Single-incision versus conventional three-port video-assisted surgery in the treatment of pneumothorax: a systematic review and meta-analysis

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Abstract

OBJECTIVES: Single-incision thoracoscopic surgery (SITS) has been applied in the treatment of pneumothorax. To establish the feasibility of SITS in comparison with conventional three-port video-assisted thoracoscopic surgery (3P-VATS), we conducted this meta-analysis.

METHODS: Relevant studies were searched in PubMed, Cochrane Library, SpringerLink and ScienceDirect. Studies that compared the outcomes between SITS and 3P-VATS were included for analysis.

RESULTS: Nine eligible studies with 768 participants were included. Our analysis indicates that when compared with 3P-VATS, SITS was associated with less postoperative pain (weight mean difference, WMD = −0.67, 95% confidence interval, CI = −1.11 to −0.22, \( P = 0.004 \) for postoperative pain at 24 h; WMD = −0.62, 95% CI = −1.11 to −0.12, \( P = 0.01 \) for postoperative pain at 72 h), lower paraesthesia rate (odds ratio, OR = 0.09, 95% CI = 0.04–0.21, \( P = 0.01 \)) and shorter hospital stay (WMD = −0.34 days, 95% CI = −0.60 to −0.08, \( P = 0.01 \)). No significant association was found in operative time, mean duration of chest tube, complications and recurrence rates.

CONCLUSIONS: SITS was a safe and efficient procedure for the treatment of pneumothorax with less postoperative pain and faster recovery. The complication and recurrence rates were equivalent when compared with 3P-VATS.

Keywords: Single-incision thoracoscopic surgery • Three-port video-assisted thoracoscopic surgery • Pneumothorax • Meta-analysis

INTRODUCTION

Pneumothorax remains a globally important health problem. The incidence of pneumothorax was reported as 24/100 000/year for men and 9.8/100 000/year for women in England [1]. On the basis of the absence or presence of clinically apparent lung disease, pneumothorax is categorized as primary and secondary spontaneous pneumothorax [2].

Pneumothorax is now commonly treated with thoracoscopic surgery, which is associated with less pain and shorter hospital stay, improved cosmetic results and overall patient satisfaction [3]. However, pain or paraesthesia due to intercostal nerve compression during conventional video-assisted thoracoscopic surgery (VATS) is often seen. Owing to the numerous refinements in scope and instrument designs, the ‘conventional three-port VATS (3P-VATs)’ has been modified to single-incision thoracoscopic surgery (SITS). In SITS, endoscopic grasper, dissector, stapler and the camera are inserted into the thoracic cavity through a single port. Bullectomy/plebectomy and abrasion are applied, and a chest drain is placed through the same incision [4]. SITS involves only one intercostal space instead of two or three, thereby reducing the surgical trauma and postoperative pain and speeding recovery and return to work. The initial report of SITS was applied in thoracic sympathectomy [5]. Then, Rocco et al. [6] developed SITS for wedge resection. Recently, with the developments in thoracoscopic instruments and techniques, more and more complex thoracic surgeries such as thymectomy, lobectomy, segmentectomy, pneumonectomy, chest wall resection, bronchial sleeve or vascular reconstructions by SITS were reported [7].

As for pneumothorax, more thoracic surgeons apply this approach and have published their results. To establish the feasibility of SITS in the treatment of pneumothorax, some studies compared this approach with conventional 3P-VATS. However, the results were inconsistent and could not give a reliable conclusion. The small sample size and limited statistic power may be a reason. Therefore, we conducted this systematic review and meta-analysis to compare SITS with 3P-VATS and to evaluate the comparative efficiency of SITS.

MATERIALS AND METHODS

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [8](Supplementary Table 1).
Literature search

The databases of PubMed, Cochrane Library, SpringerLink and ScienceDirect were used for literature search up to 10 November 2015. The search strategy was (“uni-port” or “uniport” or “one-port” or “single-port” or “single-incision”) AND (“video-assisted thoracoscopic surgery” or “thoracoscopy”) OR (“SITS”) AND (“pneumothorax” or “primary spontaneous pneumothorax” or “PSP”). The publishing language was restricted to English. The references of retrieved articles and relevant reviews were manually checked for potentially relevant studies.

Inclusion and exclusion criteria

The inclusion criteria were applied to identify the eligible studies: (i) SITS was performed through a single incision using multiple devices through the same single skin incision; (ii) the patients should be adults aged more than 18 years; (iii) comparative studies that compared SITS with 3P-VATS; (iv) at least one of the following outcomes was reported: operation time, mean duration of chest tube, hospital stay, postoperative pain [evaluated by visual analogue scales (VAS) from 0 (no pain) to 10 (worst pain ever experienced)], paraesthesia rate, complications and recurrence rate; (v) provided sufficient information to estimate odds ratio (OR) or weight mean difference (WMD) and their 95% confidence intervals (CIs). The exclusion criteria were as follows: (i) non-comparative studies, reviews or meta-analyses; (ii) studies in which necessary data were not provided. For overlapped studies, the most rounded study with more information was included.

