The impact of suction addition to simple water seal on the outcomes after pulmonary surgery: A meta-analysis

Qiongxiang Qiu[1,A–D,F], Yumin He[2,A–D,F], Wenjuan Li[1,A,B,D,F], Ximiao Ma[1,B,D,E], Xuehua Feng[1,A,B,D–F]

[1] Department of Thoracic Surgery, Haikou People's Hospital, Xiangya School of Medicine of Central South University, China
[2] Operation Room, Qionghai People's Hospital, China

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

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Address for correspondence
Xuehua Feng
E-mail: fengxuehua_sci@outlook.com

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Abstract

Background. Chest tube drainage during pulmonary surgery is fundamental to removing air and fluid, as well as for lung re-expansion. However, the advantages of adding external suction to the water seal are under debate.

Objectives. The aim of the study was to conduct a meta-analysis in order to assess the effects of adding suction to a simple water seal on the outcomes of lung surgery.

Materials and methods. A search of the literature up to November 2021 found 14 studies with 2449 lung surgery patients. Of these patients, 1092 received suction drainage and 1357 received a simple water-seal drainage. The studies reported the effects of adding suction to a simple water seal on postoperative outcomes after lung surgery. A random- or fixed-effect model determined the odds ratio (OR) or mean difference (MD) with 95% confidence intervals (95% CIs) to compare the outcomes.

Results. In patients undergoing lung surgery, suction resulted in a substantially longer chest tube duration (MD = 0.74, 95% CI: 0.90–1.40, p = 0.03, Z = 2.21) and a smaller postoperative pneumothorax (OR = 0.27, 95% CI: 0.13–0.59, p = 0.02, Z = 2.24) than a simple water seal. However, no differences existed in prolonged air leak (p = 0.91, Z = 0.12), air leak duration (p = 0.28, Z = 1.07) or length of hospital stay (p = 0.23, Z = 1.2) between the 2 approaches.

Conclusions. Suction led to considerably longer chest tube duration and lower postoperative pneumothorax, but no significant difference in sustained air leak, air leak duration or length of hospital stay was observed compared to a simple water seal in patients undergoing pulmonary surgery. Further research is needed to validate these findings and increase confidence, particularly regarding the postoperative pneumothorax results.

Key words: suction, pulmonary surgery, simple water seal, postoperative pneumothorax, prolonged air leak

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Background

The fundamental principles of chest drainage systems are to allow air and fluid drainage, remove residual space in the pleura, allow lung re-inflation, and maintain negative pressure.[1] Currently, chest tube management applies 2 main techniques, non-suction-based drainage by a simple water seal or suction drainage via a water seal with external suction.[2] The applied technique depends on clinician preference,[3] and many believe that adding suction can minimize air leaks and, thus, expedite lung rehabilitation. In contrast, others believe that a simple water seal can reduce air leakage duration after lung surgery.[4–6] This difference in opinion arises from the question of whether the addition of external suction to the water seal is beneficial. The benefits of suction include fast removal of air, fluid leakage and lung expansion. However, the question of which technique is superior and leads to better patient outcomes remains debatable.[4]

Objectives

This meta-analysis aimed to investigate the impact of suction addition to a basic water seal on postoperative outcomes following lung surgery.

Materials and methods

The current investigation used an established protocol contingent on the statement of meta-analysis of studies in epidemiology.

Search strategy and selection of studies

The included studies reported the effects of suction addition to a water seal on lung surgical treatment and compared it with a simple water seal alone.

Only research conducted on humans was included, and there were no restrictions on language, size or study type. However, review articles, editorials and studies without a level of connection were all removed. The study protocol is depicted in Fig. 1. All articles included in the meta-analysis fulfilled the following criteria:

1. Designed as a prospective or retrospective randomized controlled trial (RCT);
2. The designated target population comprised patients undergoing lung surgery;
3. The intervention approach used suction and compared it to a simple water seal;
4. The investigation included comparisons of external suction with simple water seals.

