THE CLINICAL EFFECTIVENESS OF SUCTION VERSUS WATER SEAL FOR OPTIMAL MANAGEMENT OF PLEURAL CHEST TUBES IN ADULT PATIENTS: A SYSTEMATIC REVIEW

by

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Texas Christian University Center for Evidence Based Practice and Research: A Collaborating Center of the Joanna Briggs Institute

INTRODUCTION

Background

Inflation of the lungs during inspiration occurs as a result of negative pressure as the diaphragm contracts, and the rib cage expands outward and upward. Pleural layers that line the lungs and the ribcage maintain this negative pressure. The space between these layers is called the pleural space. Any disruption in the negative pressure maintained, with subsequent collection of air or fluid in the pleural space, will likely result in a collapsed lung. Atmospheric air abnormally seeping into the pleural space because of some kind of disruption in the negative pressure is called an air leak. An air leak is monitored as bubbling in the water seal chamber. When bubbling in the chamber ceases, the air leak is considered resolved. Air collection resulting in lung collapse is called a pneumothorax.(1) The presence of a pneumothorax is verified with a chest x-ray. Resolution of a pneumothorax is determined based upon absence of an air leak, breath sounds in all lung fields, chest x-ray, or provider discretion. Abnormal fluid collection in the pleural space including blood, serous drainage or pus, is called a haemothorax, pleural effusion, or empyema.(1) Regardless of the cause, if the lung is not re-inflated and negative intrathoracic pressure restored within the pleural space, respiratory collapse and death will occur. Typical conditions that cause a disruption in the pleural space are pulmonary surgery, central line placement or trauma whereby the surgeon or an object such as a needle/bullet/knife enters the pleural space and allows atmospheric pressure into the pleural space-resulting in a collapsed lung and loss of negative intrathoracic pressure. Another condition leading to a loss of negative intrathoracic pressure is when a blister on the surface of the lung bursts and atmospheric pressure drawn in with every

breath exits the lung via the bleb (blister) collapsing the lung and filling the pleural space with air. This is referred to as a spontaneous pneumothorax.

Treatment of lung collapse dates back hundreds of years to Hippocrates' time when the technique for lung re-expansion included the use of a metal tube to drain contents from the pleural space. Newer techniques such as needle aspiration or drainage to water seal and suction did not emerge until the latter half of the 19th century.(2) Pleural drainage systems were greatly improved in the mid 20th century due to chest trauma that occurred during the Korean and Vietnam wars.(2)

The water seal acts like a one-way valve that allows continuous closed gravity drainage of pleural cavity contents (fluid and/or air) out of the lung.(3) All pleural chest tubes must have water seal at all times. The mechanism of suction is in addition to water seal. The term "primarily" for suction or water seal refers to which therapy is used the majority of time the chest tube is in place. Adding suction to the chest drainage system is thought to enhance lung expansion by more quickly removing fluid and/or air and thus decreases the length of time a patient has a chest tube in place.(4) The longer a chest tube is in place, the higher the risk of complications such as infection, empyema, recurrence of pneumothorax, and bleeding.(3)

Tang et al. (4) conducted a narrative review to identify key components of chest tube management and variations in practice. In this review, the authors identified indications for placement of chest tubes, management of the system, and determining when chest tubes should be removed. Chest tube insertion occurred with persistent pneumothorax following needle aspiration, trauma-induced lung collapse, bilateral lung collapse, and lung collapse in the mechanically ventilated patient. Additionally, chest

tubes were placed in patients developing empyema or haemothorax. The British Thoracic Society guidelines for management of pneumothorax recommend needle aspiration to re-inflate the lung as the initial treatment of choice.(5) If a chest tube is placed, gravity water seal drainage is used, and suction is only added if the lung does not re-expand as quickly as expected. These guidelines were developed based on consensus expert opinion. A few randomized controlled trials have been conducted addressing the use of primarily water seal versus added suction related to time until no air leak is noted and full lung expansion has been restored. Conclusions of these studies have varied.(6-8) Some researchers claim water seal to be optimal in chest tube management for a pneumothorax, while others promote the use of added suction.(6-8)

Medically, inserting a plastic tube called a chest tube into the pleural space treats lung collapse. The tube allows air and/or fluid collection to drain out of the body resulting in re-expansion of the patient's lung. Once it is determined the patient's lung is re-expanded, the chest tube is removed. If the pneumothorax is considered small, the physician will often use needle aspiration to attempt to re-inflate the lung. Sometimes the chest tube is connected to a gravity-only water seal drainage system, whereas other times suction is added to the drainage system to supposedly facilitate and expedite drainage of the pleural space contents. Often there is little scientific basis regarding which treatment modalities are selected and methods used are based on provider preference and training.(4)

It is important to identify which method is best in minimizing the length of time a patient has a chest tube in place as this reduces healthcare costs, length of stay, time intensity for the nurse and risk of complications.(4,7) Several randomized controlled

trials have been conducted comparing the use of gravity water seal to added suction in the treatment of air leak/pneumothorax. Findings have not consistently demonstrated that one technique is better than the other.(6-9)

A preliminary search in Cochrane Database of Systematic Reviews, Joanna Briggs Institute Library of Systematic Reviews, Medline, and CINAHL was performed in order to identify existing reviews on the proposed topic. Two systematic reviews have been conducted to date. In 2006, Sanni, Critchley and Dunning (10) developed a similar review question but only searched the Medline database. Deng et al. (11) conducted a meta-analysis of randomized controlled trials (RCTs) in 2010. We believe our review question suggests potential answers in more than the RCT designed literature alone. Also, both reviews limited their search to primarily suction or water seal following pulmonary surgeries. Our review question considered any adult receiving a pleural chest tube to resolve an air leak or pneumothorax, which included those patients needing a chest tube related to trauma or a spontaneous pneumothorax.

OBJECTIVES

The objective of this review was to identify and synthesize the best available evidence on effectiveness of suction versus water seal for optimal management of pleural chest tubes in adult patients.

The review questions were:

- Among adult patients with pleural chest tubes, does primarily suction added or water seal reduce time to resolution of air leak/pneumothorax?
- Does use of primarily suction added or water seal reduce chest tube dwell time?

• Does one method versus the other result in complications such as a prolonged air leak seven days or greater or a recurrence of a pneumothorax?

• Does use of primarily added suction or water seal result in reduced length of hospital stay?

INCLUSION CRITERIA

Types of participants

This review considered studies that included patients 18 years and older with a need to restore negative intrathoracic pressure in the pleural space thus requiring a conventional pleural chest tube insertion. Subjects were those having had lung surgeries such as a lobectomy or resection. Also, we hoped to capture studies of trauma patients who developed a pneumothorax and likely needed a pleural chest tube. Other patients needing a chest tube were anticipated to include individuals who had developed a spontaneous pneumothorax. Patients less than 18 years of age may not require a conventional pleural chest tube insertion and are typically treated with smaller tubes or needle aspiration. Therefore, studies that focused on patients less than 18 years were excluded from this review.

Types of intervention(s)/phenomena of interest

Included studies examined the management of the chest tube and specifically the use of added suction applied to the pleural chest tube versus primarily water seal. Any chest tube that was treated with approximately equal amounts of suction and water seal was excluded, as were studies that only focused on suction or water seal as a chest tube removal protocol. Any studies that used alternative interventions for a pneumothorax

independently or in association with conventional chest tubes such as small bore chest tubes, Heimlich valve, pleuradesis, or needle aspiration were outside the scope of this review and therefore excluded.

Types of studies

The review considered any experimental study design including randomized controlled trials (RCTs) quasi-experimental, and before and after studies. Analytical epidemiological study designs including prospective and retrospective cohort studies, case control studies and analytical cross sectional studies were evaluated.

Types of outcomes

Studies considered the following outcomes measured: Chest tube dwell time, time to resolution of any air leak/pneumothorax, length of hospital stay, and complications such as prolonged air leak or recurrence of a pneumothorax.

SEARCH STRATEGY

The search strategy aimed to find both published and unpublished studies in the English language. Studies included were published in the time frame of 1958 to February 2012. The year 1958 was the earliest year used because active suction technology for the pleural space was first documented in the literature at this time. A three-step search strategy was utilised in this review. An initial limited search of MEDLINE and CINAHL was undertaken followed by analysis of the text words contained in the titles and abstracts, and of the index terms used to describe the articles. A second search using all identified keywords and index terms was then undertaken across all included databases. Thirdly, the reference list of all identified reports and articles was searched for additional

studies. Also, as described earlier, this search was limited to persons 18 years and older.

The databases searched included:

Academic Search Complete

CINAHL

Cochrane

EBSCO Medline

Embase

Ovid Healthstar

Proquest

Pubmed

Science Direct

Scopus Database

The search for unpublished studies included:

New York Academy of Medicine Grey Literature Report

MEDNAR

ProQuest database for theses and dissertations.

