Suction or non-suction to the underwater seal drains following pulmonary operation: meta-analysis of randomised controlled trials

Bo Deng¹, Qun-You Tan¹, Yun-Ping Zhao, Ru-Wen Wang*, Yao-Guang Jiang

Thoracic Surgery Department, Institute of Surgery Research, Daping Hospital, Third Military Medical University, Chongqing 400042, PR China

Received 14 September 2009; received in revised form 13 January 2010; accepted 25 January 2010; Available online 2 March 2010

Abstract

Objectives: The decision to proceed to simple underwater seal drainage or to apply active suction to the underwater seal following pulmonary operation is a controversial one. For the sake of selecting the alternative to reduce postoperative air leakage, we performed a meta-analysis of randomised controlled trials (RCTs) to determine the benefit of suction or non-suction following lung surgery on patient outcomes.

Methods: RCTs published in English from 1999 to 2009 were included. A fixed-effect model was developed for postoperative pneumothorax cases. A random-effects model was developed for quantitative data synthesis, including prolonged air-leak cases, duration of air leakage, time for the removal of chest tubes and hospital stay.

Results: Odds ratio (95% confidence interval (CI)), expressed as suction versus non-suction, was 0.11 (0.03—0.49) for postoperative pneumothorax cases; relative risk was 1.48 (0.82—2.70) for prolonged air-leakage cases; weighted mean difference was 1.16 (−0.63 to 2.94) for the duration of air leakage, 0.96 (−0.12 to 2.05) for the time for removal of chest tubes and 2.19 (0.61—4.98) for the hospital stay.

Conclusion: There is no necessity to use suction in most cases, since it cannot decrease the incidence of prolonged air leak. However, suction can reduce the occurrence of postoperative pneumothorax resulting from early air leak. As a result, the early use of postoperative suction might be crucial to specific patients to whom early elimination of residual space is very important.

Keywords: Suction; Chest drain; Pulmonary surgery

1. Introduction

Chest drainage tubes are usually placed in the pleural space following thoracic surgery. These tubes are commonly connected to an underwater seal so that any persisting air or continuing air leak can escape through the low-resistance path. However, in clinical practice, pleural drainage systems are not universally standardised, and the decision to proceed to simple underwater seal drainage or to apply active suction to the underwater seal is based on the individual surgeon’s experience and opinion. Long since the introduction of active vacuum suction, controversy remains regarding the use of suction or water seal after pulmonary operations [1]. Those who advocate for the routine use of suction cite its ability to restore the intra-pleural vacuum, eliminate residual space and expedite the fullest lung expansion as the main benefits [2]. Those who elect early use of water seal cite it as a means of avoiding the promotion of higher air-leak rates through suture lines that might otherwise seal — absent the negative pressure of active suction [3]. To evaluate the therapeutic effects of the two types of management on postoperative air leaks, several randomised controlled trials (RCTs) have been done recently. However, the results are contradictory. For the sake of selecting the alternative to reduce postoperative air leakage, we performed a meta-analysis of RCTs to determine the benefit of suction or non-suction following lung surgery on patient outcomes.

2. Materials and methods

We used systematic methods to identify relevant studies, assess study eligibility, evaluate methodological quality and summarise findings regarding postoperative outcomes.

2.1. Data sources and searches

Medline and manual searches were done by two investigators independently and in duplicate to identify all published RCTs that addressed the issue of suction or non-suction following pulmonary surgery. The Medline search was done on PubMed (http://www.ncbi.nlm.nih.gov). One set
Table 1
Summary of randomised controlled trials on suction or non-suction (NS): major outcomes.