Data extraction

Two investigators (Yanlong L. Yang and Junjie J. Dong) independently reviewed the eligible studies and extracted the data. Disagreements were resolved by discussion among all authors.

Quality assessment

The quality of the methodology of the included studies was assessed by the Newcastle–Ottawa scale (NOS) recommended by the Cochrane Non-Randomized Studies Working Group. Studies with five or more stars were defined as high-quality studies. Quality assessment was performed by two investigators (Yanlong L. Yang and Junjie J. Dong) independently. Disagreements were resolved by discussion [9].

Statistical analysis

The WMDs and ORs were used to compare continuous and dichotomous variables, respectively. All outcomes were reported with 95% CIs. Heterogeneity between studies was detected by the Q test and the $I^2$ metric (no heterogeneity: $I^2 = 0–25$%, moderate heterogeneity: $I^2 = 25–50$%; large heterogeneity: $I^2 = 50–75$%; and extreme heterogeneity: $I^2 > 75$%) [10]. If $P$ was $> 0.10$ in the Q test or $I^2 < 50$%, the fixed-effect model was used [11]. Otherwise, random-effect model analysis was conducted [12].

Publication bias was assessed by the methods reported by Begg [13].

RESULTS

Eligible studies

A total of 357 records were identified from the initial search. After carefully screening the titles, abstracts and the full texts, nine studies [4, 14–21] fulfilled our criteria and were included for meta-analysis. Fig. 1 summarizes our process of article selection. A total of 768 patients (403 in SITS group and 365 in 3P-VATS group) were included. Only one study included secondary spontaneous pneumothorax [14]; the remaining eight studies all included PSP. The main characteristics of qualified studies are listed in Table 1. All relevant studies were assessed by the NOS and scored highly (with five stars or more) (Table 2 and Supplementary Table 2).

Operative time

Seven studies reported the operative time [4, 15, 16, 18–21]. No heterogeneity was detected ($I^2 = 0$, $P = 0.79$), and the fixed-effect model was applied for analysis. The pooled analysis indicated that there was no difference in operative time between SITS and 3P-VATS groups (WMD 0.01 min, 95% CI −0.30 to 0.33, $P = 0.99$) (Fig. 2A and Table 2).

Mean duration of chest tube

Six studies investigated the mean duration of chest tube [4, 14, 16, 19–21]. The random-effect model analysis was conducted as large heterogeneity exists between studies ($I^2 = 54%$, $P = 0.05$). The pooled WMD was $-0.32$ days (95% CI $-0.74$ to 0.10, $P = 0.13$), suggesting no difference between SIST and 3P-VATS in regard to mean duration of chest tube (Fig. 2B and Table 2).
Table 1: The main characteristic of included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Patient enrolling</th>
<th>Design</th>
<th>No. of patients</th>
<th>Matching variables</th>
<th>Conversion to open</th>
<th>Follow-up (month)</th>
<th>Quality score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jutley et al. [14]</td>
<td>UK</td>
<td>2002–2004 Retr</td>
<td>16/19</td>
<td>1,3,4,5</td>
<td>NR</td>
<td>9.4/32.1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Chen et al. [16]</td>
<td>China</td>
<td>2009–3–6 Retr</td>
<td>10/20</td>
<td>1,2,6,7,8,9,10</td>
<td>0</td>
<td>≥3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Chen et al. [17]</td>
<td>China</td>
<td>2008–2009 Retr</td>
<td>36/26</td>
<td>1,2,8,10</td>
<td>0</td>
<td>16.3/30.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Yang et al. [18]</td>
<td>Korea</td>
<td>2011–3–8 Retr</td>
<td>27/13</td>
<td>1,2,8,11</td>
<td>NR</td>
<td>3.5/4.6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Kang et al. [19]</td>
<td>Korea</td>
<td>2012–2013 Retr</td>
<td>33/19</td>
<td>1,2,8,11</td>
<td>0</td>
<td>14/15</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Tsuobushima et al. [20]</td>
<td>Japan</td>
<td>2009–2013 Retr</td>
<td>34/35</td>
<td>1,2,8,9</td>
<td>NR</td>
<td>6.7/19.9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Ocakcioglu et al. [4]</td>
<td>Turkey</td>
<td>2011–2013 Retr</td>
<td>37/40</td>
<td>1,2,8,10</td>
<td>0</td>
<td>21</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Song et al. [21]</td>
<td>Korea</td>
<td>2013–2014 Retr</td>
<td>37/23</td>
<td>1,2,8,10,11</td>
<td>0</td>
<td>2.9/3.1</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>