OpenSIGLE

Virginia Henderson Library

Initial keywords used were:

Chest tube or thoracotomy tube or thoracostomy tube or thorax drain

Pneumothorax

Suction or water seal or no suction

Air leak

METHOD OF THE REVIEW

Quantitative papers selected for retrieval were assessed by three independent reviewers for methodological validity prior to inclusion in the review using standardised critical appraisal instruments from the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI). Any disagreements that arose between the reviewers was resolved through consensus.

DATA COLLECTION

Quantitative data was extracted from papers included in the review by three independent reviewers using the standardised data extraction tools from JBI-MAStARI. The data extracted included specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives.

DATA SYNTHESIS

Quantitative papers were, where possible, pooled in statistical meta-analysis using the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI). All results were subject to double data entry. Odds ratio (for categorical data) and weighted mean differences (for continuous data) and their 95% confidence intervals were calculated for analysis. Heterogeneity was assessed using the

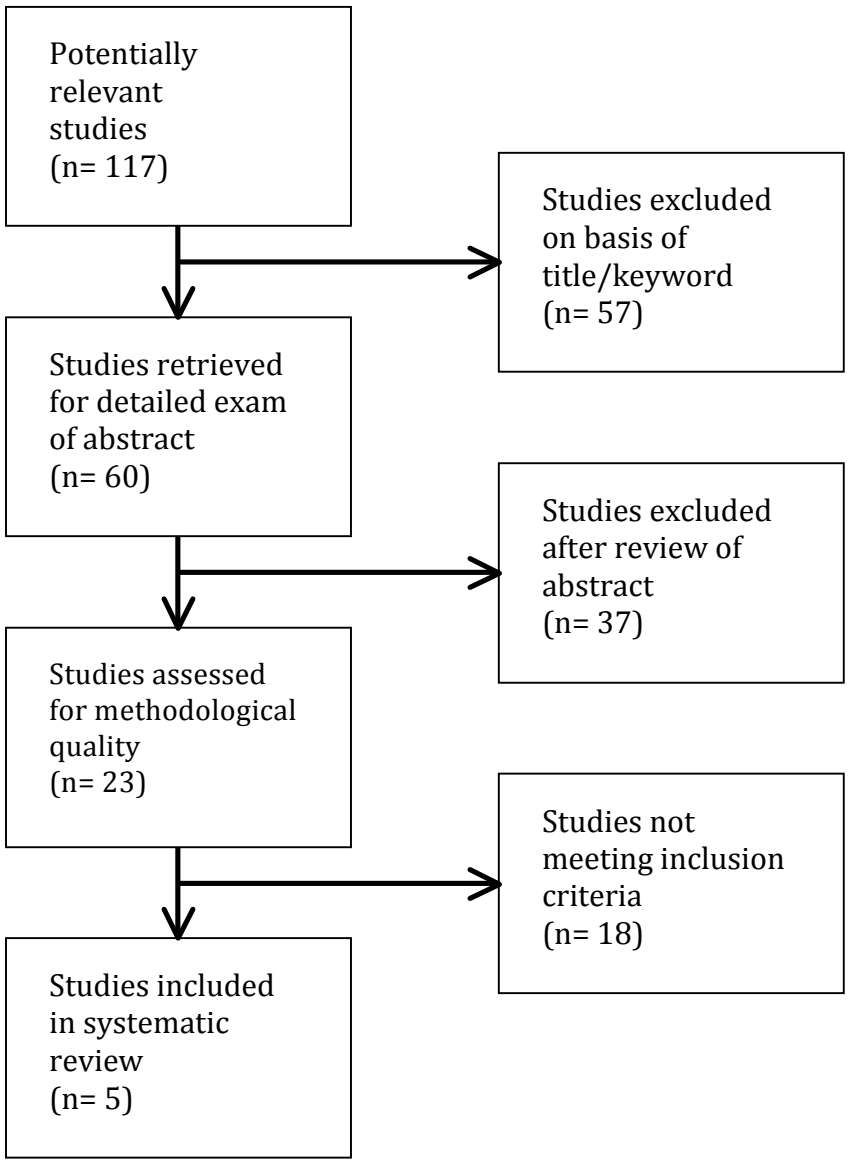
standard Chi-square. Where statistical pooling was not possible, the findings are presented in narrative form.

RESULTS

Description of studies

The advanced search strategy led to a total of 117 potentially relevant studies. After the authors reviewed these studies by title and key words, 57 were excluded. Abstracts of the remaining 60 studies were then reviewed, with 37 being excluded. The remaining 23 studies were subjected to complete review and analysis of methodological quality. Eighteen articles did not meet the inclusion criteria for this systematic review; therefore, 5 studies were identified to be included in this systematic review. See Figure 1 for the process described above. Details of included studies are presented in Appendix V. List of excluded studies and reasons for exclusion are presented in Appendix VI.

Figure 1. Flowchart of study selection



A total of five studies were included in this review. Four were randomized control trials (RCT) and one was a retrospective study. The date range for the included studies was 2002-2008.

The population for all included studies was patients undergoing a variety of lung surgeries resulting in the placement of a conventional pleural chest tube to restore negative intrathoracic pressure in the pleural space. One study was conducted in London; one was a study in Greece, one in Italy and the remaining two studies were conducted in the United States. Total number of participants was 652.

The participants of the studies identified were adult patients over age 18 that were undergoing pulmonary surgical procedures such as wedge resection, segmentectomy, or lobectomy. All patients required chest tube placement following surgery to restore negative intrathoracic pressure and reinflate the lung. In comparing demographic characteristics between studies, there were similarities in age, gender, and pre-operative diagnoses. All randomized controlled studies compared various outcomes between a control and treatment group. In all studies, one group included patients with chest tube placement to water seal alone and the other group consisted of patients with chest tube placement and added suction. No studies had subjects with a pneumothorax from trauma or spontaneous pneumothorax.

In the Alphonso et al. study (6), researchers examined patients undergoing thoracotomy or video assisted thoracoscopic surgery for lobectomy or wedge resection culminating with a chest tube insertion. The goal of this study was to test the null hypothesis that applying suction versus using water seal alone to manage a pleural chest tube caused no difference in duration of air leak. There were 328 eligible patients but in

71 cases, consent was not obtained or the research team could not be reached to allocate the patients after surgery. Three patients were mistakenly not entered into the trial after consent was obtained, and data was not collected for a further 15 patients resulting in a total of 239 cases for analysis. There was computer-generated, unbiased allocation by minimization with 116 participants assigned to the added suction group and 123 to water seal alone. Demographic characteristics between the study arms were equivalent.

The Antanavicius researchers (12) conducted a retrospective study examining 109 patients that underwent a lobectomy or segmentectomy with subsequent placement of a pleural chest tube to suction or water seal alone. The goal of this study was to determine if chest tube management with water seal alone decreased time until chest tube removal and decreased length of hospital stay compared to suction added. There were 39 cases in the water seal group and 70 in the suction group. Patients with an air leak lasting more than 10 days were discharged with a Heimlich valve and were thus excluded.

In the Brunelli et al. RCT (13), researchers studied 145 patients undergoing a pulmonary lobectomy with insertion of a pleural chest tube to be placed to suction added or water seal alone. The goal of this study was to assess whether chest tubes placed on water seal alone resulted in a shorter duration of a postoperative air leak compared to suction. Patients were randomized to two groups, one group of 72 patients with chest tubes placed to water seal alone and the other group with 73 patients to added suction. All patients had -20 cm H_20 suction applied until the first postoperative day morning. If an air leak was present, patients were randomized to one of the two groups; if no air leak was present, patients were treated with water seal only and excluded from the study. Demographic characteristics, preoperative and operative characteristics were all similar

between groups. Six patients were excluded from the study: three patients died and three required mechanical ventilation for more than 24 hours postoperatively.

In the Marshall et al. study (9), researchers examined 68 patients undergoing pulmonary resection (wedge resection, segmentectomy or lobectomy) with pleural chest tube placement. The aim of this study was to evaluate whether added suction or water seal is superior in the management of chest tubes postoperatively. The study had two arms: one with suction applied to the chest tube and one using water seal alone in chest tube management. Randomization of patients occurred in the recovery room. Groups were evenly matched for demographic characteristics, operation performed, severity of lung disease and nutritional status.

In the Prokakis et al. study (14), researchers examined 100 patients undergoing lobectomy or bilobectomy for lung cancer. This study was designed to determine if application of suction to the chest tube postoperatively is necessary. At the end of surgery, patients were randomized in to the two groups of the study, suction added or water seal alone, using relevant data tables. Nine patients were later excluded due to benign or metastatic lung pathology leaving 91 patients for final data analysis. Group I included 47 patients receiving suction and Group II had 44 patients on water seal alone.

METHODOLOGICAL QUALITY

Four included studies were randomized control trials; the fifth study was retrospective in nature. Three independent reviewers assessed the five studies as high-level evidence using JBI-MASTaRI appraisal criteria. There was general agreement among the reviewers to include these 5 studies in the final analysis. All five studies demonstrated similarity between the two groups with respect to patient demographic

characteristics. Additionally, all five studies looked at some combination of the following variables for both groups: chest tube dwell time, duration of air leak, hospital length of stay, incidence of recurrent pneumothorax, and other complications. Sample sizes of the study ranged from 68 to 239 participants. This review considered the comparison of water seal alone with suction applied in postoperative pleural chest tube management.