<table>
<thead>
<tr>
<th>Author</th>
<th>Subjects</th>
<th>Year Randomisation</th>
<th>Group and suction pressure</th>
<th>Case (N)</th>
<th>Postoperative pneumothorax case (n)</th>
<th>Prolonged air leak case (n)</th>
<th>Duration of air leakage (days)</th>
<th>Condition for removal of chest tube</th>
<th>Time to removal of chest tubes (days)</th>
<th>Hospital stay (days)</th>
<th>Favoured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerfolio et al. [5]</td>
<td>Lung resection including thoracotomy for lobectomy, segmentectomy and wedge resection</td>
<td>2001 Allocation concealment</td>
<td>Suction (−10 to −20 cm H₂O)</td>
<td>15</td>
<td>N/A *</td>
<td>N/A *</td>
<td>N/A *</td>
<td>N/A *</td>
<td>N/A *</td>
<td>N/A *</td>
<td>Water seal</td>
</tr>
<tr>
<td>Marshall et al. [6]</td>
<td>Lung resection including thoracotomy for lobectomy, segmentectomy and wedge resection</td>
<td>2002 Not mentioned</td>
<td>Suction (−20 cm H₂O)</td>
<td>34</td>
<td>0</td>
<td>N/A *</td>
<td>3.27 (0.80) b</td>
<td>Pleural fluid drainage &lt;300 ml d⁻¹ and no air leak</td>
<td>5.47 (0.98) b</td>
<td>11.13 (4.58) b</td>
<td>Water seal</td>
</tr>
<tr>
<td>Ayed [7]</td>
<td>VATS in pneumothorax including apical wedge resection by stapling device</td>
<td>2003 Not mentioned</td>
<td>Suction (−20 cm H₂O)</td>
<td>50</td>
<td>0</td>
<td>7</td>
<td>1.50 (0.32) b</td>
<td>Pleural fluid drainage &lt;100 ml d⁻¹ and no air leak</td>
<td>3.33 (0.35) b</td>
<td>4.67 (0.37) b</td>
<td>Water seal</td>
</tr>
<tr>
<td>Brunelli et al. [2]</td>
<td>Lung resection including thoracotomy for lobectomy</td>
<td>2004 Simple unrestricted randomisation without balance techniques</td>
<td>Suction (−20 cm H₂O)</td>
<td>73</td>
<td>N/A</td>
<td>22</td>
<td>6.3 (7.2) b</td>
<td>Pleural fluid drainage &lt;200 ml d⁻¹ and no air leak</td>
<td>10.3 (7.6) b</td>
<td>11.6 (8.5) b</td>
<td>Suction</td>
</tr>
<tr>
<td>Alphonso et al. [8]</td>
<td>All lung procedures including thoracotomy or VATS for lobectomy or wedge resection</td>
<td>2005 Unbiased allocation by minimisation</td>
<td>Suction (−2 KPa)</td>
<td>116</td>
<td>N/A</td>
<td>9</td>
<td>6.5 (7.5) b</td>
<td>Pleural fluid drainage &lt;200 ml d⁻¹ and no air leak</td>
<td>N/A *</td>
<td>N/A *</td>
<td>No difference</td>
</tr>
<tr>
<td>Prokakis et al. [9]</td>
<td>Lung resection including thoracotomy for lobectomy</td>
<td>2008 Sequentially numbered, opaque, sealed envelop</td>
<td>Suction (−15 to −20 cm H₂O)</td>
<td>47</td>
<td>1</td>
<td>7</td>
<td>3.6 (2.9) b</td>
<td>Pleural fluid drainage &lt;200 ml d⁻¹ and no air leak</td>
<td>3.4 (3.1) b</td>
<td>10.3 (4.5) b</td>
<td>Suction</td>
</tr>
</tbody>
</table>

Note: All the RCTs have excluded those cases with severe emphysematous bullous disease, chronic obstructive pulmonary disease or predicted postoperative forced expiratory volume in 1 s (ppoFEV₁) less than 30%.

* N/A means unavailable.

b It is expressed as means (SD).
was created using the medical subject headings (MeSH) term 'Thoracic Surgery OR Thoracic Surgical Procedures OR Thoracic Surgery, Video-Assisted' (205 015 citations – 22 May 2009) and another was created using the MeSH term 'suction' (8725 citations). Combining the two sets with the Boolean 'AND' function yielded 742 citations. This set was limited by the publication type 'randomised controlled trial' to give 55 citations in English. Manual searches were then done by reviewing articles cited in the reference lists of identified RCTs, and also by reviewing the first author's article file. Thereby, a total of six published RCTs were identified (Table 1). We did not include unpublished data. Because of the limited number of RCTs, we designed the article selection process to be inclusive as opposed to exclusive. In other words, trials were not excluded because of trial quality (design) or insufficient number of patients. A trial quality score was assigned (scale of 1—5) according to the method of Jadad et al. [4] One investigator screened the articles and identified article abstracts for full review.

2.2. Data abstraction

Two investigators abstracted the following information from the eligible articles without blinding: author, location of study site, journal, year of publication, study design, number of patients and demographic characteristics of participants. In all the RCTs, postoperative patients were given one or two chest tubes, and randomly assigned to receive –10 to –20-cm H$_2$O active suction applied to the underwater seal drainage (group I) or simple underwater seal drainage (group II). Major outcomes for quantitative data synthesis included prolonged air-leak case, postoperative pneumothorax, duration of air leakage, time for removal of chest tubes and hospital stay. Disagreements were resolved by consensus review with a third investigator.

