



# A systematic review and meta-analysis of video-assisted thoracoscopic surgery treating spontaneous pneumothorax

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**Background:** With the adoption of high-tech thoracoscopic surgical instruments, video-assisted thoracoscopic surgery (VATS) has gradually replaced traditional thoracotomy and is used in the clinical treatment of spontaneous pneumothorax.

**Methods:** The composite logic retrieval and Boolean logic retrieval methods were adopted for this meta-analysis. Databases such as PubMed, Medline, Cochrane Library, CNKI, Wanfang, VIP, and Google Scholar were searched using the combination of search terms “Video-assisted thoracoscopic surgery”, “spontaneous pneumothorax”, and “thoracotomy”. Literatures which used video-assisted thoracoscopic surgery for spontaneous pneumothorax as the experimental group were screened. The software RevMan 5.3 provided by the Cochrane system was employed for meta-analysis.

**Results:** A total of 12 studies were included. After the meta-analysis, heterogeneity testing of the operation time in 8 studies showed that  $Tau^2 = 29.99$ ,  $Chi^2 = 16.99$ , degrees of freedom (df) = 7,  $I^2 = 59% > 50%$ , and the operation time of participants in the experimental group was considerably inferior to that of control group. The mean difference (MD) was  $-31.02$ , 95% confidence interval (95% CI):  $-36.07$  to  $-25.97$ ,  $Z = 12.03$ ,  $P < 0.0001$ . The heterogeneity test of the length of hospital stay in 9 studies showed that  $Tau^2 = 4.41$ ,  $Chi^2 = 122.58$ ,  $df = 8$ ,  $I^2 = 59% > 50%$ ,  $P < 0.01$ , and the length of hospital stay of participants in the experimental group was remarkably shorter than that of the control group. The MD was  $-7.29$ , 95% CI:  $(-8.76$  to  $-5.82)$ ,  $Z = 9.74$ , and  $P < 0.01$ . The heterogeneity test of the bleeding volume in 6 studies showed that  $Tau^2 = 191.74$ ,  $Chi^2 = 27.65$ ,  $df = 5$ ,  $I^2 = 82% > 50%$ ,  $P < 0.01$ , and the bleeding volume of participants in the experimental group was remarkably lower in contrast to that of the control group. The MD was  $-65.48$ , 95% CI:  $(-77.84$  to  $-53.13)$ ,  $Z = 10.39$ , and  $P < 0.01$ . The heterogeneity test of the chest tube removal time in 7 studies showed that  $Tau^2 = 0.29$ ,  $Chi^2 = 28.27$ ,  $df = 6$ ,  $I^2 = 79% > 50%$ ,  $P < 0.05$ , and the chest tube removal time of participants in the experimental group was substantially lower in contrast to that of the control group. The MD was  $-3.10$ , 95% CI:  $(-3.56$  to  $-2.64)$ ,  $Z = 13.30$ ,  $P < 0.01$ .

**Discussion:** This meta-analysis confirmed that VATS for spontaneous pneumothorax is better than other surgical methods.

**Keywords:** Video-assisted thoracoscopic surgery (VATS); spontaneous pneumothorax; curative effect; meta-analysis; systematic review

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## Introduction

Spontaneous pneumothorax is a common emergency presentation in the respiratory department. It is mainly caused by a sudden increase of pressure in the lungs caused by severe cough and breath-holding, and the rupture of the parenchyma of the lungs and pulmonary vesicles. Pressure rises after gas enters the pleural cavity, leading to respiratory and circulatory dysfunction (1). Spontaneous pneumothorax is classified into primary pneumothorax and secondary pneumothorax. Primary pneumothorax is more common in young patients, whereby under the condition of no exogenous factors affecting the lung parenchyma, patients' pulmonary bullae spontaneously rupture (2). Secondary pneumothorax is more common in middle-aged and elderly patients, wherein generally, based on the lung parenchymal disease, bullae are damaged. Spontaneous pneumothorax is mainly primary pneumothorax, with a male to female ratio of about 6:1. It is more common in young males, and especially among those who smoke (3).

There are various treatment methods for spontaneous pneumothorax, including closed thoracic drainage, pleural fixation, thoracoscopic surgery, and traditional open thoracotomy (4). In the past, closed thoracic drainage and other treatments have been used to improve the patient's condition, but they do not completely address the root of the disease; thus relapse can easily occur. Schnell *et al.* [2019] (5) pointed out that the use of closed thoracic drainage to treat pneumothorax was related to a recurrence rate of up to 30%. Therefore, thoracic surgery is the fundamental way to treat spontaneous pneumothorax. MacDuff *et al.* [2010] (6) used traditional thoracotomy to treat spontaneous pneumothorax, and in doing so achieved better therapeutic effects. Due to the large incision of thoracotomy, it is necessary to cut the muscles around the chest wall and use a stretcher to support it. Generally, the chest pain index after the operation is high and is long-lasting (7). Elderly patients give up treatment opportunities due to unbearable pain, while young patients are worried that the scars left after surgery will affect their appearance and refuse open thoracic surgery (8).

In the early 1990s, Schramel *et al.* [1996] (9) first used video-assisted thoracoscopic surgery (VATS) to treat spontaneous pneumothorax, and the therapeutic effect was very satisfactory. VATS is a new minimally invasive surgery for thoracic surgery. With the continuous improvement of medical equipment conditions, the treatment range of VATS has also expanded. With the continuous improvement of medical equipment, the treatment range of

VATS has also expanded (10). With the advantages of less trauma, fewer complications, and quick recovery, VATS has gradually replaced traditional open thoracic surgery and is now widely used in clinical practice (11).