The exclusion criteria were:

1. Studies with missing or incomplete data;

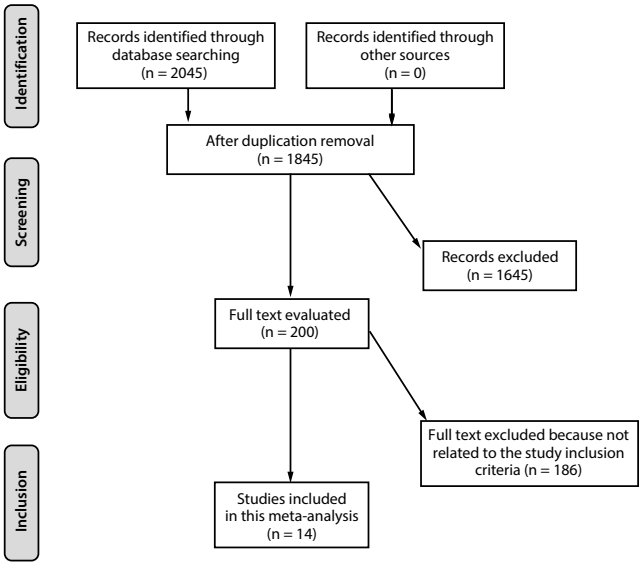

Fig. 1. Flowchart of the study

2. Studies designed with objectives other than an examination of the effects of suction compared to a simple water seal during pulmonary surgery;
3. Studies with methods other than suction and a simple water seal;
4. Studies without the investigation of the impact of comparative results.

Identification

A search protocol was devised based on the PICOS criteria, which were identified as follows: P (population): patients undergoing pulmonary surgical procedures; I (interventional/experimental): comparison of suction with a simple water seal; C (comparison): suction compared to a simple water seal; O (outcome): chest tube length, postoperative pneumothorax, prolonged air leakage, duration of air leak, and hospital stay duration; and S (study protocol/design): no limitations.[7] During a systematic and comprehensive search of electronic engines, including Embase, Google Scholar, Cochrane Library, PubMed, and OVID, articles published up to November 2021 were retrieved. The search used a combination of selected keywords and words related to suction and pulmonary surgery, water seal, chest tube use and its duration, postoperative pneumothorax, prolonged air leak, air leak duration, and hospital admission duration, as summarized in Table 1. All selected research publications were collated in a single EndNote file (Clarivate, London, UK), with duplicates omitted. Examination of the titles and abstracts excluded publications that did not report an association between the effect of adding suction and a water seal and the consequences after pulmonary surgery. The retrieved studies were then investigated for relevant data.

Table 1. Search strategy for each database

Database	Search strategy
Pubmed	#1 "suction" [MeSH terms] OR "pulmonary surgery" [all fields] OR "simple water-seal" [all fields] #2 "chest tube duration" [MeSH terms] OR "postoperative pneumothorax" [all fields] OR "prolonged air leak" [all fields] OR "air leak duration" [all fields] OR "length of hospital stay" [all fields] #3 #1 AND #2
Embase	#1 "suction"/exp OR "pulmonary surgery"/exp OR "simple water-seal"/exp #2 "chest tube duration"/exp OR "postoperative pneumothorax"/exp OR "prolonged air leak"/exp OR "air leak duration"/exp OR "length of hospital stay"/exp #3 #1 AND #2
Cochrane Library	#1 "suction": ti,ab,kw OR "pulmonary surgery": ti,ab,kw OR "simple water-seal": ti,ab,kw (word variations have been searched) #2 "chest tube duration": ti,ab,kw OR "postoperative pneumothorax": ti,ab,kw OR "prolonged air leak": ti,ab,kw or "air leak duration": ti,ab,kw or "length of hospital stay": ti,ab,kw (word variations have been searched) #3 #1 AND #2
OVID	#1 "suction" OR "pulmonary surgery" OR (simple water seal or lung adj2 (disturb* or dysfunction*)): tw,kw,kf #2 "chest tube duration" OR "length of hospital stay" (acute adj2 (postoperative pneumothorax or pneumothorax rate)): tw,kw,kf #3 (air leak duration* or prolonged air leak): tw,kw,kf
Web of Science	#1 ("suction" OR "simple water seal") AND "pulmonary surgery" (word variations have been searched) #2 "chest tube duration" AND "postoperative pneumonthorax" (word variations have been searched) #3 "length of hospital stay" OR "prolonged air leak" OR "air leak duration") (word variations have been searched)