Table 2: The summarized meta-analysis results

<table>
<thead>
<tr>
<th>Outcome of interest</th>
<th>No.</th>
<th>No. of patients</th>
<th>WMD/OR (95% CI)</th>
<th>P-value</th>
<th>I²</th>
<th>P</th>
<th>Egger’s P</th>
<th>Begg’s P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating time (min)</td>
<td>7</td>
<td>206/173</td>
<td>0.01 (−3.30 to 3.33)</td>
<td>0.99</td>
<td>0</td>
<td>0.79</td>
<td>0.97</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean duration of chest tube (days)</td>
<td>6</td>
<td>167/156</td>
<td>−0.32 (−0.74 to 0.10)</td>
<td>0.13</td>
<td>54</td>
<td>0.05</td>
<td>0.48</td>
<td>1.00</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>8</td>
<td>222/192</td>
<td>−0.34 (−0.60 to −0.08)</td>
<td>0.01</td>
<td>4</td>
<td>0.4</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>Postoperative pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>5</td>
<td>114/115</td>
<td>−0.67 (−1.11 to −0.22)</td>
<td>0.004</td>
<td>61</td>
<td>0.04</td>
<td>0.76</td>
<td>0.46</td>
</tr>
<tr>
<td>48 h</td>
<td>3</td>
<td>74/73</td>
<td>−0.4 (−1.25 to 0.46)</td>
<td>0.36</td>
<td>87</td>
<td>0</td>
<td>0.21</td>
<td>1.00</td>
</tr>
<tr>
<td>72 h</td>
<td>3</td>
<td>84/83</td>
<td>−0.62 (−1.11 to −0.12)</td>
<td>0.01</td>
<td>65</td>
<td>0.06</td>
<td>0.56</td>
<td>1.00</td>
</tr>
<tr>
<td>Paraesthesia (%)</td>
<td>4</td>
<td>100/63</td>
<td>0.09 (0.04 to 0.21)</td>
<td>&lt;0.001</td>
<td>0</td>
<td>0.66</td>
<td>0.19</td>
<td>0.73</td>
</tr>
<tr>
<td>Complications (%)</td>
<td>5</td>
<td>165/125</td>
<td>0.61 (0.22 to 1.71)</td>
<td>0.35</td>
<td>0</td>
<td>0.47</td>
<td>0.82</td>
<td>1.00</td>
</tr>
<tr>
<td>Recurrence (%)</td>
<td>6</td>
<td>199/160</td>
<td>0.61 (0.28 to 1.35)</td>
<td>0.22</td>
<td>0</td>
<td>0.71</td>
<td>0.6</td>
<td>0.71</td>
</tr>
</tbody>
</table>

CI: confidence interval; OR: odds ratio; WMD: weight mean difference.

Hospital stay

Hospital stay was reported by eight studies [4, 14–16, 18–21]. The pooled WMD was −0.34 days (95% CI −0.60 to −0.08, P = 0.001) with no heterogeneity (I² = 4%, P = 0.40). Our results suggested that SITS was associated with shorter hospital stay when compared with conventional 3P-VATS in the treatment of pneumothorax (Fig. 2C and Table 2).

Postoperative paraesthesia

Four studies evaluated postoperative paraesthesia [14, 15, 18, 19]. The pooled OR was 0.09, with the 95% CI = 0.04–0.12, P < 0.001. No heterogeneity was detected (I² = 0%, P = 0.66), indicating that the postoperative paraesthesia rate was significantly lower in the SIST group compared with that in 3P-VATS groups (Fig. 4A and Table 2).

Complications

Five studies reported the complications [4, 15, 17, 18, 21]. There was no difference in the two groups in complication rate (OR = 0.61, 95% CI = 0.22–1.71, P = 0.35; I² = 0%, P = 0.47) (Fig. 4B and Table 2).

Recurrence

Recurrence was reported by six studies [4, 15, 17, 18, 20, 21]. There was no heterogeneity found (I² = 0%, P = 0.71) and the pooled OR = 0.61 (95% CI = 0.28–1.35, P = 0.22). The result suggested there...
was no significant association in regard to recurrence between the two groups (Fig. 4C and Table 2).

**Publication bias**

No significant publication biases were detected in all comparisons (Table 2).

**DISCUSSION**

SITS is a branch within the evolution of minimally invasive VATS [22]. The present study indicates that the operative time, mean duration of chest tube, complications and recurrence rate were similar between SITS and 3P-VATS in the treatment of pneumothorax. However, SITS was associated with less postoperative pain, lower paraesthesia rate and shorter hospital stay. This evidence suggests that SITS is a safe and feasible procedure in the treatment of pneumothorax and might be associated with less postoperative pain and faster recovery when compared with conventional 3P-VATS.