Three studies were excluded after thorough review and analysis of methodological quality. The Okamoto et al. (15) study utilised different methodologies for cases before and after 2001 with an unclear explanation of the change. The Sharma et al. study was deemed to be missing details related to methodology. In addition, the outcomes of the study were not appropriately analyzed nor met our criteria for quality of literature. Details of the methodology of the So and Yu study were unclear and outcomes were stated but not explained or discussed, leading to its exclusion from our meta-analysis.

MASTARI

Number of studies included and excluded

Number of studies included	Number of studies excluded
5	3

Randomised Control Trial / Pseudo-randomised Trial

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Alphonso, Tan, Utley, Cameron, Dussek, Lang-Lazdunski,	Y	Y	Y	Y	Y	Y	Y	Y	U	Y

Treasure, 2005										
Brunelli, Monteverde, Borri, Salati, Marasco, Refai, Fianchini, 2004	U	N	N	N	N	Y	Y	Y	U	Y
Marshall, Deeb, Bleier, Kucharczuk, Friedberg, Kaiser, Shrager, 2002	U	N	N	N/A	N	Y	N	Y	Y	Y
Prokakis, Koletsis, Apostolakis, Panagopoulos, Kouki, Sakellaropoulos, 2008	Y	N	N	N	N	Y	Y	Y	U	Y
%	50.0	25.0	25.0	33.3	25.0	100.0	75.0	100.0	25.0	100.0

Comparable Cohort / Case Control Studies

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Antanavicius, Lamb, Papasavas, Caushaj, 2005	Y	Y	Y	N	N	Y	N/A	U	Y
%	100.0	100.0	100.0	0.00	0.00	100.0	N/A	0.00	100.0

Y = yes; N = no; U = unclear, N/A = not applicable

RESULTS

Alphonso et al.

In the Alphonso et al. RCT (6), researchers examined 239 patients undergoing thoracotomy or video assisted thoracoscopic surgery for lobectomy or wedge resection culminating with a chest tube insertion. The incidence of persistent air leak lasting greater than seven days was 9 of 116 patients in the added suction group and 13 of 123 patients in the water seal only group. Alphonso et al. also measured the complication of recurrent pneumothorax. Two patients on suction and three patients on water seal alone had a recurrent pneumothorax. Results showed no significant difference in duration of air leak between the two groups and any advantages of suction or water seal only were deemed negligible.

Antanavicius et al.

In the Antanavicius et al. retrospective study (12), researchers examined 109 patient charts who underwent a lobectomy or segmentectomy with subsequent placement of a pleural chest tube to suction or water seal alone. Chest tube dwell time in the suction group was 5.44 ± 0.53 days and for water seal alone was 4.09 ± 0.37 days. Length of hospital stay was 7.85 ± 0.68 days in the suction group and 5.85 ± 0.65 days in the water seal only group. The study also recorded incidence of death as a complication. One of 70 patients in the suction group died and 0 of 39 patients in the water seal alone group died. Results showed both chest tube dwell time ($p=0.001$) and length of hospital stay ($p < 0.05$) were significantly lower in the water seal alone group.

Brunelli et al.

In the Brunelli et al. RCT (13), researchers studied 145 patients undergoing a pulmonary lobectomy with insertion of a pleural chest tube to be placed to suction or water seal alone. Chest tube dwell time in the suction group was 10.3 ± 7.6 days. Chest tube dwell time in the water seal alone group was 11.5 ± 8.3 days. Length of hospital stay was 11.6 ± 8.5 days in the suction group and 11.5 ± 5.5 days in the water seal only group. The duration of air leak in the suction group was 6.3 ± 7.2 days while air leak duration in the water seal group was 6.5 ± 7.5 days. Incidence of prolonged air leak greater than 7 days was also measured. Prolonged air leak was noted in 22 patients in the suction group and 20 patients in the water seal alone group. Results showed that using water seal alone did not reduce the incidence or duration of air leak, incidence of a prolonged air leak, or the length of hospital stay compared to suction.

Marshall et al.

In the Marshall et al. RCT (9), researchers examined 68 patients undergoing pulmonary resection with pleural chest tube placement to evaluate whether suction or water seal is superior in the management of chest tubes postoperatively. Air leak duration in the suction group lasted 3.27 ± 0.80 days and in the water seal alone group lasted 1.50 ± 0.32 days. In the suction group, chest tube dwell time was 5.47 ± 0.98 days. With water seal alone, chest tube dwell time was 3.33 ± 0.35 days. Length of hospital stay with the suction group was 11.13 ± 4.58 days and with the water seal alone group was 4.67 ± 0.37 days. Prolonged air leak was noted in one patient in the suction group and zero patients with water seal only. The complication of a pneumothorax greater than 25% in the recovery room was also measured. In the suction group, incidence was 0 out of 34; in

the water seal alone group, incidence was 4 out of 34 patients. Results showed that placement on water seal alone after a brief period of suction resulted in a shorter duration of air leak, chest tube dwell time, and length of hospital stay. Duration of air leak ($p = 0.05$) and chest tube dwell time ($p = 0.06$) were statistically significant. Results for length of hospital stay were not statistically significant ($p = 0.18$).

Prokakis et al.

In the Prokakis et al. RCT (14), researchers examined 100 patients undergoing lobectomy or bilobectomy for lung cancer. Chest tube dwell time in the suction group was 3.60 ± 2.90 days and in the water seal alone group was 3.40 ± 3.10 days. Length of hospital stay for the suction group was 11.20 ± 5.40 days and for the water seal group was 10.30 ± 4.50 days. Incidence of prolonged air leak was noted in 7 patients in the suction group and 5 patients in the water seal alone group. The complication of a persistent pneumothorax lasting greater than three days was measured. Six patients in the suction group and 10 patients in the water seal alone group showed persistent pneumothorax. Results showed no statistical difference ($p > 0.05$) between the suction and water seal alone groups related to chest tube dwell time, length of hospital stay, or complications. Researchers deemed routine application of suction not necessary.

META-ANALYSIS

Quantitative papers were pooled for statistical meta-analysis using the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI). Meta-analyses were performed using the JBI-MAStARI software package to calculate the Peto and DerSimonian and Laird weighted mean difference for chest tube dwell time, length of stay, duration of air leak, prolonged air leak greater than seven days,

and other complications for the two groups. Three randomized control trials and one retrospective study were included in the meta-analysis for the purpose of determining chest tube dwell time and length of stay for individuals receiving suction versus water seal alone to their chest tube. Two randomized control trials were included in the meta-analysis for the purpose of determining duration of an air leak again for individuals who received suction versus water seal alone to their chest tube. A random effects model was chosen for the analysis because of the variability in chest tube management between studies. A random effects analysis makes the assumption that individual studies are estimating different treatment effects.(16) In this review, it is assumed that chest tube care is influenced, but not completely predicted by the use of suction. The random effects model assumes that the true treatment effects in the individual studies may be different from each other. This infers there to be no single number to estimate in the meta-analysis, but a distribution of numbers.(17) The Peto statistical formula for dichotomous variables analyzed the variables of prolonged air leak greater than seven days and complications. Four randomized control trials were considered for prolonged air leak greater than seven days and three randomized control trials and one retrospective study reported complications associated with either suction to a chest tube or water seal alone.

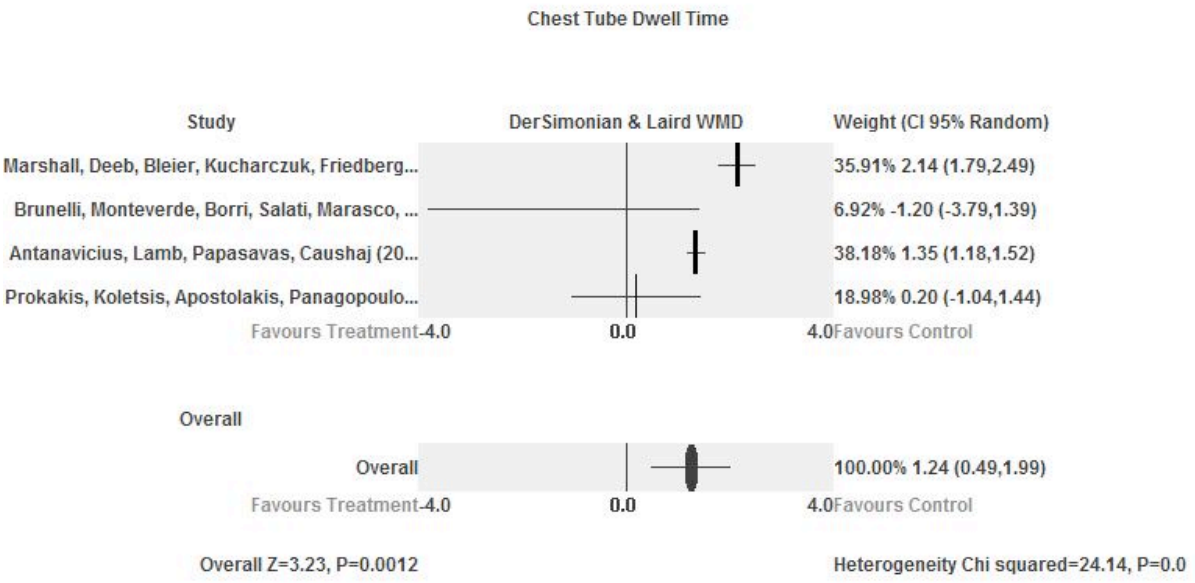
Heterogeneity was calculated utilizing the JBI-MAStARI software package using Chi-square, which shows statistically significant heterogeneity for chest tube dwell time (24.14, $p < 0.0012$) and length of stay (35.33, $p < 0.044$). In a fundamental approach to meta-analyses, it would not be appropriate to combine results of these diverse studies. However, in a JBI systematic review, the goal is to generate clinically useful information

by combining results of individual studies into an aggregate of knowledge designed to answer questions broader than the individual studies alone.