In recent years, related studies have reported that only 4.5% of patients had complications when using VATS to treat spontaneous pneumothorax (12). However, there is still a lack of randomized controlled trials (RCTs) to compare the clinical efficacy of VATS and non-VATS for spontaneous pneumothorax. To further explore the efficacy of VATS for spontaneous pneumothorax, we performed a meta-analysis to evaluate the published research since the establishment of the database. We hypothesized the effect of VATS in the treatment of spontaneous pneumothorax is more obvious than that of other treatment methods, and aimed to provide a scientific theoretical basis for the promotion of VATS.

We present the following article in accordance with the PRISMA reporting checklist (available at <http://dx.doi.org/10.21037/jtd-21-652>).

## Methods

### *Literature searching*

We searched the databases PubMed, Medline, Cochrane Library, China National Knowledge Network (CNKI), Wanfang, VIP, and Google Academic. The retrieval time was from the establishment of each database to 20 December 2020. Composite logic retrieval and Boolean logic retrieval were used to select relevant literature. Chinese databases were searched by the combination of "Video-assisted thoracoscopic surgery", "spontaneous pneumothorax", and "thoracotomy", while the English databases were searched for the terms "Video-assisted thoracoscopic surgery", "spontaneous pneumothorax", and "thoracotomy". The quality of the literature was evaluated using the software RevMan 5.3 (Copenhagen: The Nordic Cochrane Center, the Cochrane Collaboration, 2014).

Each database was subjected to a joint search strategy of free words and subject words. After repeated literature searches, search engines were used to locate the articles. Experts and researchers in the field were contacted to maintain currency with the latest research progress.

### *Inclusion and exclusion criteria of literatures*

The inclusion criteria were as follows: (I) literature

exploring VATS for spontaneous pneumothorax; (II) RCTs; (III) pathological control analysis, with an index comparison that was reliable within the 95% confidence interval (CI); (IV) language of the literature was in both Chinese and English; (V) the diagnosis of spontaneous pneumothorax met the standards of the World Health Organization (WHO).

The exclusion criteria were as follows: (I) studies that were not relevant to this research; (II) literatures published in duplicate; (III) literature review, summary, or case report; (IV) literatures for which complete data could not be obtained by contacting the original author; (V) literatures published in languages other than Chinese and English.

The title, abstract, and full text of the articles were screened by two senior experts independently, and three preliminary experiments were confirmed before screening. If there were inconsistencies in opinion among the experts, a consensus conclusion was achieved through discussion, or a third expert was invited to arbitrate.

#### *Literature screening method*

Literature screening was mainly divided into three steps. First, the titles and abstracts of the research article were read, and literature that was irrelevant to this study was excluded. Then, the full text was read, data in the research results were analyzed, and any literature that did not meet the inclusion requirements was excluded. Finally, the quality evaluation was performed, and two experts independently extracted the data with a unified Excel table. It was crucial that three preliminary experiments had been performed before data extraction. If there were inconsistencies among experts, a consensus was sought through discussion, or a third expert was invited to arbitrate.

#### *Data extraction*

The data extracted from the included research included: (I) the title of the research paper; (II) the first author and publication year; (III) the name of the publication; (IV) time of publication; (V) general information of the research cohort such as the average age, gender, and surgery method; (VI) the grouping method of the experimental and control groups and the statistical method; (VII) the source, sample size, and outcome indicators of the cases.

#### *Outcome indicators*

The outcome indicators included operation time (min),

length of hospital stay (d), complication rate (case), intraoperative bleeding volume (mL), recurrence rate (case), and chest tube removal time (d).

#### *Literature quality assessment*

The risk of bias was assessed by two experts at the same time, and if there was disagreement, the outcome was determined through discussion, or a third expert was asked to arbitrate. The quality evaluation of this study referred to the Oxford system score (JADAD score) in the Cochrane System Review Manual: whether an RCT was performed; whether the random method was adequately described; whether the blinding method was used appropriately; whether the baseline of the literature was similar and consistent; whether the reason for participants' withdrawal was clearly described. A score of 2 or less was considered low-quality research, a score of 3–5 was medium-quality research, and a score of 6 or more was considered high-quality research.

#### *Bias risk assessment*

The risk of bias was assessed by two experts at the same time, and if the two disagreed, the outcome was determined through discussion, or a third expert was asked to arbitrate. In this work, the Cochrane Collaboration was used as a tool for "bias risk assessment" of RCTs. The evaluation criteria included generation of random sequence, blind method, hiding of allocation scheme, integrity of data results, and research results. The above five aspects were respectively judged as "high risk bias", "low risk bias", and "unclear".

#### *Statistical methods*

The statistical software Stata SE release 12.0 (Stata Corp., College Station, TX, USA) was employed for statistical analysis. Odds ratio (OR) was adopted to evaluate the recurrence rate. Mean difference (MD) was adopted to evaluate operation time, length of hospital stays, intraoperative bleeding volume, and chest tube removal time. Rev Man 5.3's risk of bias assessment chart was utilized to assess the bias risk of included literatures. Each effect was expressed using a 95% CI. When the heterogeneity test showed that  $P > 0.1$  and  $I^2 < 50\%$ , the fixed effects model was used for meta-analysis. When the heterogeneity test showed that  $P < 0.1$  and  $I^2 > 50\%$ , the random effects model was used for meta-analysis.