MeSH – medical subject headings; ti,ab,kw – terms in either title or abstract or keyword fields; exp – exploded indexing term; tw – title or abstract; kw – author-provided keyword exact; kf – word in a provided keyword; TS – topic search.

Screening

A pre-designed form summarized the study- and participant-related properties, including the last name of the first author, study time frame, region, year of publication, target population, study protocol, subject numbers, demographic data, and properties of clinical treatments applied. Additionally, the form included the assessment period, quantitative and qualitative techniques of evaluation, information resources, and outcome assessment, as well as whether statistical analysis used mean difference (MD) or odds ratio (OR) with 95% confidence intervals (95% CIs).[7] If a study met the inclusion criteria and conformed to relevant guidelines, 2 authors independently retrieved the information. In case of disagreement, the corresponding author made the final decision. When there was variability in the data retrieved from one of the trials, based on the examination of the association between suction and water seal impacts on the postoperative outcomes of patients undergoing lung surgical procedures, data were extracted separately. For the assessment of bias, 2 authors independently evaluated the procedural quality of the selected trials.

Risk of bias

The Cochrane risk-of-bias tool for randomized trials v. 2 (RoB 2; Cochrane, London, UK) evaluated bias risk and procedural quality. Risk of bias evaluation criteria categorized a study as a low risk of bias if it fully met quality standards. If the quality requirements (one or more) were only partially met or were unclear, the publication was assigned to the moderate risk of bias category. High-risk publications did not fulfill the quality standards. Any inconsistencies were resolved by re-investigating the original article.

Eligibility

The main finding focused on the impact of suction addition to a simple water seal on lung surgery outcomes. A summary was created based on the evaluation of the suction addition effect and simple water seal approach on chest tube duration, postoperative pneumothorax, prolonged air leak, air leakage duration, and hospital stay duration.

Inclusion

Sensitivity analyses were only applied to studies that demonstrated an effect of suction addition to a simple water seal on postoperative outcomes of lung surgery. Suction and a simple water seal were compared in terms of subgroup and sensitivity analyses.

Statistical analyses

All measurements and graphs were made using Reviewer Manager (RevMan) v. 5.3 (Cochrane). A continuous or dichotomous technique with a fixed- or random-effect model estimated the MD, OR and 95% CIs. Estimations of the I^2 index ranged between 0% and 100%, with an I^2 index value of approx. 0% interpreted as no heterogeneity and I^2 index values of 25%, 50% and 75% interpreted as low, moderate and high heterogeneity, respectively. The random-effect model was applied if I^2 was 50% or above, and when I^2 was less than 50%, the likelihood of applying fixed influence rose. However, additional characteristics of the studies, with a high degree of similarity, were also analyzed to confirm the employment of the correct model.[8] The subgroup analysis was performed as defined before, using the stratification of the original calculation per result category.

