	~			70		Not estimable		_
Hirai et al.2019 Al-Ameri et al.2019	ő	142					2020	
Hirai et al.2019 Al-Ameri et al.2019 Bourdages-Pageau et al.2020	0 0	247	2	247	35.8%	0.20 [0.01, 4.15]		
Hirai et al.2019 Al-Ameri et al.2019 Bourdages-Pageau et al.2020 Tian et al.2021	0 0 0	247 38	2 0	30	35.8%	Not estimable	2021	
Hirai et al.2019 Al-Ameri et al.2019 Bourdages-Pageau et al.2020 Tian et al.2021	0 0	247	2		35.8%			•
Hirai et al.2019 Al-Ameri et al.2019 Bourdages-Pageau et al.2020 Tian et al.2021 Sun et al.2022 Total (95% CI)	0 0 0 0	247 38	2 0	30 143	35.8% 100.0%	Not estimable	2021	•
Tosi et al.2019 Hira et al.2019 A-Ameri et al.2019 Bourdages-Pageau et al.2020 Tian et al.2021 Sun et al.2022 Total (95% CI) Total events	0 0 0 0	247 38 143 1617	2 0 0	30 143		Not estimable Not estimable	2021	
Hirai et al.2019 Al-Ameri et al.2019 Bourdages-Pageau et al.2020 Tian et al.2021 Sun et al.2022 Total (95% CI)	0 0 0 0 0 0	247 38 143 1617	2 0 0	30 143		Not estimable Not estimable	2021	

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

		Adenocarcinoma	Squamous cell carcinoma		
Han et al.) B)	0.50 [0.05, 0.96]	H	-0.21 [-0.68, 0.27]	
Chang et al.	H	1.04 [-0.30, 2.38]	⊢_ ∎-∔1	-1.06 [-2.65, 0.54]	
Liu et al.	⊢ ∎ <u>∔</u> →	-0.15 [-0.64, 0.34]	H i	0.15 [-0.34, 0.64]	
Wang et al.	⊢	0.10 [-0.53, 0.72]	⊢ ∎1	0.28 [-0.50, 1.07	
Zhu et al.	⊢ ∔	0.59 [-0.44, 1.61]	•	-6.24 [-9.17, -3.31]	
Chung et al.	⊢	-0.65 [-1.37, 0.08]		0.26 [-0.67, 1.19]	
Hirai et al.	⊢ 	-0.25 [-0.91, 0.42]	H H H	0.25 [-0.42, 0.91]	
Liu et al. (b)	⊢	0.99 [-0.16, 2.13]		0.38 [-0.37, 1.13]	
Zhao et al.	⊢ ∎≟(-0.38 [-1.13, 0.37]		0.15 [-0.33, 0.64	
Bourdages-Pageau et al.	⊢ ≞ i1	-0.07 [-0.48, 0.34]		0.02 [-0.80, 0.84	
Perna et al.	⊢	-0.02 [-0.84, 0.80]		-0.19 [-1.39, 1.01	
Song et al.	⊢	0.36 [-0.82, 1.55]		• •	
Ye et al.	⊢∔∎ −−−1	0.30 [-0.45, 1.06]	H	-0.28 [-1.16, 0.60	
Xu et al.	⊢−−−	-0.10 [-0.98, 0.78]		0.26 [-0.75, 1.27]	
Tosi et al.	⊢ ∎	0.04 [-0.31, 0.40]	H	-0.15 [-0.65, 0.35	
Ke et al.	·i	0.32 [-1.25, 1.88]	⊢	-0.32 [-1.88, 1.25	
Al-Ameri et al.	⊢ -∎	0.86 [0.36, 1.37]	H H H	0.06 [-0.72, 0.85	
RE Model	-	0.14 [-0.08, 0.35]	•	0.01 [-0.17, 0.19	

В	Stage I		Stage II		Stage	e III
Han et al.	⊢	0.38 [-0.09, 0.85]	⊢∎ →	-0.10 [-0.64, 0.44]	⊢∎ -i	-0.65 [-1.36, 0.05]
Chang et al.	⊢ ∎ (-0.13 [-1.08, 0.82]	· · · · · · · · · · · · · · · · · · ·	0.20 [-0.92, 1.33]	—	-0.02 [-1.31, 1.27]
Dai et al.	·	0.45 [-0.26, 1.16]	·	0.41 [-0.39, 1.21]	- -	-0.07 [-0.83, 0.68]
Liu et al.	⊢	-0.03 [-0.54, 0.47]	→	0.27 [-0.35, 0.88]	H H	-0.29 [-1.01, 0.42]
Wang et al.		0.14 [-0.51, 0.80]		0.04 [-0.65, 0.73]		0.17 [-1.46, 1.80]
Zhu et al.	H	0.01 [-0.94, 0.97]	·	0.10 [-0.94, 1.14]		-0.32 [-2.08, 1.44]
Chung et al.	—	-0.05 [-0.71, 0.62]	·•	-0.21 [-1.20, 0.79]		1
French et al.	⊢ ∎ i	-0.23 [-1.18, 0.72]	·	0.81 [-0.34, 1.97]	H B H	0.34 [-0.41, 1.09]
Bourdages-Pageau et al.	⊢	-0.06 [-0.52, 0.41]	⊢ _	0.06 [-0.41, 0.52]		-1.12 [-4.34, 2.11]
Perna et al.	⊢−−−− 1	0.01 [-0.85, 0.86]	·	-0.17 [-0.94, 0.60]	H H H	0.20 [-0.64, 1.04]
Song et al.	·	0.57 [-0.65, 1.79]		-0.80 [-2.07, 0.47]	·	1.14 [-2.11, 4.38]
Xu et al.	—	0.07 [-0.66, 0.79]	·	-0.18 [-1.01, 0.65]	⊢⊷	0.12 [-0.83, 1.06]
Al-Ameri et al.	⊢	0.02 [-0.50, 0.54]	⊢ ∎	-0.27 [-0.86, 0.33]	⊢ ∎1	0.58 [-0.32, 1.49]
RE Model	*	0.09 [-0.09, 0.27]	•	0.01 [-0.19, 0.21]	•	-0.02 [-0.31, 0.26]

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

Sun et al^[25]

Ye et al^[8]

Li et al^[45]

Rao et al^[23]

Xu et al^[40]

Tosi et al^[39]

Xu et al^[41]

Ke et al^[33]

Lim et al^[44]

Wang et al^[46]

McElnay et al^[21]

Al-Ameri et al^[19]

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
Fian 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
_iu 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 (Seg- mentectomy)	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
_i 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

Three-port VATS

Multy-port VATS

Multy-port VATS

Open surgery

143

74

87

60

172

60

40

153

15

122

247

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

2022

2019

2013

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2018

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2019

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China

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China

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Sweden

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single-port VATS

VATS

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1980

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Retrospective

RCT

Retrospective

Retrospective

Retrospective

Retrospective

Retrospective

Retrospective

Retrospective

Retrospective

Retrospective

RCT

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