2.3. Statistical analysis

2.3.1. Test- and study-specific estimates

Major postoperative outcomes are defined in the index tests as follows. (1) Prolonged air-leak case: the definition of prolonged air leak in the included RCTs varies from 3 to 7 days. Hence, we ‘cut-off’ the categorical variable as ‘air leakage lasting $\geq$3 days’. (2) Early postoperative pneumothorax cases: the cases with postoperative pneumothorax, the size of which is more than 20% thoracic space on the initial postero-anterior chest radiograph on the third postoperative day. (3) Duration of air leakage: the duration (days) of postoperative air leakage. (4) Time for removal of chest tubes: the duration (days) between operation and removal of chest tubes. (5) Hospital stay: the duration (days) between operation and discharging for rehabilitation. The quantities in (3)—(5) are expressed as means ± standard deviation (SD) in the index tests (Table 1).

2.3.2. Meta-analysis model

A fixed-effect model was applied when the $P$ values of test for heterogeneity is more than 0.05. A random-effects model was used as it provided conservative confidence intervals (CIs) for postoperative outcomes between study variability ($P < 0.05$). Odds ratio, relative risk (RR) or weighted mean difference (WMD) was the principal measure of effect. They were presented as a point estimate with 95% CIs and $P$ values in parentheses. Reviewer Manager 4.2.2 (The Cochrane Collaboration, Wintertree Software Inc., Canada) statistical software was used.

Publication bias could not be properly assessed because there were insufficient RCTs to construct a funnel plot. However, several of the RCTs were ‘negative’ in their conclusions. Bias against publication of negative trials therefore seems unlikely.

3. Results

The two trial assessors agreed upon the six identified and selected RCTs. Data from these six RCTs are summarised in Table 1. RCT quality scores ranged from 3 to 5 (5-point scale). Trial assessor agreement on quality assessment was strong (100%). Odds ratio (95% CI) for early postoperative pneumothorax cases and RR for prolonged air-leakage cases, WMD for duration of air leakage, WMD for time for removal of chest tubes and WMD for hospital stay are depicted in Figs. 1—5. Odds ratio (95% CI), expressed as suction versus non-suction (treatment vs control), was 0.11 (0.03—0.49) for postoperative pneumothorax cases. RR (95% CI), expressed as suction versus non-suction (treatment vs control), was 1.48 (0.82—2.70) for prolonged air-leakage cases, mean WMD was 1.16 (0.63 to 2.94) for duration of air leakage, 0.96 (0.12 to 2.05) for the time for removal of chest tubes and 2.19 (0.61 to 4.98) for the hospital stay.

From Fig. 1, we can see that odds ratio for postoperative pneumothorax (0.11) favoured the suction management ($P = 0.60$) since odds ratio may be statistically more robust as
a measure of effect than RR. As a result, suction can significantly decrease the occurrence of early postoperative pneumothorax.

By our meta-analysis (Fig. 3), there was no significant difference between suction and non-suction on the duration of prolonged air leaks \( (P = 0.11) \). Fig. 2 shows that RR for the incidence of prolonged air leaks slightly favoured the non-suction management \( (P = 0.04) \). The WMD for removal of chest tubes or hospital stay strongly favoured non-suction management. However, \( P \) value of test for heterogeneity in either removal of chest tubes or hospital stay is dramatically small \( (P = 0.0002 \text{ and } P < 0.00001) \). As a result, we believe that random-effects meta-analysis model is methodologically superior for the data.
4. Discussion

Postoperative air leak continues to be an untoward and frequent complication after lung resections. Some surgeons theoretically believe that suction has the advantages of favouring the apposition of parietal and visceral pleurae, promoting the sealing of air leaks [2,10]. This approach seems more reasonable, particularly after pulmonary lobectomy when a greater pleural residual space is created compared with minor resections. On the other hand, suction applied to the tubes may lead to an increase in the volume of air leaking from the parenchyma, hindering the sealing process [6]. Hence, the benefit of active suction applied to the underwater seal drainage for the reduction of postoperative leaks is inconclusive. The published RCTs interestingly provided different conclusions. In 2006, Sanni et al. [11] made a systemic analysis of the published RCTs and indicated that no studies found in favour of suction to reduce the incidence of air leak. However, more recent literature should be supplemented. Besides, we think it is necessary to synthesise the recently published RCTs and analyse the overall parameters with meta-analysis — the important evidence-based medical tool. The results will guide the clinical practice to improve therapeutic effects and reduce hospital stay costs.

It should be noted that all the RCTs have excluded those cases with severe emphysematous bullous disease, chronic obstructive pulmonary disease (COPD) or predicted postoperative forced expiratory volume in 1 s (ppoFEV₁) less than 30%. We find that the studies regarding active suction in such patients with significant COPD and bullous disease are very rare. We believe that the security of postoperative suction among those patients should be carefully assessed.