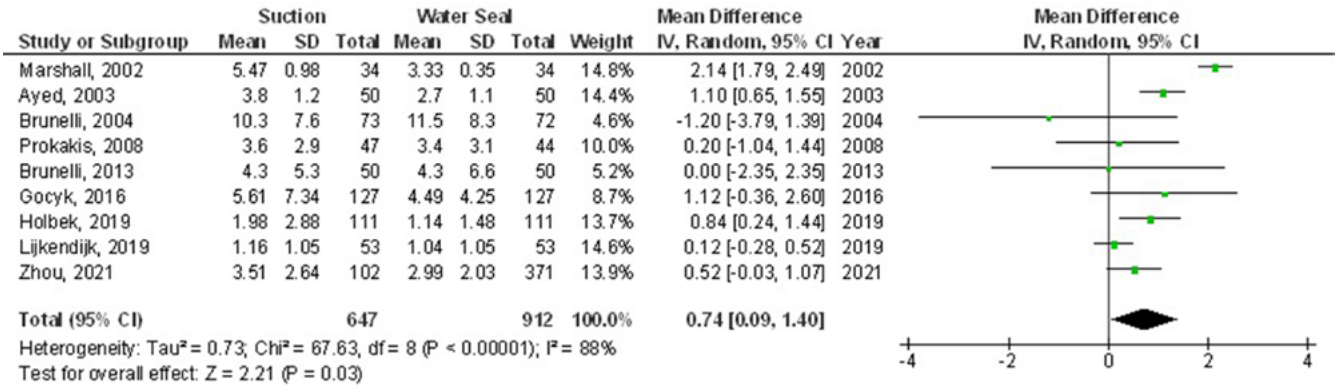

Fig. 2. Forest plot comparing chest tube duration in pulmonary surgery patients receiving suction to a simple water seal

95% CI – 95% confidence interval; df – degrees of freedom; SD – standard deviation.

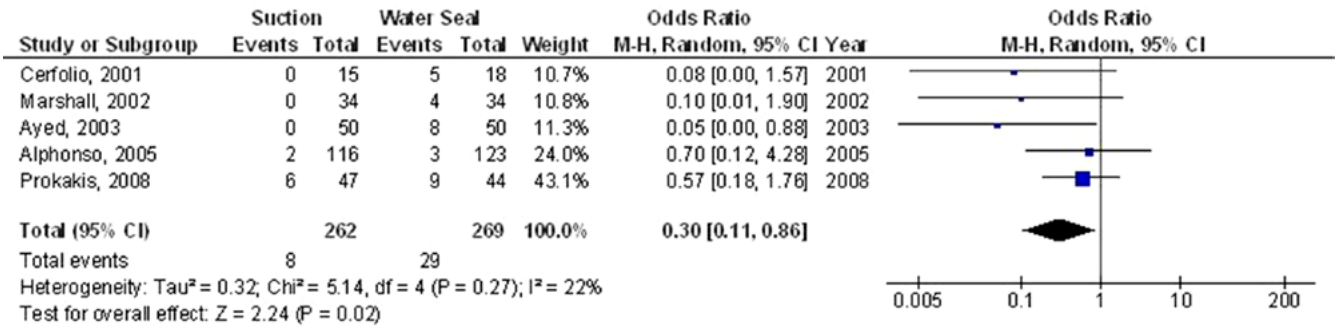

Fig. 3. Forest plot comparing postoperative pneumothorax in pulmonary surgery patients receiving suction to a simple water seal

95% CI – 95% confidence interval; df – degrees of freedom.

The Egger's regression test for bias assessment was quantitatively measured (bias was present if $p \leq 0.05$) and examined by visual inspection of funnel plots of logarithmic ORs against standard errors. All estimated p-values were two-tailed, and a value of $p < 0.05$ for discrepancies amongst subgroups reflected statistical significance.

Results

A total of 2045 studies were retrieved, with 14 studies between 2001 and 2021 meeting the inclusion criteria for integration in the meta-analysis.[5,6,9–20] The studies included 2449 participants undergoing surgical lung procedures, with 1092 receiving suction and 1357 receiving a simple water seal. All studies investigated suction addition to a basic simple water seal on lung surgery outcomes.