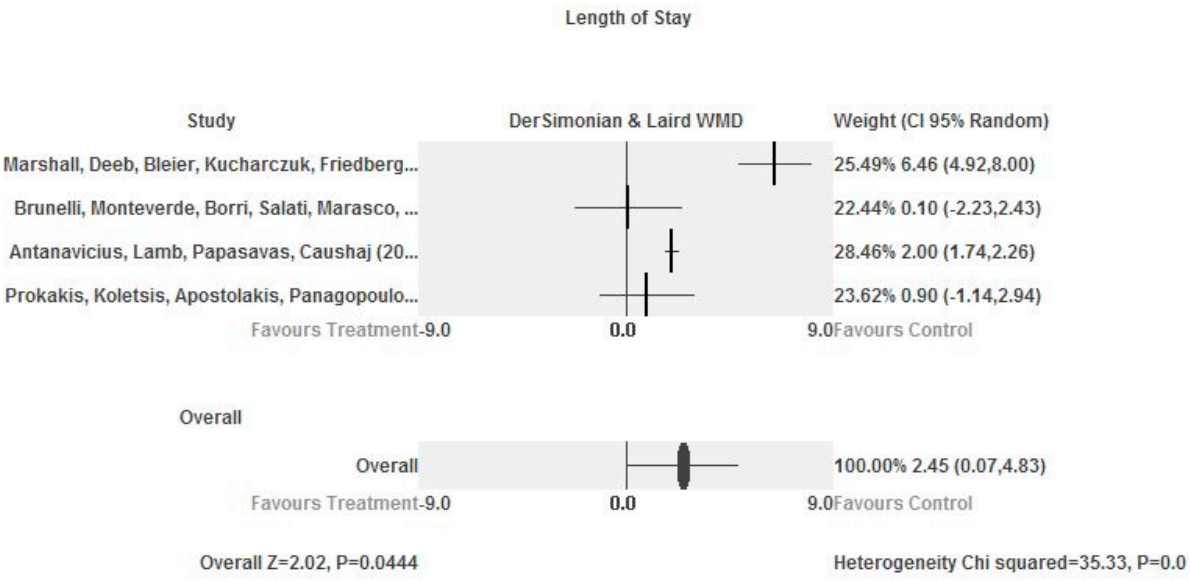
Although statistical heterogeneity between studies is shown, it was decided to perform a meta-analysis on the data for several reasons. First, the nature of the studies all looked at the same variables: suction versus water seal alone. Additionally, the studies included were of exceedingly high quality and although the protocols varied between studies, the administration of primarily suction versus water seal was the same among all studies. Furthermore, some degree of heterogeneity is expected in a treatment systematic review because the very nature of the review incorporates multiple studies of varying clinical settings. Finally, utilizing the random effects model for statistical interpretation of continuous variables allows for assumption that the true treatment effects between studies may be different from each other.(16) Lastly, a meta-analysis was performed not to determine if management of chest tubes with water seal alone was superior, but rather if the addition of suction improved patient outcomes. A meta-analysis using the random effect model was performed to calculate the Peto and DerSimonian and Laird weighted mean difference at the 95% confidence interval in individuals with suction applied to their chest tube versus water seal alone.

RESULTS OF META-ANALYSIS OF QUANTITATIVE RESEARCH

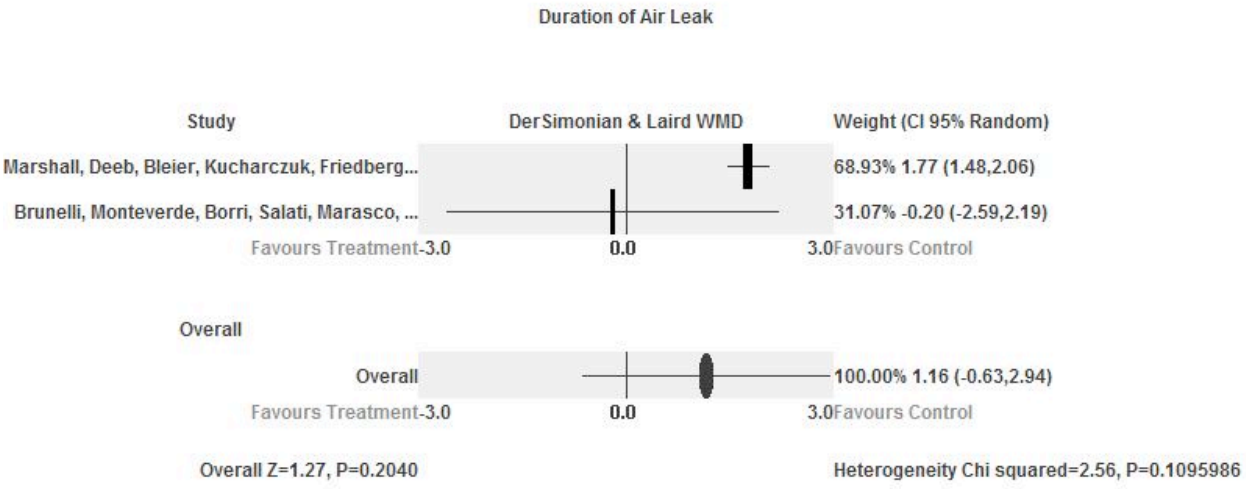
Summary of Results of Meta-Analysis



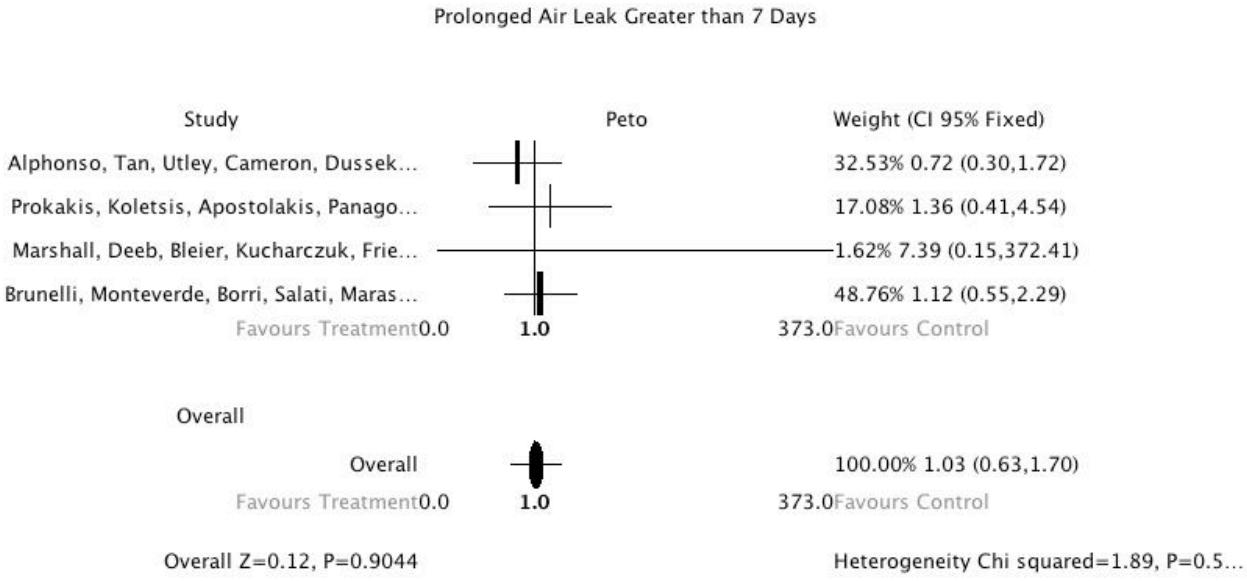
It was determined that a statistically significant (p=0.0012) 1.24 day reduction in chest tube dwell time for those individuals with water seal alone applied to their chest tube was realized. Only one study - Brunelli - seemed to have much variability and therefore not much weight in the analysis. The other three studies seemed to carry a reasonably distributed weight toward the outcome. This information suggests that individuals with water seal alone have their chest tubes removed a full 1.24 days sooner than those with suction applied.