Operative time was similar between the two groups, and no heterogeneity was found between the two groups. The early period of SITS mainly focused on minor thoracic surgeries such as sympathectomy, pleural decollations, mediastinal biopsies, pericardial window and lung wedge resections. In recent years, with the development and refinements in scope and instrument designs, we have seen uniportal VATS maturing and the capability of complex major lung resections [7]. For minor thoracic surgery, most surgeons experienced in bullectomy/blebectomy and abrasion through SITS showed similar operative times with 3P-VATS. Inter-surgeon variability was minimal.

Postoperative pain and the incidence of paraesthesia may be affected by many factors. The number and the length of the incision were recognized as important factors. SIST has only one port; the number of incisions was obviously less than that with 3P-VATS, and the potential intercostal nerve injury was less with one
incision. Therefore, less postoperative pain and a lower incidence of paraesthesia might be a consequence. But a significant association was not found for postoperative pain at 48 h. First, only a few studies with limited sample size (five studies with 259 patients for 24 h, three studies with 147 patients for 48 h and three studies with 167 patients for 72 h) evaluated postoperative pain using the VAS. Such a small sample size may not give us a reasonable result and sometimes may mislead us. Besides, most studies that evaluated postoperative pain at 24, 48 and 72 h with VAS were included in our study. Some studies reported VAS at innumerable times after surgery [14, 15] or only reported mean VAS without standard deviation (SD) [17]; and VAS was not included in our study, although it reported less pain in SITS groups. Also, significant heterogeneity was observed in postoperative pain. Many factors may contribute to it. For example, the surgical techniques used in different centres may not be uniform. In fact, the single incision size, the type of instruments used and the use of skin/intercostal space spreaders could be considered bias factors for the pain and paraesthesia. The inter-surgeon and the instrument variability should also be considered. To allow triangulation of the instruments and exposure, additional stress on the port incision, or a longer incision at the port site, might not be avoided by some surgeons. The pain from mechanical pleurodesis may also affect the patient's overall pain tolerance [18]. In addition, different centres may use different ways to obtain adhesions. Even in this case, a different strategy could bias the analysis of pain. These factors would more or less affect the postoperative pain.

The hospital stay was shorter in the SITS group. Maybe SITS was less invasive and associated with less postoperative pain, preserving pulmonary function and helping the patient get out of bed and do activities soon; and it was beneficial for recovery. We did not find significant association in the mean duration of chest tube and complication rate between the two groups. But these parameters were hard to assess, because no specific criteria were documented for chest tube removal, hospital stay and some specific complications. It is hard to judge whether all the studies were uniform for the administration of patients, and it is not possible for different centres to manage the postoperative course with similar protocols. In fact, a different policy of chest tube management could heavily bias the results on duration of chest tube and length of stay. There was no difference in recurrence rate, so we used odds ratio to evaluate recurrence rate. In fact, the hazard ratio is appropriate for the analysis of events during follow-up. However, we could not extract relevant data [HR with its 95% CI, or log (HR) estimates and their variances]. To some degree, we may arrive at a misleading conclusion. But all six studies we included did not find a significant difference between two approaches. As SITS was a new technology applied in practice, the long-term recurrence data were not sufficient. So the evidence supporting the long-term efficacy of SITS in pneumothorax is still lacking. Also the follow-up period was not long enough, especially in SITS groups. SITS began only a decade ago, so we observed a trend that the follow-up time of SITS was shorter than that of 3P-VATS in patients with pneumothorax.

The present study had some limitations. First, we lacked randomized controlled trials. There is a possibility of evident selection bias and observer bias with regard to the adoption of the operative approach. It may lead to less powerful results. Secondly, most
studies were limited to small observational studies. Only nine studies with 768 patients were included for analysis, and the small sample size may not lead to a sound result. Thirdly, heterogeneity was observed in some outcomes (mean duration of chest tube and postoperative pain). Finally, we did not detect publication bias; nevertheless, potential bias may exist because we did not include articles published in other databases we did not access, or articles published in languages other than English.

In conclusion, the present meta-analysis demonstrates that SITS is a safe and efficient procedure for the treatment of pneumothorax with less postoperative pain and faster recovery. The complication and recurrence rates are equivalent when compared with 3P-VATS. SITS, the newly developed non-intubated approach [23] that could potentially minimize the surgical trauma, is one of the important parts of fast-track thoracic surgery. However, because of the limitations, heterogeneity and bias of meta-analysis, our conclusions need to be interpreted with caution. A well-designed, prospective, multi-institutional randomized controlled trial with rigorously designed methods and a longer follow-up period is required to evaluate the feasibility of SITS.

SUPPLEMENTARY MATERIAL

Supplementary material is available at ICVTS online.

Conflict of interest: none declared.

REFERENCES