The sample sizes of the studies ranged from 31 to 500 participants, and the data retrieved from 14 trials are depicted in Table 2. Thirteen trials provided data on chest tube duration, 5 reported data on postoperative pneumothorax, 7 provided data on protracted air leaks, 5 reported tiered air leak duration data, and 6 reported data on length of hospital stays.

Suction resulted in significantly longer chest tube duration (MD = 0.74, 95% CI: 0.09–1.40, p = 0.03, Z = 2.21) with considerably high heterogeneity (I^2 = 88%), and a lower incidence of postoperative pneumothorax (OR = 0.27, 95% CI: 0.30 (0.11–0.86), p = 0.02, Z = 2.24) with low estimated heterogeneity (I^2 = 22%), in comparison to a simple water seal in patients undergoing lung surgery (Fig. 2,3). However, when compared to a simple water seal, suction made no significant difference in terms of prolonged air leak (OR = 1.08, 95% CI: 0.29–4.06, p = 0.91, Z = 0.12) with highly estimated heterogeneity (I^2 = 93%), air leak duration (MD = 0.58, 95% CI: −0.48–1.64, p = 0.28, Z = 1.07) with heterogeneity value of 94%, or length of hospital stay (OR = 1.30, 95% CI: −0.81–3.41, p = 0.23, Z = 1.2) with highly estimated heterogeneity (I^2 = 90%) (Fig. 4–6).

The analysis of the studies' stratification and adjustment for gender, race and age was not performed because none of the studies included adjustments or stated the influence of these variables. The Egger's regression analysis estimates (p = 0.89) revealed no publication bias based on visual and quantitative evaluation of the funnel plots. Despite this, most studies included in the meta-analysis had low procedure quality due to their limited sample size. None of the studies had selective reporting bias or inadequate outcome data.

Discussion

This meta-analysis included 14 trials with 2449 patients who had undergone lung surgery, of which 1092 participants

Table 2. Characteristics of the studies selected for the meta-analysis

Study, year, reference	Country	Total	Suction	Water seal	Participant	Disease type	Number of tubes	Initial suction	Suction pressure [mm Hg]	Drainage system type	Definition of prolonged air leak	Drainage threshold of removal [mL/day]
Cerfolio et al., 2001 [9]	USA	33	15	18	lung surgery	lung disease	1–2	no	–20	regular	>6	<200
Marshall et al., 2002 [10]	USA	68	34	34	video-assisted thoracic surgery	lung disease	1–2	no	–20	regular	>6	<200
Ayed, 2003 [11]	Kuwait	100	50	50	lobectomy	lung disease	1	no	–20	regular	>6	<200
Brunelli et al., 2004 [6]	Italy	145	73	72	lobectomy	primary spontaneous pneumothorax	2	yes	–20	regular	>5	<100
Alphonso et al., 2005 [12]	UK	239	116	123	lung surgery	lung cancer	2	yes	–20	regular	>5	<100
Daneshvar Kakhki et al., 2006 [13]	Iran	31	13	18	lung surgery	lung cancer	2	yes	–11 to –20	digital	>6	<100
Prokakis et al., 2008 [14]	Greece	91	47	44	lung surgery	lung cancer	1–2	yes	–20	digital	>6	<150
Brunelli et al., 2013 [15]	Italy	100	50	50	lung surgery	lung cancer	1–2	yes	–20	digital	>6	<300
Leo et al., 2013 [16]	Italy	500	250	250	lung surgery	lung cancer	1	no	–20	regular	>5	<300
Gocyk et al., 2016 [5]	Poland	254	127	127	lung surgery	lung cancer	2	no	–10 to –18	regular	>5	<200
Lijkendijk et al., 2019 [17]	Denmark	106	53	53	lobectomy	lung cancer	1–2	no	–15	regular	>8	<200
Holbek et al., 2019 [18]	Denmark	222	111	111	lobectomy	lung cancer	1–2	yes	–15	digital	>7	<100
Vageriya et al., 2020 [19]	India	87	51	36	lobectomy	lung cancer	2	yes	–15	regular	>7	<100
Zhou et al., 2021 [20]	China	473	102	371	lobectomy	lung cancer	2	yes	–15 to –20	regular	>7	<100
Total		2449	1092	1357	–							