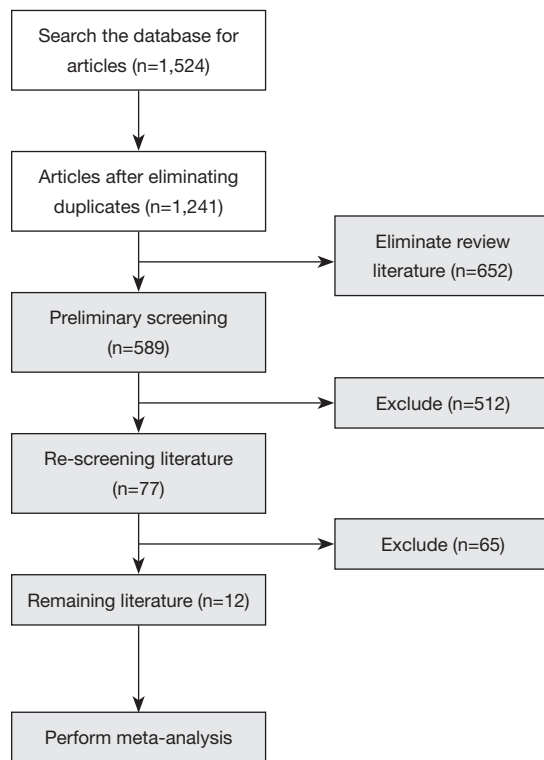


Figure 1 Literature search flow chart.

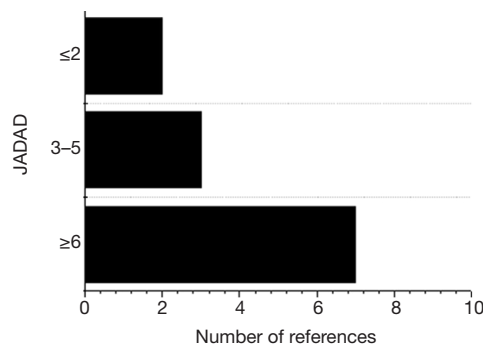


Figure 2 Literature quality rating results.

## Results

### Search results and basic information of included literatures

In total, 1,524 literatures were screened; among which, 1,447 were eliminated after the abstracts and titles had been read, and 65 were eliminated after the full text of the article was read. Finally, 12 literatures were included in the meta-analysis. Literatures were excluded for the following reasons: repeated research subjects (532 articles); literature type not case-controlled analysis (254 articles), the research

object not VATS for spontaneous pneumothorax (481 articles), and the study-related information could not be extracted (263 articles) (Figure 1).

Figure 2 shows the quality classification results. There were 7 articles with a score of 6 or more, 3 with a score of 3–5, and 2 with a score of 2 or less.

A total of 12 articles met the inclusion criteria, including 8 retrospective analyses and 4 RCTs. A total of 744 participants were included. The experimental group was set as VATS for spontaneous pneumothorax, and non-VATS for spontaneous pneumothorax was set as the control group. Among the 12 articles, all were small sample studies, with sample sizes of 43–91 cases. The gender, age, number of cases, intervention measures, and outcome indicators of all articles were statistically analyzed. The general information of the research participants is shown in Table 1.

### Results of literature risk bias evaluation

The results of multiple risk bias evaluations of literatures drawn by Rev Man 5.3 are shown in Figures 3 and 4. Among the 12 RCTs included in this work, 3 (13–15) described the correct random allocation method; 2 (16,17) described the correct random allocation method and described the concealment of the allocation plan in detail; 1 (18) was evaluated by blind method, and the other articles did not use a blind method. However, the measurement indicators in this work were laboratory indicators determined by computer, so it could be considered that all articles were blinded correctly.

### Contrast of operation time

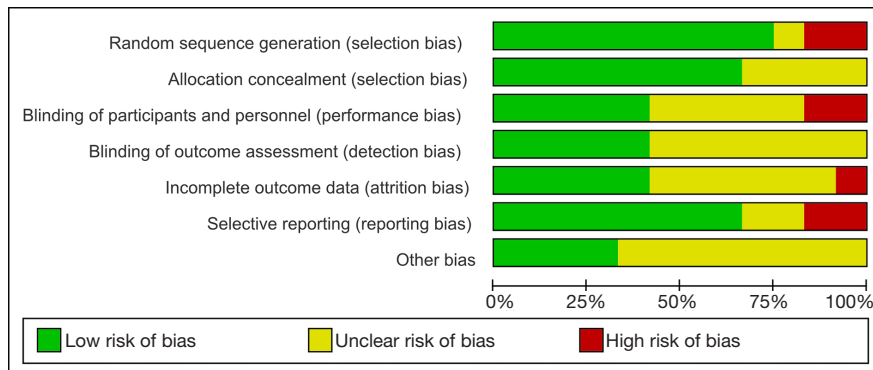
The operation time of RCTs was analyzed in eight studies. There were 509 cases in total, 255 cases in the experimental group, and 254 cases in the control group. The overall heterogeneity test showed that  $\text{Tau}^2 = 29.99$ ,  $\text{Chi}^2 = 16.99$ , degrees of freedom (df) = 7, and  $I^2 = 59\% > 50\%$ . Therefore, the random effects model was adopted for meta-analysis. The horizontal line of the 95% CI of all studies was to the left of the invalid vertical line. Meta-analysis showed that the operation time of the experimental group was greatly lower than that of the control group. The MD was  $-31.02$ , 95% CI:  $(-36.07 \text{ to } -25.97)$ , with statistically considerable differences ( $Z = 12.03$ ,  $P < 0.01$ ) (Figure 5).