The analysis estimated that a statistically significant (p=0.04) 2.45 day reduction in length of stay exists for those individuals with water seal alone applied to their chest tube. Remarkable to note is that all four studies carried similar distributed weights to the mean difference. This analysis suggests that patients are discharged nearly two and a half days sooner if the chest tube is to water seal as opposed to suction.

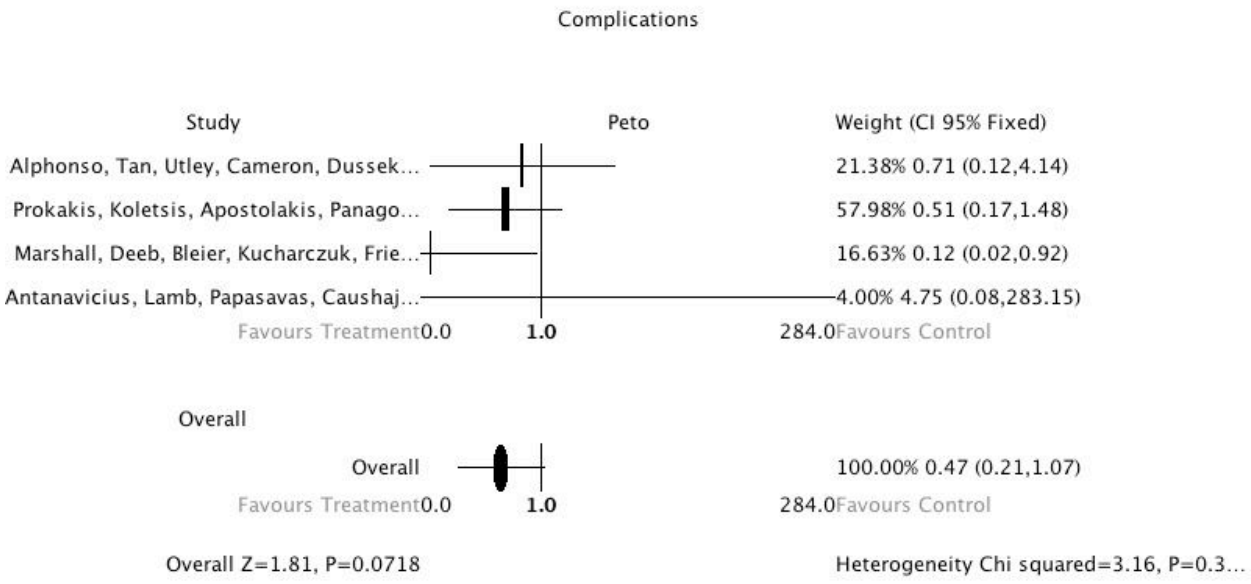


It was estimated that there is a statistically non-significant (p=0.20) 1.16 day reduction in the duration of an air leak if water seal alone is utilized to manage a chest tube. The results are interpreted at the 95% confident interval as a statistically non-significant 1.16 days reduction in duration of an air leak. From a clinical point of view, the results are interpreted as a potentially important, perplexing parameter. It is unlikely to discontinue a chest tube or discharge a patient if an air leak is still present; yet, as noted earlier, patients with water seal alone applied to their chest tube would have shorter chest tube dwell times and lengths of stay.



A statistically non-significant (p=0.90) incidence was estimated for a prolonged air leak greater than seven days. There seems to be little difference for either the suction or water seal alone group when it comes to developing a prolonged air leak greater than seven

days. From a clinical point of view, the results are interpreted as reasonable for both groups of patients to experience similar incidences of this complication.



It was estimated that a statistically non-significant (p=0.0718) incidence of complications other than prolonged air leak greater than seven days was noted. For the purpose of this review, complications refer to incidence of recurrent pneumothorax, incidence of death, occurrence of pneumothorax greater than 25% in the recovery room, and a persistent pneumothorax greater than 3 days. These separate variables from our five included studies were combined in the meta-analysis for the outcome of complications. From a statistical point of view, the p value is approaching significance and therefore will be treated as notable. From a clinical point of view, suction applied to chest tubes does seem to represent more complications as noted by three randomized control trials and one retrospective study within this meta-analysis.

DISCUSSION

Currently, the decision to use water seal alone or apply suction to a pleural chest tube postoperatively is often based on the provider's training and preference. This systematic review compiled and analyzed data on duration of air leak, chest tube dwell time, length of hospital stay, incidence of prolonged air leak and other complications to determine whether suction added or water seal alone provided optimal management of the chest tube and best patient outcomes.

All studies in this systematic review included a control group of chest tubes placed to water seal alone and a treatment group using primarily suction applied to the pleural chest tube. Sample sizes ranged from 68 to 239 patients. Four studies were randomized control trials and one was a retrospective study. Similarities between studies include populations comprised of postoperative lung surgery patients with the placement of a pleural chest tube. No studies included patients with a spontaneous pneumothorax or a pneumothorax caused by trauma. We would have liked to include spontaneous and traumatic pneumothoraces in this systematic review; however, no relevant studies could be found that included these two patient populations.

Variability in the procedures and time of randomization in the included studies created heterogeneity in our data. In some studies, suction was applied to all chest tubes during an initial postoperative period (whether hours or until the morning of postoperative day (POD) 1) and then was either continued on suction or converted to water seal alone based on allocation. Brunelli et al. (13) placed all chest tubes to -20 cm H_20 suction until the morning of POD 1. At that point, allocation to the two arms was done for patients with an air leak. Similarly, all patients in the Marshall (9) study were

also managed with -20 cm H_20 suction until arrival in the recovery unit where they were randomized to remain on suction or water seal alone. This brief period of suction may contaminate the results as the effects cannot be identified or determined, especially in regards to postoperative air leaks and incidence of postoperative pneumothoraces. Alphonso, Antanavicius and Prokakis all studied data from strict suction added versus water seal alone groups.(6,12,14) Randomization in these three studies occurred immediately following the surgical procedure.

Okamoto et al. (15) performed a retrospective study examining the influence of suction or water seal alone on the duration of air leaks. This study was not included in our meta-analysis because all chest tubes before 2001 were placed to suction; after 2001, either suction or water seal was used based on surgeon discretion. The two groups were not compared concurrently. Results of this study showed the duration of air leak to be similar in the two groups; therefore, the researchers concluded that water seal was safe and effective for management of chest tubes without the unnecessary additional application of suction. This conclusion supports the results of our meta-analysis.

Sharma et al. (18) conducted an experimental study of 40 patients with spontaneous pneumothorax. The study design was not explicitly expressed. Every other patient was subjected to added suction for chest tube management. Study results did not favor use of suction or water seal alone. Vague methodology, no statistical analysis, and poor study description resulted in exclusion of this study.

So et al. (19) conducted a randomized control study of 23 patients with spontaneous pneumothorax and 30 patients with secondary pneumothorax. Each group was randomized into added suction versus water seal alone. Findings of the study did not

favor use of suction or water seal alone. Use of a pediatric unconventional chest tube, variation in the amount of suction applied, and comparison of two demographically diverse patient populations resulted in exclusion of this study.

In this systematic review, data for the duration of air leak was not statistically significant ($p = 0.20$). Only two of the included studies recorded duration of air leak (in days) and the weighting of the studies in meta-analysis was unequal. However, the credible Marshall study strongly favors water seal alone. Our meta-analysis results show that an air leak resolves an average of 1.16 days faster when water seal alone is used. We found this data clinically significant as a decreased duration of air leak leads to a decrease chest tube dwell time and shorter length of stay.

The meta-analysis results for chest tube dwell time were statistically significant ($p = 0.001$) favoring water seal alone by 1.24 days. Though the weighting of the four included studies was not equal, results showed statistical significance. The use of water seal alone expedites the removal of the chest tubes by more than one day, which facilitates earlier patient mobilization and hospital discharge. Early ambulation contributes to improving the hazards of immobility. We also found results for length of hospital stay to be statistically significant ($p = 0.04$). Water seal alone was favored by 2.45 days over suction. The four studies were equally weighted during meta-analysis as a result of the variable being well represented throughout the four studies.

Meta-analysis of the incidence of prolonged air leak greater than 7 days as a complication suggests neither suction nor water seal alone is notably favored. The weight of the four studies was highly variable and results were not statistically significant ($p = 0.90$). The use or non-use of suction does not make a significant difference in the

occurrence of prolonged air leaks greater than 7 days postoperatively.

Complications in the five studies were combined into one variable. Alphonso et al. (6) measured incidence of recurrent pneumothorax and Antanivicius et al. (12) recorded incidence of death. From Marshall et al. (9), we included occurrence of pneumothorax greater than 25% in the recovery room and from Prokakis et al. (14), a persistent pneumothorax greater than 3 days. These separate variables were combined in the meta-analysis for the outcome of complications. Results were approaching significance ($p = 0.07$) with more complications occurring in the suction added treatment group versus the water seal alone group. This finding supports the conclusions of all studies that water seal alone is a safe and effective management option for chest tubes.