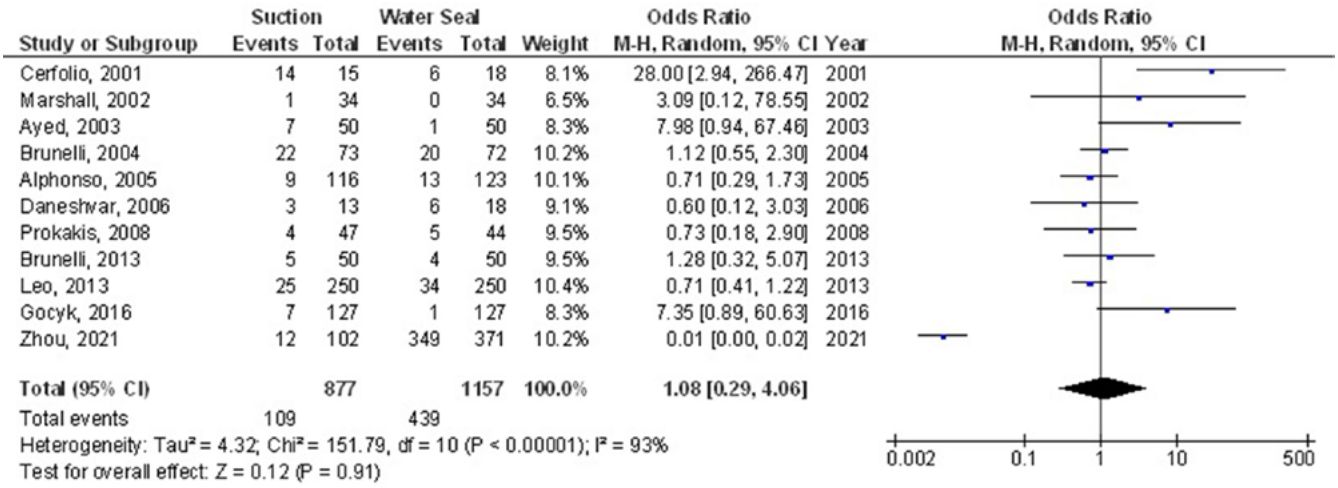

Fig. 4. Forest plot comparing prolonged air leak in pulmonary surgery patients receiving suction to a simple water seal

95% CI – 95% confidence interval; df – degrees of freedom.

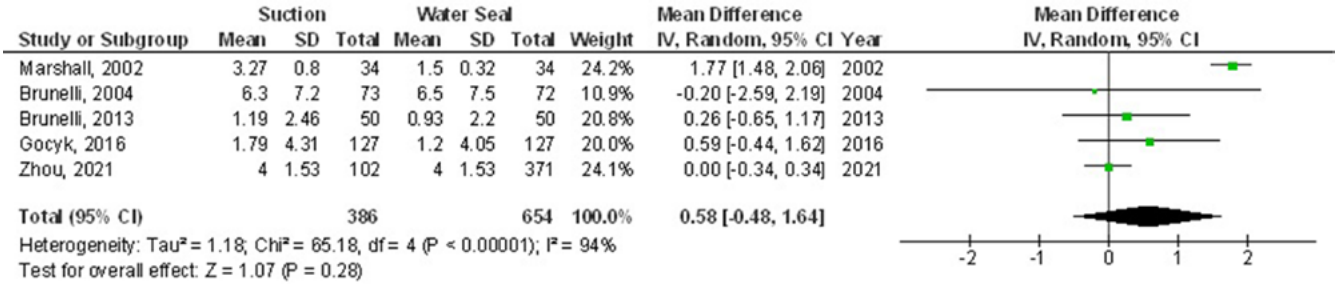

Fig. 5. Forest plot comparing air leak duration in pulmonary surgery patients receiving suction to a simple water seal

95% CI – 95% confidence interval; df – degrees of freedom; SD – standard deviation.