In the index RCTs, the authors defined early postoperative pneumothorax by initial chest radiograph on the third postoperative day. As residual air resulting from the operation should vanish on the third postoperative day, the obvious air space in the chest film could be thought of as early pneumothorax resulting from air leakage. Interestingly, Fig. 1 shows that the occurrence of early postoperative pneumothorax among the suction group is significantly less than that among the non-suction group, which means that the active suction applied to the underwater seal drainage does reduce the occurrence of early air leakage and consequent pneumothorax in postoperative initial stage (<3 days), consistent with the recent study in our analysis [9]. However, active suction cannot decrease the duration of prolonged air leakage (≥3 days), and even slightly increase its occurrence whether the lung is re-expanded or not. In the meanwhile, our meta-analysis even shows that there is an increase in either time for chest tube removal or length of hospital stay following postoperative continuous suction. Besides, each type of procedure might require a different drain policy and drain management should be tailored to the type of procedure and to the patient. It is not necessary to use suction in the absence of a clinically important postoperative air space, and earlier removal could result in shorter hospital stays in those patients.

Although there are minimal concerns regarding postoperative pneumothorax, some surgeons do not obtain postoperative chest X-rays routinely. We consider the early suction strategy to reduce retained air space might be crucial in the following conditions, in which the early elimination of residual air is of utmost importance. (1) Patients with spontaneous pneumothorax undergoing apex wedge resection: the early adherence between visceral and parietal might decrease the recurrent possibility. (2) Patients undergoing upper lobectomy: the early elimination of residual space might decrease the possibility of infection. (In addition, some reports [2,10,12] used pleural tents along with suction in upper lobectomies to significantly reduce the duration of air leaks and the hospital stay.) (3) It makes sense to use suction following debridement/decortication to expedite lung re-expansion. (4) Patients with predictors of alveolar air leaks, including steroid use, diabetes or malnutrition [13].

The P values of test for heterogeneity regarding the data, including postoperative pneumothorax, prolonged air-leak cases and duration of air leakage, are relatively tolerable (P = 0.60, P = 0.04 and P = 0.11). However, the P values regarding time for removal of chest tubes and hospital stay are dramatically lower (P = 0.0002 and P < 0.00001). As for the cause of mild heterogeneity in case of prolonged air leak cases and duration of air leakage, our arguments are as follows. (1) A few studies managed their chest tubes somewhat differently. For example, Marshall et al. [6] who noted in their methods that they subjected all their patients to a brief period of suction immediately postoperatively; thereafter, even if randomised to ‘water seal’ in the recovery room, they were replaced on suction if a ≥20% pneumothorax was manifest on the chest film for the sake of medical security. In their patients who randomised to suction, they had a water seal instituted as soon as their air leakage (checked twice daily) ceased. (2) We chose 3 days as the cut-off for prolonged air leak as the research articles that met our criteria had used cut-offs from 3 to 7 days. Considering the studies individually, the cut-offs were Cerflolio 3 days, Marshall — NA, Ayed 5 days, Brunelli 7 days, Alphonso 6 days and Prokakis 3 days.

As for the causes of strong heterogeneity regarding time for removal of chest tubes and hospital stay, we think that the variations in diseases and surgical approaches are very important. For example, either lung cancer or pneumothorax is included. Some patients underwent video-assisted thoracoscopic surgery (VATS), while others underwent thoracotomy. Besides, the threshold of daily drainage before removing the chest tube ranged from 100 to 300 ml in all the RCTs. All the above-mentioned conditions might cause the strong heterogeneity regarding hospital stay and time for removal of chest tubes. Hence, the random-effects meta-analysis model is methodologically superior for the data. However, we do not think that the heterogeneity of these management points in different studies invalidates the attempt to perform a meaningful meta-analysis. At the very least, suctions are universally applied in all the RCTs, at least initially, post-pulmonary resection.

Collectively, according to the meta-analysis, there is no necessity to use suction in most cases, since it cannot decrease the incidence of prolonged air leak. It is inconsequential to use suction in the absence of a clinically important postoperative air space, and earlier removal could result in shorter hospital stays in those patients. However,
meta-analysis indicated that suction can reduce the occurrence of postoperative pneumothorax resulting from early air leak. As a result, the early use of suction might be crucial to the specific patients to whom early elimination of air residual is very important.

Acknowledgements

Bo Deng and Qun-You Tan participated as trial assessors. Bo Deng, Qun-You Tan, Yun-Ping Zhao, Ru-Wen Wang and Yao-Guang Jiang participated in analysing the data and writing the manuscript. The authors appreciate the statistical review from Lee in epidemiological department, third military medical university. The authors also appreciate P.A. Thomas, the associate editor of EJCTS, for his excellent comments.

References