Alphonso, Antanavicius and Prokakis implemented a policy of using water seal alone to allow the patient earlier mobilization, provide for potential cost savings and to reduce nursing tasks in postoperative chest tube management. Suction would only be applied when specific clinical judgment deemed it necessary.(6,12,14) Similarly, Marshall and Okamoto recommend the use of water seal alone. (9,15) Following the results of Brunelli's RCT, the hospital implemented a policy combining suction and water seal. Patients would be placed to a moderate -10 cm H_20 suction overnight but use water seal alone during the day to allow for earlier and free mobilization.(13) Furthermore, Baumann (20) explains that pleural air and fluid will typically drain from the chest without the need for suction and that suction need only be applied if the drainage is not clearing adequately to gravity. All of these resulting policies parallel the results of our meta-analysis supporting the management of chest tubes with water seal alone.

In theory, suction should improve sealing of an air leak and decrease the chest tube dwell time by improving the apposition of the pleura and facilitating the drainage/clearance of air and fluid to eliminate the residual space, thus promoting the expansion of the lung. Cerfolio (21) observed that suction in fact may make an air leak larger while water seal helps the apposition of the pleura to enhance healing. Like Marshall et al. (9), we believe suction may actually slow the sealing of the air leak. The duration of the air leak remains the central variable in chest tube management and is a common cause for prolonged hospitalization and increased costs. A chest tube will typically not be removed until the air leak has sealed. Hastening the removal of the chest tube has the added benefits of lowering the risk of infection, enhancing patient mobility and decreasing the number of cumbersome nursing responsibilities for that patient. Furthermore, with an earlier discharge, both the patient and the hospital will incur fewer costs.

A published article by Baumann (20) on the management of chest tubes raises other concerns about the additional application of suction to a pleural chest tube. Baumann points out that pleural drainage units (PDU's) that control suction often vary considerably in their accuracy of the negative pressure delivered. With too much negative pressure, damage could be done to lung tissue, potentially causing complications such as pleural edema or tension pneumothorax; with too little negative pressure, there may be inadequate fluid and air removal from the pleural space. In 2001, Cerfolio (21) similarly discussed the issue of an inconsistent amount of suction being applied. The water creating the negative pressure had to be replaced by nurses to compensate for bubbling and evaporation and was not guaranteed to provide specific amounts of suction.(21)

Only the included Brunelli (13) study addresses these concerns raised by Baumann related to accuracy of applied suction. Two different types of drainage apparatuses were used in the Brunelli RCT – one of which did not have a leak meter that allowed researchers to supposedly quantify the air leaks better. They did, however, test the water used in the suction group with a water manometer to ensure -20 cm H_20 negative pressure was being used.

Included studies did not quantify the size of air leaks. This potentially has an impact on results. Cerfolio (22) mentions the need to classify large versus small air leaks to determine whether suction or water seal should be used for a specified case. Additionally, Antanavicius et al. (12) believe "larger air leaks require suction and are associated with increased chest tube duration and longer length of stay". Surgeon preference or clinical practice may vary between suction and water seal depending on the size of the air leak. Further research would need to be done to investigate the efficacy of water seal alone versus suction in air leaks of varying size.

Pleural tenting, a technique used during surgery to minimize the risk of postoperative air leaks, could have an influence on results. In the Brunelli study (13), approximately 80% of patients undergoing upper lobectomy had pleural tenting. This percentage as well as the differences in surgical procedures could potentially contaminate results and needs to be considered in analysis. No other studies included in our review address this technique as part of the surgical procedure.

Patients under 18 years of age or pediatric patients were not included in our meta-analysis because those cases may use smaller chest tube sizes or pigtails. Only Brunelli and Prokakis addressed the size of chest tubes used in their studies: Brunelli using 28F

and Prokakis with 32F chest tubes.(13,14) Smaller sized or non-conventional chest tubes may respond better to different management techniques and further investigation should be done with these cases.

Our results show that the use of water seal alone reduces duration of air leak, duration of chest tube placement and hospital stay. These findings carry clinical significance in the postoperative care of a pleural chest tube. The use of suction is an unnecessary intervention, as it does not significantly reduce the duration of air leak. In addition, water seal alone appears to be more cost-effective than applying suction. A shorter duration of air leak and chest tube dwell time also shortens length of hospital stay – all of which we expect would lower expenditures. An economic study should be done in the future to investigate the implications of these findings.

Limitations of the Review

This review was limited to adult patients (over 18 years of age) with a pleural chest tube placed either to primarily suction or on water seal alone to restore negative intrathoracic pressure. The results cannot be applied to patients less than 18 years of age as they may not require a conventional pleural chest tube but are typically treated with smaller tubes or needle aspiration.

Studies that were not in the English language were excluded. None of the reviewers had expertise in another language nor were translation services available. Studies involving chest tubes placed in cases of haemothorax or empyema were also excluded from the meta-analysis.

Two of the included studies, Brunelli (9) and Marshall (9,13) , randomized patients after an initial period of suction on all patients postoperatively. In these studies, the initial

period of suction may distort the data and results. However, there was limited research available on studies involving exclusive water seal versus suction added.

None of the studies quantified the size of air leaks, which could impact chest tube management. Further exploration should be done of suction versus water seal in air leaks of varying sizes.

CONCLUSION

Implications for practice

Based on the results of this review, the use of suction in pleural chest tube management is unnecessary. Management by water seal alone could result in decreases in duration of air leaks, chest tube dwell time, and length of hospital stay. Although the results in regards to reduction in duration of air leak do not show statistical significance with the use of water seal alone, clinical significance is noteworthy. A difference of 1.16 days in the duration of an air leak can have a ripple effect culminating in a shorter hospital visit and in turn, decreased patient and hospital costs. Both variables of chest tube dwell time and length of stay were statistically significant favoring the water seal only group. These findings further support the clinical significance of using water seal alone for quicker air leak resolution.

Marshall et al. (9) commented that the use of suction in a patient with an air leak might in fact slow the sealing of that leak. Our results support Marshall's hypothesis as we found the duration of air leak is shorter with water seal alone by 1.16 days. Furthermore, meta-analysis results showed complications occurred more in the treatment group using suction. The use of water seal alone also allows for earlier mobilization and ambulation, which could contribute to the decreased incidence of complications.

Implications for research

Further research is indicated to investigate the use of strict water seal alone versus suction added postoperatively. Few studies exist that do not use an initial period of suction in the investigation of optimal management for pleural chest tubes. Also, additional research with spontaneous and traumatic pneumothoraces cases needs to be done comparing suction to water seal alone. Future research on the use of suction versus water seal on quantified, large versus small air leaks could be done to further our results. A formal cost-benefit analysis to determine the actual financial advantage of utilizing water seal alone should be performed. This additional economic research regarding any potential cost savings from decreased length of hospital stay resulting from shorter chest tube dwell time should also be performed. The use of water seal alone shortened the duration of an air leak, expediting the removal of the chest tube as well as the time until discharge. This would possibly translate into a cost savings as well as decreased nursing labor.

CONFLICT OF INTEREST

No conflicts of interest exist.

REFERENCES

(1) Lazzara D. Eliminate the air of mystery from chest tubes. Nursing 2002;32(6):36.

(2) KAM AC, O'BRIEN M, KAM PCA. Pleural drainage systems. Anaesthesia 1993;48(2):154-161.

(3) Daly RC, Mucha P, Pairolero PC, Farnell MB. The risk of percutaneous chest tube thoracostomy for blunt thoracic trauma. Ann Emerg Med 1985 9;14(9):865-870.

(4) Tang ATM, Velissaris TJ, Weeden DF. An evidence-based approach to drainage of the pleural cavity: evaluation of best practice. J Eval Clin Pract 2002;8(3):333-340.

(5) Miller AC HJ. Guidelines for the management of spontaneous pneumothorax. BMJ 1993;7(10):114.

(6) Alphonso N, Tan C, Utley M, Cameron R, Dussek J, Lang-Lazdunski L, et al. A prospective randomized controlled trial of suction versus non-suction to the under-water seal drains following lung resection. European journal of cardio-thoracic surgery 2005;27(3):391-394.

(7) Cerfolio RJ, Bryant AS, Singh S, Bass CS, Bartolucci AA. The Management of Chest Tubes in Patients With a Pneumothorax and an Air Leak After Pulmonary Resection*. Chest 2005 August 01;128(2):816-820.

(8) Cerfolio RJ, Minnich DJ, Bryant AS. The removal of chest tubes despite an air leak or a pneumothorax. Ann Thorac Surg 2009 Jun;87(6):1690-4; discussion 1694-6.

(9) Marshall MB, Deeb ME, Bleier JIS, Kucharczuk JC, Friedberg JS, Kaiser LR, et al. Suction vs Water Seal After Pulmonary Resection*. Chest 2002;121(3):831-835.

(10) Sanni A, Critchley A, Dunning J. Should chest drains be put on suction or not following pulmonary lobectomy? Interactive CardioVascular and Thoracic Surgery 2006;5(3):275.