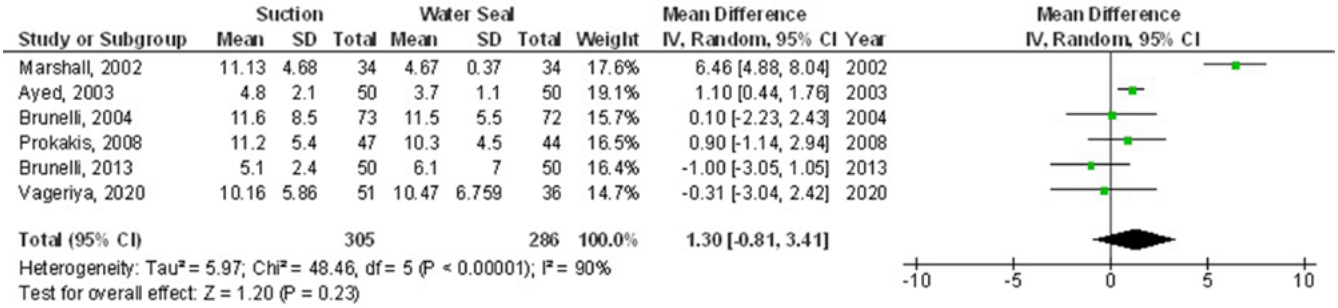

Fig. 6. Forest plot comparing hospital stay duration in pulmonary surgery patients receiving suction to a simple water seal

95% CI – 95% confidence interval; df – degrees of freedom; SD – standard deviation.

received suction drainage and 1357 a simple water-seal drainage.[5,6,9–20] In those undergoing pulmonary surgery, suction led to considerably longer chest tube duration and lower postoperative pneumothorax than a simple water seal. However, suction did not impact sustained air leak, air leakage time span or hospital stay duration. Nonetheless, caution must be taken when interpreting the results due to the relatively few studies included and the limited sample size of most of them. Indeed, 6 out of 12 trials had a sample size <100 subjects. Therefore, further studies are required to confirm these outcomes and increase confidence in the effects observed.

Meta-analysis is a methodical assessment of numerous RCTs, followed by statistical pooling of the data.[21] Randomized clinical studies showed that suction enhanced postoperative drainage volume[5] and increased chest drainage volume due to higher suction pressure.[18] However, suction can lead to concurrent negative pressure that may increase the production of fluid. Adding external suction to a water seal may speed up the drainage of fluid. In pulmonary surgery, there are 2 contradictory consequences of fluid production and removal, including equilibrium being biased towards removal with suction, resulting

in a lower drainage volume. Nonetheless, patients who received suction had far longer duration of chest tube use than those treated with a simple water seal. Chest tube removal criteria may help to clarify the situation. The withdrawal of a chest tube depends on detecting no air leakage and minimal fluid drainage. Suction addition to the water seal should accelerate the removal of chest tube. However, the development of a prolonged air leak may contribute to the postponement of chest tube removal. Given the pleura's tendency to absorb fluid, the frequency of prolonged air leaks may result in a longer chest tube duration than the output of the fluid chest drainage.