A funnel plot of operative time was created using Rev Man 5.3 (Figure 6). It is obvious that the circle and the midline of some studies are basically symmetrical,

**Table 1** General information of participants in the included studies

Author	Year	Gender (male/ female)	Age (years old)	Cases		Interventions	
				Experimental group	Control group	Experimental group	Control group
Schramel <i>et al.</i> (9)	1996	36/13	45.62±8.65	25	24	VATS	Thoracotomy
Haraguchi <i>et al.</i> (10)	2008	45/31	35.22±5.64	38	38	VATS	Small incision surgery
Chambers (11)	2009	35/15	55.42±6.62	24	26	VATS	Thoracotomy
Case (12)	2015	58/26	36.25±5.64	42	42	VATS	Thoracotomy
Imperatori <i>et al.</i> (13)	2015	37/15	43.45±9.63	26	26	VATS	Thoracotomy
Ayed (14)	2006	38/11	–	25	24	VATS	Small incision surgery
Shaikhrezai <i>et al.</i> (15)	2011	45/23	45.62±8.65	34	34	VATS	Thoracotomy
Doddoli <i>et al.</i> (16)	2004	63/28	43.72±7.65	46	45	VATS	Thoracotomy
Cho <i>et al.</i> (17)	2018	37/19	–	28	28	VATS	Small incision surgery
Chen <i>et al.</i> (18)	2019	29/14	38.62±6.65	22	21	VATS	Thoracotomy
Williams <i>et al.</i> (19)	2018	42/24	43.52±4.64	34	32	VATS	Thoracotomy
Elsayed (20)	2016	43/17	44.64±4.52	30	30	VATS	Small incision surgery

VATS, video-assisted thoracoscopic surgery.

**Figure 3** Literature risk of bias evaluation results.

suggesting that the research accuracy was high and there was no bias in publication.

### Contrast of length of hospital stay

The length of hospital stay of RCTs was analyzed in 9 studies. There were 559 cases in total, 281 cases in the experimental group, and 278 cases in the control group. The overall heterogeneity test showed that  $\tau^2 = 4.41$ ,  $\chi^2 = 122.58$ ,  $df = 8$ ,  $I^2 = 93\% > 50\%$ , and  $P < 0.01$ . Therefore, the random effects model was adopted for meta-analysis. The

horizontal line of the 95% CI of all studies was to the left of the invalid vertical line. Meta-analysis results showed that the length of stay in the experimental group was remarkably lower than that in the control group. The MD was  $-7.29$ , 95% CI:  $(-8.76 \text{ to } -5.82)$ , with statistically considerable differences ( $Z = 9.74$ ,  $P < 0.01$ ) (Figure 7). The software Rev Man 5.3 was used to create a funnel plot of intraoperative bleeding volume (Figure 8). It is obvious that the circle and the midline of some studies are basically symmetrical, suggesting that the research accuracy was high and there was no publication bias.

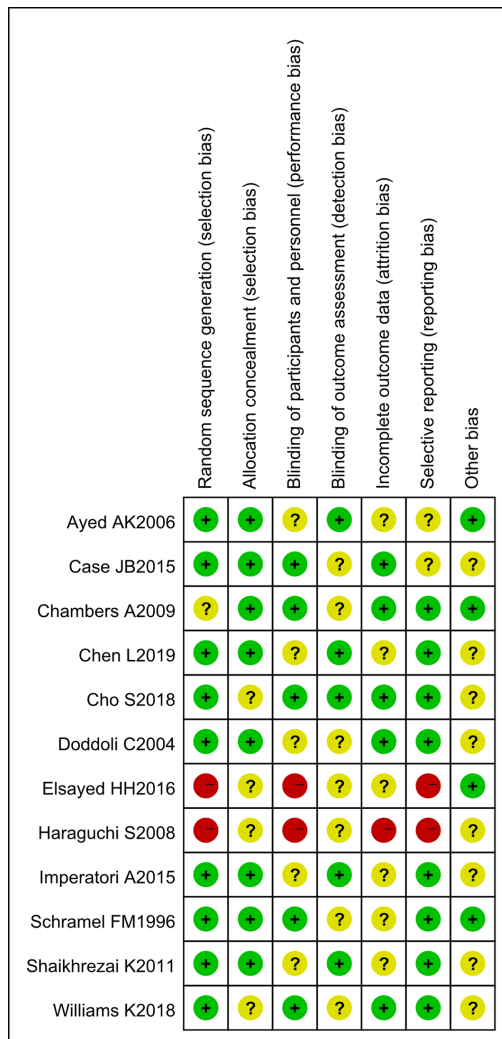


Figure 4 Bias evaluation results of included studies corresponding to multiple risks.

**Contrast of intraoperative bleeding volume**

The intraoperative bleeding volume was analyzed in 6 RCTs. There were 384 cases in total, 193 cases in the experimental group, and 191 cases in the control group. The overall heterogeneity test showed that  $Tau^2 = 191.74$ ,  $Chi^2 = 27.65$ ,  $df = 5$ ,  $I^2 = 82\% > 50\%$ , and  $P < 0.01$ . Therefore, the random effects model was adopted for meta-analysis. The horizontal line of the 95% CI of all studies was to the left of the invalid vertical line. Meta-analysis results showed that the bleeding volume of participants in the experimental group was remarkably lower compared to that of the control group. The MD was  $-65.48$ , 95% CI:  $(-77.84$  to  $-53.13)$ , with statistically considerable differences ( $Z = 10.39$ ,  $P < 0.01$  (Figure 9).