(11) Deng B, Tan Q, Zhao Y, Wang R, Jiang Y. Suction or non-suction to the underwater seal drains following pulmonary operation: meta-analysis of randomised controlled trials. European Journal of Cardio-Thoracic Surgery 2010 08;38(2):210-215.

(12) Antanavicius G, Lamb J, Papasavas P, Caushaj P. Initial chest tube management after pulmonary resection. Am Surg 2005;71(5):416-419.

(13) Brunelli A, Monteverde M, Borri A, Salati M, Marasco RD, Al Refai M, et al. Comparison of water seal and suction after pulmonary lobectomy: a prospective, randomized trial. Ann Thorac Surg 2004;77(6):1932.

(14) Prokakis C, Koletsis EN, Apostolakis E, Panagopoulos N, Kouki HS, Sakellaropoulos GC, et al. Routine suction of intercostal drains is not necessary after lobectomy: A prospective randomized trial. World J Surg 2008 /;32(11):2336-2342.

(15) Okamoto J, Okamoto T, Fukuyama Y, Ushijima C, Yamaguchi M, Ichinose Y. The use of a water seal to manage air leaks after a pulmonary lobectomy: a retrospective study. Annals of thoracic and cardiovascular surgery 2006;12(4):242.

(16) Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta- analysis. British Medical Journal 2003;327:557-560.

(17) Cochrane Collaboration. Cochrane Handbook of Systematic Reviews. 2011.

(18) Sharma T, Agnihotri S, Jain N, Madan A, Deopura G. Intercostal tube thoracostomy in pneumothorax. Indian J Chest Dis & All Sci 1988;30(1):32-33, 34, 35.

(19) So S, Yu D. Catheter drainage of spontaneous pneumothorax: suction or no suction, early or late removal? Thorax 1982;37:46-47, 48.

(20) Baumann MH. What size chest tube? What drainage system is ideal? And other chest tube management questions. Curr Opin Pulm Med 2003;9(4):276.

(21) Cerfolio RJ, Bass C, Katholi CR. Prospective randomized trial compares suction versus water seal for air leaks. Ann Thorac Surg 2001;71(5):1613-1617.

(22) Cerfolio RJ, Bryant AS. The Management of Chest Tubes After Pulmonary Resection. Thoracic Surgery Clinics 2010;20(3):399-405.

APPENDIX I: SEARCH STRATEGY

MAStARI

The search strategy aimed to identify published and unpublished studies of adult subjects, reported in English. An initial search was conducted in MEDLINE and CINAHL databases to identify keywords and subject headings. A second search was then conducted across all included databases using identified keywords and index terms. A third search was conducted of articles included in the references sections of articles pulled for detailed reading of the manuscripts. The time frame for relevant studies was from 1958 to February 2012. The year 1958 was selected because active suction technology for the pleural space was first documented in the literature at this time.

The databases searched included:

- Academic Search Complete
- CINAHL
- Cochrane
- EBSCO Medline
- Embase
- Ovid Healthstar
- Proquest
- Pubmed
- Science Direct
- Scopus Database
- New York Academy of Medicine Grey Literature Report
- MEDNAR
- OpenSIGLE
- Virginia Henderson Library

Initial keywords used were:

- Chest tube
- Thoracotomy tube
- Thoracostomy tube
- Thorax drain
- Pneumothorax
- Suction
- Water seal
- No suction
- Air leak

Search 1: This search was carried out in:

Ovid Databases, Medline, PubMed, CINAHL, EBSCO host (MeSH headings and keywords)

1. chest tubes
2. chest tube
3. thoracotomy tube
4. thoracostomy tube
5. thoracostomy
6. thorax drain
7. 1 or 2 or 3 or 4 or 5 or 6
8. pneumothorax
9. 7 and 8
10. gravity
11. water seal
12. suction
13. no suction
14. non-suction
15. 10 or 11 or 12 or 13 or 14
16. air leak
17. airleak
18. 16 or 17
19. 9 and 15 and 18
20. limited to adults and English

Search 2: Science Direct, Scopus, Proquest (keywords and all fields)

1. “chest tube” [All Fields] OR “thoracotomy tube” [All Fields] OR “thoracostomy tube” [All Fields] OR “chest drain” [All Fields] OR “thorax drainage” [All Fields]
2. “pneumothorax” [All Fields]
3. “waterseal” [All Fields] OR “gravity” [All Fields] OR “suction” [All Fields]
4. “air leak” OR “airleak” [All Fields]
5. 1 and 2 and 3 and 4
6. Limit 5 to (English language AND “adult”)

Search 3: Grey literature databases

1. 1. “chest tube” [All Fields] OR “thoracotomy tube” [All Fields] OR “thoracostomy tube” [All Fields] OR “chest drain” [All Fields] OR “thorax drainage” [All Fields]
2. “pneumothorax” [All Fields]
3. “waterseal” [All Fields] OR “gravity” [All Fields] OR “suction” [All Fields]
4. “air leak” OR “airleak” [All Fields]
5. 1 and 2 and 3 and 4
6. Limit 5 to (English language AND “adult”)

A total of 114 articles were determined to be relevant for inclusion in our review. Following detailed examination of all titles and abstracts, the reference lists in the remaining articles were analyzed for potential relevance. As a result of this analysis an additional 3 articles were retrieved.

APPENDIX II: STUDIES SELECTED FOR RETRIEVAL

Alphonso, Tan, Utley, Cameron, Dussek, Lang-Lazdunski, Treasure. A prospective randomized controlled trial of suction versus non-suction to the underwater seal drains following resection. European Journal of Cardio-thoracic Surgery.2005; 27( ): 391-394.

Antanavicius, Lamb, Papasavas, Caushaj. Initial chest tube management after pulmonary resection. The American Surgeon.2005; 71(5): 416

Brunelli, Monteverde, Borri, Salati, Marasco, Refai, Fianchini. Comparison of water seal and suction after pulmonary lobectomy: A prospective, randomized trail. Annals of Thoracic Surgery.2004; 77(6): 1932-1937.

Marshall, Deeb, Bleier, Kucharczuk, Friedberg, Kaiser, Shrager. Suction vs water seal after pulmonary resection. Chest.2002; 121( ): 831-835.

Okamoto, J., Okamoto, T., Fukuyama, Y.,Ushijima, C., Yamaguchi, M., Ichinose, Y. . The Use of Water Seal to Manage Air Leaks after a Pulmonary Lobectomy: A Retrospective Study. Annals of Thoracic Cardiovascular Surgery.2006; 12(4): 242-244.

Prokakis, Koletsis, Apostolakis, Panagopoulos, Kouki, Sakellaropoulos. Routine suction of intercostal drains is not necessary after lobectomy: A prospective randomized trial. World Journal of Surgery.2008; 32(11): 2336-2342.

Sharma, T., Agnihotri, S., Jain, N., Madan, A., Deopura, G.. Intercostal tube thoracostomy in pneumothorax. Indian J. Chest Dis & All Sci.1988; 30(1): 32-35.

So, S., Yu, D.. Catheter drainage of spontaneous pneumothorax: suction or no suction, early or late removal?. Thorax.1982; 37( ): 46-48.

APPENDIX III: APPRAISAL INSTRUMENTS

MAStARI Appraisal Instrument

JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial

Reviewer _____ Date _____

Author _____ Year _____ Record Number _____

	Yes	No	Unclear	Not Applicable
1. Was the assignment to treatment groups truly random?	☐	☐	☐	☐
2. Were participants blinded to treatment allocation?	☐	☐	☐	☐
3. Was allocation to treatment groups concealed from the allocator?	☐	☐	☐	☐
4. Were the outcomes of people who withdrew described and included in the analysis?	☐	☐	☐	☐
5. Were those assessing outcomes blind to the treatment allocation?	☐	☐	☐	☐
6. Were the control and treatment groups comparable at entry?	☐	☐	☐	☐
7. Were groups treated identically other than for the named interventions	☐	☐	☐	☐
8. Were outcomes measured in the same way for all groups?	☐	☐	☐	☐
9. Were outcomes measured in a reliable way?	☐	☐	☐	☐
10. Was appropriate statistical analysis used?	☐	☐	☐	☐
	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info. ☐

Comments (Including reason for exclusion)

_____

_____

_____

JBI Critical Appraisal Checklist for Descriptive / Case Series

Reviewer _____ Date _____

Author _____ Year _____ Record Number _____

	Yes	No	Unclear	Not Applicable
1. Was study based on a random or pseudo-random sample?	☐	☐	☐	☐
2. Were the criteria for inclusion in the sample clearly defined?	☐	☐	☐	☐
3. Were confounding factors identified and strategies to deal with them stated?	☐	☐	☐	☐
4. Were outcomes assessed using objective criteria?	☐	☐	☐	☐
5. If comparisons are being made, was there sufficient descriptions of the groups?	☐	☐	☐	☐
6. Was follow up carried out over a sufficient time period?	☐	☐	☐	☐
7. Were the outcomes of people who withdrew described and included in the analysis?	☐	☐	☐	☐
8. Were outcomes measured in a reliable way?	☐	☐	☐	☐
9. Was appropriate statistical analysis used?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