Suction-based drainage was found to be a risk factor for a higher incidence of prolonged air leakage, suggesting that the addition of external suction to the basic water seal could increase air leakage. The relationship between suction drainage and the incidence of prolonged air leaks is still debatable[16,18] as it depends on the type of surgery and target population selection. Numerous definitions of prolonged air leaks have been recommended, including postoperative air leaks that last for 3–10 days,[22,23] although a leak greater than 5 days is the most widely used and based on the average postoperative hospital stay length.[24] Once a prolonged air leak occurs, late chest tube removal and hospital discharge are expected.[25] Reducing the duration of air leakage can be achieved by applying endobronchial valves, sterilized compressed sponges, or through non-interventional supportive therapy.[26–29] Additionally, digital chest drainage, a relatively new system, can be implemented to guide chest tube removal.[30] Although the old drainage method was more widely employed in the assessed studies, the digital drainage approach was used in a limited number of studies at a considerable financial cost.[5]

This meta-analysis investigated the impact of adding suction to a water seal on postoperative outcomes following lung surgery. However, more research is warranted to confirm the possible connection between the two and to demonstrate clinically significant results. This was also suggested in previous meta-analyses that found that suction and a simple water seal had similar impact on patients undergoing different types of surgery.[30–33] The insignificant results between suction and a simple water seal in several studied outcomes require further investigation and clarification, because no obvious rationale could explain these clinical outcomes. Well-conducted prospective trials are also needed to investigate these factors and the effect of different co-factors, such as age, gender and ethnicity. Indeed, this meta-analysis did not find any impact of these variables.

In 2013, the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) Statement was established as a procedure to help improve clinical trial protocol quality.[34] The Consolidated Standards of Reporting Trials (CONSORT) Statement (2010) contains a 25-item checklist and a flowchart to help the authors depict the randomized trials with more clarity.[35] The design and report of clinical trials according to the SPIRIT and CONSORT protocols and checklists will help ensure the recording of all critical trial features, which will decrease the risk of bias and improve the quality of suction and simple water seal RCTs.[34,35] Conducting properly designed RCTs to assess the effects of suction and a simple water seal on lung surgery patients is essential, and because published data should guide clinical practice, the publication of completed research studies is fundamental.[36]

In summary, suction led to significantly longer chest tube use and decreased postoperative pneumothorax in patients undergoing lung surgery than in those receiving a simple water-seal drainage. However, suction had no significant impact on sustained air leakage, air leak duration or length of hospital stay. More research is warranted to validate these findings.

Limitations

Due to a large number of the retrieved studies initially being eliminated from the current meta-analysis, selection bias could be present in the study. However, the studies which were eliminated did not meet the inclusion criteria, with several failing to connect outcomes to characteristics such as age and ethnicity. Furthermore, some studies assessed the effects of suction and a water seal on clinical outcomes by comparing their results to those of previous studies, which may have introduced bias due to incomplete information. This meta-analysis included 14 studies, out of which 6 were relatively small, with less than 100 subjects. There was significantly high heterogeneity in some of the studies, and the sensitivity analysis indicated publication bias in favor of suction, which could explain this variability. Also, co-factors such as ethnicity, age and nutritional status were likely bias-causing factors that need further investigation. Furthermore, the pooled results may be skewed due to unpublished papers and missing data, as well as variability in management methods, doses and healthcare organization standards. Indeed, the length of suction and simple water seal management were inconsistent, and they did not adequately assess the cost burden and patient's quality of life, which are vital outcomes.

Conclusions

In participants undergoing pulmonary surgery, suction led to considerably longer chest tube duration and smaller postoperative pneumothorax than a simple water seal. However, suction was no better than water seal at preventing prolonged hospital stays, air leaks or air leak duration. Nonetheless, the small number of studies included and the relatively small sample sizes mean the results must be interpreted cautiously. Therefore, well-designed and in-depth additional studies are recommended to validate and improve confidence in these findings.

ORCID iDs

Qiongxiang Qiu https://orcid.org/0009-0005-9126-9658
Yumin He https://orcid.org/0009-0003-4562-8141
Wenjuan Li https://orcid.org/0000-0002-7174-6075
Ximiao Ma https://orcid.org/0000-0002-5386-0050
Xuehua Feng https://orcid.org/0000-0001-7715-5578

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