The software Rev Man 5.3 was used to create a funnel plot of intraoperative bleeding volume (Figure 10). It is obvious that the circle and the midline of some studies are basically symmetrical, suggesting that the research accuracy was high and there was no publication bias.

**Contrast of complication rates**

The incidence of complications was analyzed in 8 RCTs. There were 522 cases in total, 262 in the experimental group, and 260 in the control group. The overall heterogeneity test showed that  $Chi^2 = 1.07$   $df = 7$ ,  $I^2 = 0\% < 50\%$ ,  $P = 0.99 > 0.01$ . Therefore, the fixed effects model was adopted for meta-analysis. The horizontal line of the 95% CI of all studies intersects the left side of the invalid vertical line. Meta-analysis results showed that the complication rate of the experimental group was significantly lower than that of the control group, the OR was 0.40, 95% CI:  $(0.25$  to  $0.65)$ , and the difference was substantial and considerable ( $Z = 3.69$ ,

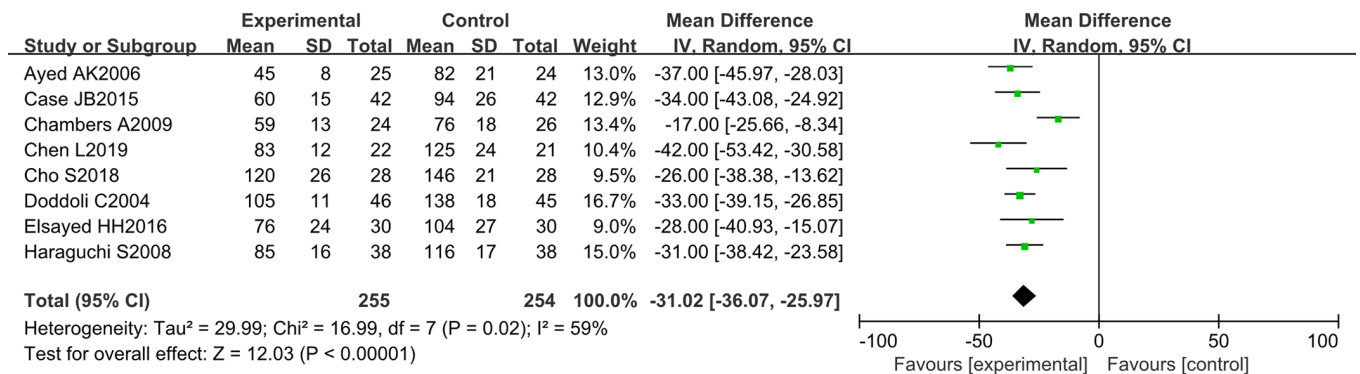


Figure 5 Forest plot of comparison of operation time between the experimental and control groups. SD, standard deviation; CI, confidence interval.

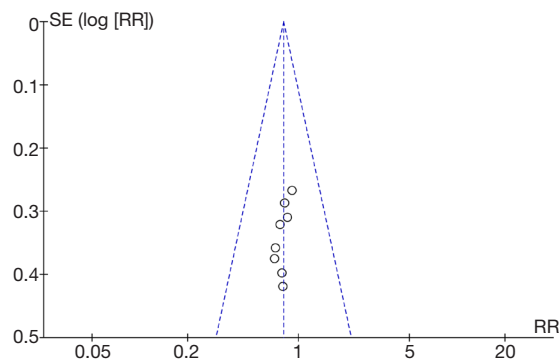


Figure 6 Funnel chart comparing operation time between the experimental and control groups.

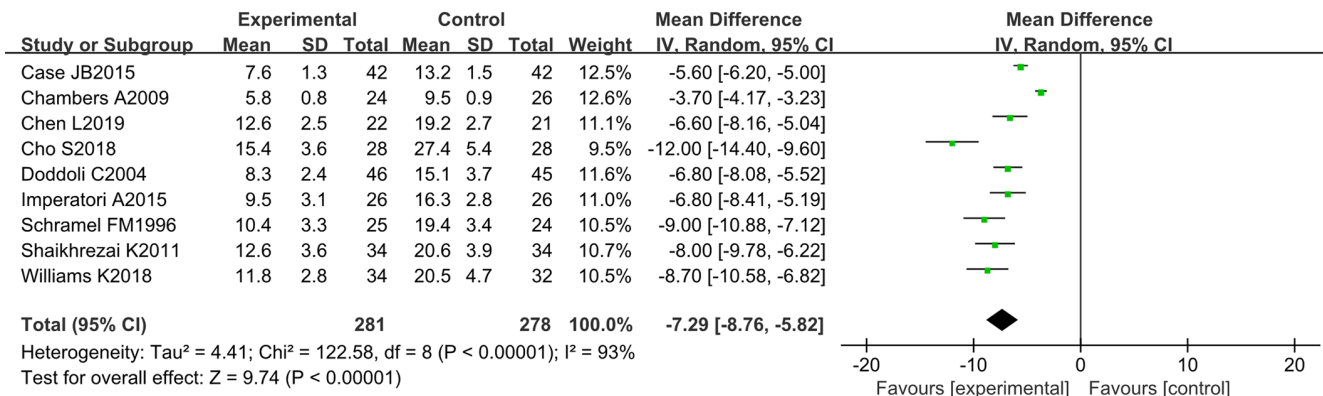


Figure 7 Forest plot comparing length of hospital stay between the experimental and control groups. SD, standard deviation; CI, confidence interval.