_____

_____

_____

JBI Critical Appraisal Checklist for Comparable Cohort/ Case Control

Reviewer _____ Date _____

Author _____ Year _____ Record Number _____

	Yes	No	Unclear	Not Applicable
1. Is sample representative of patients in the population as a whole?	☐	☐	☐	☐
2. Are the patients at a similar point in the course of their condition/illness?	☐	☐	☐	☐
3. Has bias been minimised in relation to selection of cases and of controls?	☐	☐	☐	☐
4. Are confounding factors identified and strategies to deal with them stated?	☐	☐	☐	☐
5. Are outcomes assessed using objective criteria?	☐	☐	☐	☐
6. Was follow up carried out over a sufficient time period?	☐	☐	☐	☐
7. Were the outcomes of people who withdrew described and included in the analysis?	☐	☐	☐	☐
8. Were outcomes measured in a reliable way?	☐	☐	☐	☐
9. Was appropriate statistical analysis used?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info. ☐

Comments (Including reason for exclusion)

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APPENDIX IV: DATA EXTRACTION INSTRUMENTS

MAStARI Data Extraction Instrument

JBI Data Extraction Form for Experimental / Observational Studies

Reviewer _____ Date _____

Author _____ Year _____

Journal _____ Record Number _____

Study Method

RCT ☐ Quasi-RCT ☐ Longitudinal ☐

Retrospective ☐ Observational ☐ Other ☐

Participants

Setting _____

Population _____

Sample size

Group A _____ Group B _____

Interventions

Intervention A _____

Intervention B _____

Authors Conclusions: _____

Reviewers Conclusions: _____

Study results

Dichotomous data

Outcome	Intervention ( ) number / total number	Intervention ( ) number / total number

Continuous data

Outcome	Intervention ( ) number / total number	Intervention ( ) number / total number

APPENDIX V: INCLUDED STUDIES

MAStARI

Study	Methods	Participants	Intervention A	Intervention B	Notes
[0], Alphonso, Tan, Utley, Cameron, Dussek, Lang-Lazdunski, Treasure, 2005	RCT	All patients undergoing thoracotomy or video-assisted thorascopic surgery for lobectomy or wedge resection between June 2002 and February 2004. Randomization was made at end of operation after drains placed. Minimization was applied to consider demographic data and patient history. The two arms were balanced with respect to factors used in minimization process. All participants had a PCA for pain management and paravertebral lidocaine was used in thoracotomies. A specialist or consultant determined	Primarily Suction (2 kPa as suction measurement)	Primarily Water Seal	The authors did not report data regarding duration of air leak, chest tube dwell time or length of stay. Data was reported as a Kaplan-Meier curve with the air leak duration on the x-axis and cumulative persistance on the y-axis. This study did capture chest x-ray quantifiable pneumothorax information different from other studies that did not use chest x-ray as a measurement. The measuremen

		resolution of air leaks. Air leak and fluid output was regularly assessed. Chest tube was removed when no air leak and less than 200 mL/day of drainage was evident. Chest x-rays were done on Day 1, 3, 7 and following chest tube removal. Lobectomies had two chest tubes placed and VATS had one.			t unit for applied suction was unique from other studies (2 kPa is ~15 mmHg suction which is about ~20 cm of water). The randomizati on process was rigorous and thorough. This study had a clean differentiati on between suction and no suction.
[0], Antanavici us, Lamb, Papasavas, Caushaj, 2005	Retrospe ctive	Consecutive patients at least 18 years old undergoing lobectomy or segmentectomy with a preoperative diagnosis of pulmonary nodule.	Suction - 20 cm of water for patients with and without air leaks. Placed immediately after surgery. Most patients put on suction underwent lateral thoracotomies .	Water Seal Only - placed on patients with and without air leaks immediately after surgery. Most patients underwent Vertical Muscle-Sparing Thoracotom y (VMST) surgeries.	Due to the retrospectiv e methodolog y, surgeon and selection bias is evident. There is a sample size limitation. Quantifying an air leak is a problem noted. Because the study sub-categorized into air leak and no air leak arms and then in

					to suction and no suction arms, the data became convoluted. The mean days and standard deviations for air leak and no air leak arms were averaged.
[0], Brunelli, Monteverde, Borri, Salati, Marasco, Refai, Fianchini, 2004	RCT	Patients who underwent pulmonary lobectomy or bilobectomy for non-small cell carcinoma from June 2001-August 2003. Surgery was performed by one of four surgeons.	Primarily Suction - POD 1, if air leak present, patient was randomized to suction.	Primarily Water Seal - Suction until POD 1. If air leak of POD 1, then randomized to water seal only at that time.	Presence of air leak checked twice a day at AM and PM rounds, during which patients were encouraged to repeat efforts of forced exhalation and coughing to reveal air leak. No routine chest x-rays were done. CPT and IS for all patients were utilized as well as bronchodilators. Chest tube

					removed when no air leak for 24 hours after clamping and pleural effusion less than 200 ml/24 hours. Pleural tenting was a part of every procedure. Two different types of drainage devices were used - one with an air leak meter and one without - though evenly distributed between arms. Did test devices for accuracy of 20cm of water suction. 2 patients in the water seal group were converted to suction for a 24 hour period due to large air leaks before returning back to the

					water suction intervention. These participants should have been excluded.
[0], Marshall, Deeb, Bleier, Kucharczuk, Friedberg, Kaiser, Shrager, 2002	RCT	consecutive patients undergoing wedge resection, segmentectomy, or lobectomy from June 2000-August 2000. Surgery was performed by one of three surgeons	Suction - 20 cm of water suction	Primarily Water Seal - All were put to suction in the OR. In recovery room, randomized to water seal group.	Small sample size. In the water seal group, if pneumothorax >25% in the recovery room according to x-ray, they were placed on suction 10 cm until pneumo decreased to < 10%. Then they returned to water seal. The chest tubes were removed when there was no air leak and less than 300 mL/24 hours. Air leaks were checked twice a day. Chest tubes were removed when no air leak was noted. There

					was no time to confirm air leak was gone.
[0], Prokakis, Koletsis, Apostolakis, Panagopoulos, Kouki, Sakellaropoulos, 2008	RCT	patients undergoing lobectomy or bilobectomy with lung CA, Jan 2002-Dec 2002	Suction - 15-20cm of water. Suction applied immediately following surgery.	Water Seal Only - Water seal only applied immediately following surgery.	Air leak size was measured and classified in this study. Removal of chest drains was staggered. The removal of the second chest tube was on POD 3 if there was no air leak and less than 200 mL drainage in 24 hours. Chest x-ray was used for confirmation. Patients had high epidural continuous infusions, local anesthesia for pain, and PO pain medication. CPT and early mobilization was expected on POD 1. Length of chest tube

					dwell time was measured based upon removal of second chest tubes. Study also records time for removal of first chest tube. Number of complications are reported but it appears to be incidence of complications, not the number of patients with complications. There was one death in the suction group and two deaths in the water seal group.

APPENDIX VI: EXCLUDED STUDIES

MAStARI

[1] Okamoto, J., Okamoto, T., Fukuyama, Y.,Ushijima, C., Yamaguchi, M., Ichinose, Y. , The Use of Water Seal to Manage Air Leaks after a Pulmonary Lobectomy: A Retrospective Study

Reason for exclusion: Pre and post 2001 methodologies differed and explanations were unclear.

[1] Sharma, T., Agnihotri, S., Jain, N., Madan, A., Deopura, G., Intercostal tube thoracostomy in pneumothorax

Reason for exclusion: There was too much detail about the study missing. The outcomes of the study were not analyzed appropriately nor were they written up well.

[1] So, S., Yu, D., Catheter drainage of spontaneous pneumothorax: suction or no suction, early or late removal?

Reason for exclusion: Detail around methodology was not clear. Also, outcomes were stated but not explained or discussed.

ABSTRACT

The objective of this comprehensive systematic review was to identify and synthesize the best available evidence on effectiveness of suction versus water seal for optimal management of pleural chest tubes in adult patients. A thorough literature search across fifteen databases was conducted to identify relevant articles. Twenty-three articles were appraised for methodological quality with five studies being included in the final meta-analysis. This analysis indicated use of water seal alone decreases: duration of air leak by 1.16 days ($p=0.20$), chest tube dwell time by 1.24 days ($p=0.001$), and length of hospital stay by 2.45 days ($p=0.04$). Water seal alone also decreases the incidence of prolonged air leak greater than seven days ($p=0.90$) and incidence of complications ($p=0.07$). The results of this systematic review and meta-analysis demonstrate that the use of suction is an unnecessary intervention. Water seal alone provides for optimal management of a pleural chest tube in adult patients. Use of water seal alone is less nursing time intensive and appears to be more cost-effective as a shorter duration of air leak and chest tube dwell time shortens the length of hospital stay – all of which would lower expenditures.