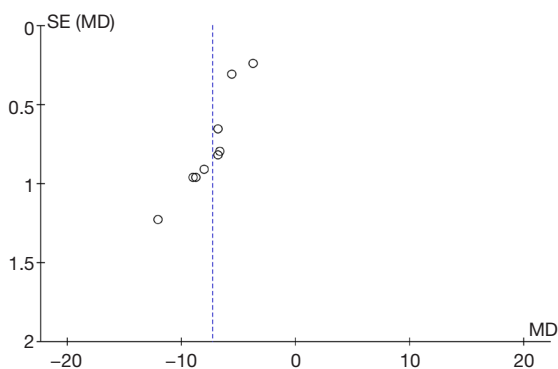


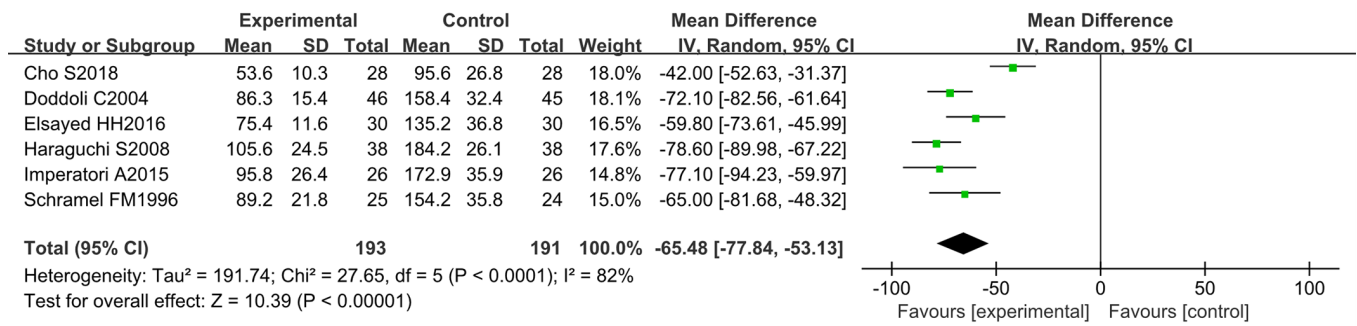
Figure 8 Funnel chart comparing length of hospital stay between the experimental and control groups.

P=0.0002<0.01) (Figure 11).

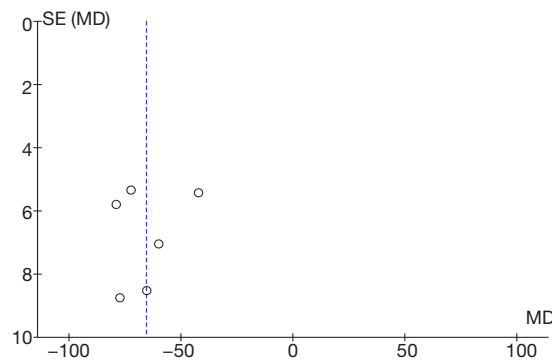
Funnel plot of complications was visualized using Rev Man 5.3 (Figure 12). It is obvious that the circles and the midline of some studies are basically symmetrical, suggesting that the research accuracy was high and there was no publication bias.

**Contrast of recurrence rate**

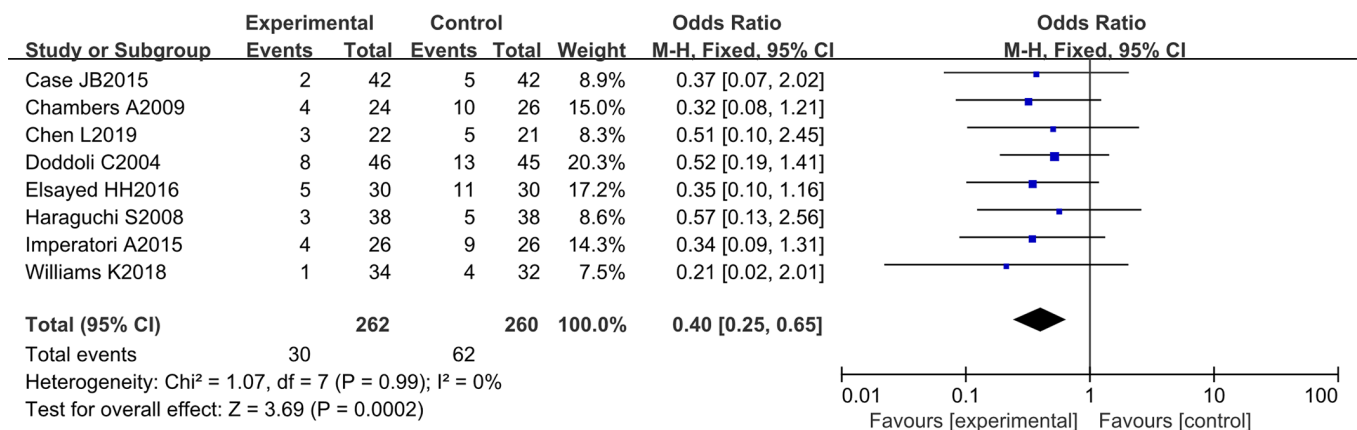
The recurrence rate was analyzed in 7 RCTs. There were 468 cases in total, 235 in the experimental group, and 233 in the control group. The overall heterogeneity test showed



**Figure 9** Forest plot comparing intraoperative bleeding volume between the experimental and control groups. SD, standard deviation; CI, confidence interval.



**Figure 10** Funnel chart comparing intraoperative bleeding volume between the experimental and control groups.



**Figure 11** Forest plot comparing complications between the experimental and control groups. SD, standard deviation; CI, confidence interval.



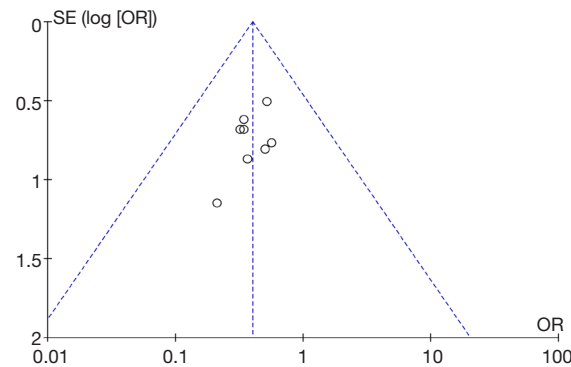


Figure 12 Funnel chart comparing occurrence of complications between the experimental and control groups.

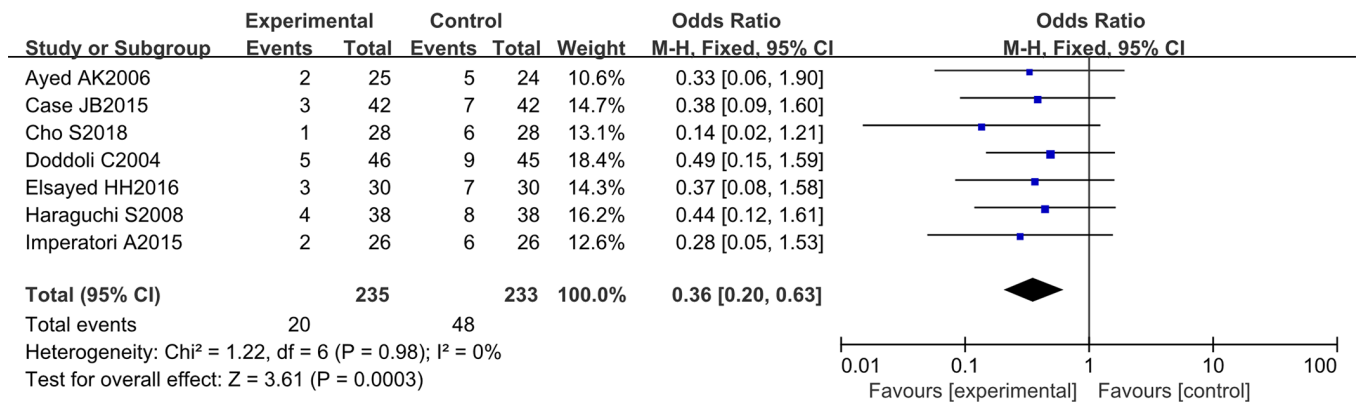


Figure 13 Forest plot comparing recurrence rates between the experimental and control groups. SD, standard deviation; CI, confidence interval.

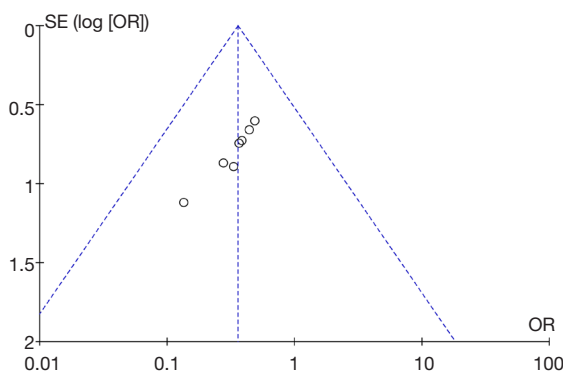
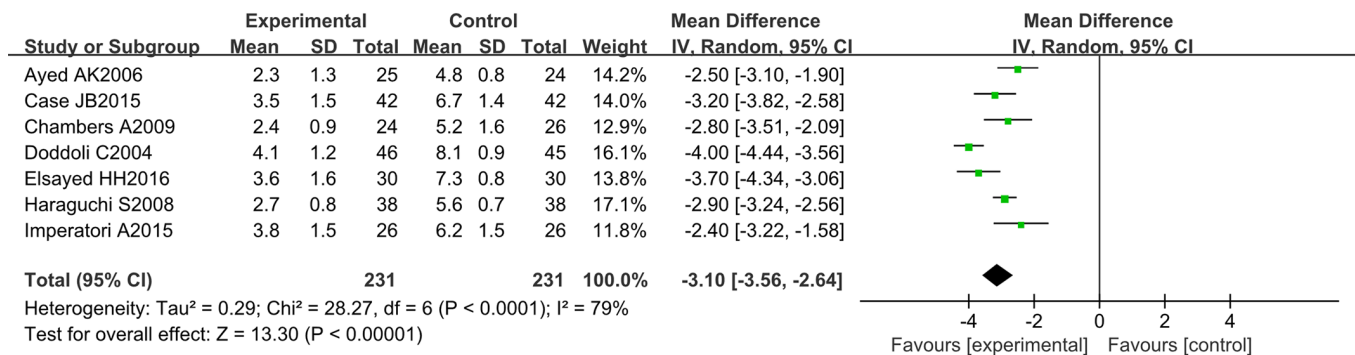


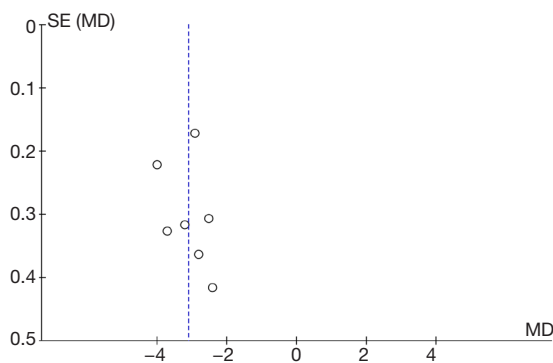
Figure 14 Funnel chart comparing recurrence rate between the experimental and control groups.

that  $\text{Chi}^2 = 1.22, \text{df} = 6, I^2 = 0\% < 50\%$ , and  $P = 0.98 > 0.01$ . Therefore, the fixed effects model was adopted for meta-analysis. The horizontal line of the 95% CI of all literatures intersected the left side of the invalid vertical line. Meta-analysis results showed that the recurrence rate of the experimental group was lower than that of the control group, the OR was 0.36, 95% CI: (0.20 to 0.63), and the difference was substantial and considerable ( $Z = 3.61, P = 0.0003$ ) (Figure 13).

A funnel plot of recurrence rates was created using Rev Man 5.3 (Figure 14). It is obvious that the circle and the midline of some studies are basically symmetrical, suggesting that the research accuracy was high and there



**Figure 15** Forest plot comparing chest tube removal time between the experimental and control groups. SD, standard deviation; CI, confidence interval.



**Figure 16** Funnel chart comparing chest tube removal time between the experimental and control groups.

was no publication bias.

### Contrast of chest tube removal time

The chest tube removal time was analyzed in 7 RCTs. The total number of cases was 462, and the experimental group and the control group each had 231 cases. The overall heterogeneity test showed that Tau<sup>2</sup> = 0.29, Chi<sup>2</sup> = 28.27, df = 6, I<sup>2</sup> = 79% > 50%, and P < 0.01. Therefore, the random effects model was adopted for meta-analysis. The horizontal line of the 95% CI of all studies was to the left of the invalid vertical line. Meta-analysis results showed that the chest tube removal time for participants in the experimental group was substantially lower compared to that of the control group. The MD was -3.10, 95% CI: (-3.56 to -2.64), with statistically significant differences (Z = 13.30, P < 0.01) (Figure 15).

A funnel plot for chest tube removal time was created using Rev Man 5.3 (Figure 16). It is obvious that the circle and the midline of some studies are basically symmetrical, suggesting that the research accuracy was high and there was no publication bias.

### Discussion

Spontaneous pneumothorax is caused by obstruction of the bronchial valve, which prevents the normal flow of gas, leading to gas retention, swelling of the bullae, and rupture to a certain extent. The VATS procedure is minimally invasive, with small wounds, short operation time, and quick recovery time (19). This study conducted meta-analysis to evaluate the efficacy of VATS. The quality classification results showed that there were 7 studies with a score of 6 or more, 3 with a score of 3–5, and 2 with a score of 2 or less. Among the 12 RCTs, 3 described the correct random allocation method, and only 2 described the correct random allocation method and described the concealment of the allocation plan in detail.

In this work, the operation time, hospital stay, complication rate, intraoperative blood loss, recurrence rate, and chest tube removal time were analyzed and compared between the VATS group and the non-VATS group. The results showed that the operation time of the experimental group was significantly inferior to that of the control group, the MD was -31.02, 95% CI was (-36.07, -25.97), Z = 12.03, P < 0.01. It showed that VATS treatment of spontaneous pneumothorax can greatly shorten the time during the operation and improved safety. The length of hospital stay in the experimental group was notably lower

than that in the control group. The MD was  $-7.29$ , the 95% CI was  $(-8.76, -5.82)$ ,  $Z=9.74$ ,  $P<0.01$ . The intraoperative blood loss of the experimental group was obviously inferior to that of the control group. The MD was  $-65.48$ , 95% CI was  $(-77.84, -53.13)$ ,  $Z=10.39$ ,  $P<0.01$ . It showed that the VATS treatment of spontaneous pneumothorax can reduce the trauma to the patient, speeded up the recovery of the patient, and reduced the risk of occurrence. The complication rate of the experimental group was dramatically lower than that of the control group. The OR was  $0.40$ , 95% CI was  $(0.25, 0.65)$ ,  $Z=3.69$ ,  $P=0.0002<0.01$ . The recurrence rate of the experimental group was inferior to that of the control group, the OR was  $0.36$ , and the 95% CI was  $(0.20, 0.63)$ ,  $Z=3.61$ ,  $P=0.0003<0.01$ .

The data generated through meta-analysis showed that the effect of VATS in the treatment of spontaneous pneumothorax is better than that of other treatments, which is consistent with the study of Elsayed *et al.* [2016] (20). The software Rev Man 5.3 was used to create a funnel chart of each outcome indicator, showing that the circles in some studies are basically symmetrical with the midline, which indicated that the research accuracy is high and there is no bias in publication.

## Conclusions

In this study, in order to explore the efficacy of VATS through meta-analysis, a composite logic search method was adopted to retrieve 12 studies which used VATS for spontaneous pneumothorax as the trial group. The meta-analysis confirmed that VATS for spontaneous pneumothorax is superior to other surgical methods. The limitations of this study were time constraints and limited literature resources. Literature retrieval may have been incomplete, and some literature may have been missing. In addition, the data of these studies were not included in this systematic review, which may have affected the results, and the included literature sample size was relatively small. Therefore, it is necessary to expand the sample size to include more recent clinical RCTs for further verification. In short, this study provides a reliable theoretical basis for the clinical treatment of spontaneous pneumothorax with VATS.

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## Footnote

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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