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ISSN: 2639-9229

International Journal of Innovative Surgery

Open Access | Research Article

Safety of Suction in Management of Pneumothorax-A Review of the Literature, Evidence and Physiological Basis for Negative Pressure Suction

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Received: Dec 15, 2021
Accepted: Jan 18, 2022
Published Online: Jan 21, 2022
Journal: International Journal of Innovative Surgery
Publisher: MedDocs Publishers LLC
Online edition: http://meddocsonline.org/

Abstract

A pneumothorax is a collection of air in the space outside the lungs that is trapped within the thorax. Drainage of this air can be achieved with the insertion of an intercostal catheter or chest tube. Resolution of a pneumothorax may be aided by the use of negative pressure suction applied to an underwater seal drain. This method has long been regarded with caution due to several perceived adverse consequences such as re-expansion pulmonary oedema or tissue damage. This article aims to review the literature that such caution is based on and assess its validity, as well as provide reassurance about the safety of negative pressure suction when managing a pleural space.

Introduction

A pneumothorax is a collection of air in the space outside the lungs that is trapped within the thorax. This abnormality can occur spontaneously, secondary to underlying lung disease or as the result of trauma, iatrogenic causes [1] and is the inevitable result of thoracic surgical procedures. Current management of pneumothorax is variable, with little evidence from randomised controlled trials to guide treatment unless there is evidence of tension physiology. The accepted standard of care is that a pneumothorax greater than 2 cm or a one that causes breathlessness, should be drained [2,3]. Whether this occur via needle aspiration or with an intercostal drain, (tube thoracostomy) depends on the patient, the size of the pneumothorax and the treating medical practitioner. An area of contention in this management is whether to apply suction to an underwater seal system. Most often, the objections raised are due to safety concerns.

During normal respiration, the pleural space is a closed system with a pressure that is negative, relative to the surrounding atmosphere. This negative pressure is maintained by the mechanical properties of the lung tissue, the chest wall, tensile forces of pleural fluid and lung surfactant [1]. The thoracic intrapleural pressure in a healthy upright lung at relaxed end-expiration lies between -3 cm H_2O at the lung bases and -8 cm H_2O at the apices. The mean intrapleural pressure is approximately -5 cm H_2O. During normal physiological tidal breathing, the mean intrapleural pressure is reduced further to -8 cm H_2O at end-inspiration [1]. The intrapleural pressure can be increased to a positive pressure of 100-250 cm H_20 during coughing [4].

If there is a disruption to this system, which allows direct communication with the surrounding atmosphere, negative pressure is lost. This impedes ventilation and allows the lung to collapse under its own elastic recoil, resulting in pneumothorax. Pleural drains with either one way valve or underwater

Cite this article: Winkle BD. Safety of Suction in Management of Pneumothorax-A Review of the Literature, Evidence and Physiological Basis for Negative Pressure Suction. Int J Innov Surg. 2022; 5(1): 1024.

seal allow air or fluid that has accumulated in these spaces to be removed without back-flow of air or fluid and function due to the hydrostatic pressure of the accumulated fluid or, in the case of pneumothorax without air-leak, due to transiently increased intrapleural pressure generated by coughing [1,5].

The application of suction to these chest drains is contentious. Most sources contend that the transient increases in pressure due to coughing and normal respiration are sufficient to drain a pneumothorax. However, in an open system such as the pneumothorax with a large air leak, there is no difference in pressure between the body space and the surrounding atmospheric pressure to drive drainage and so the use of suction would appear necessary.

There is a lack of evidence guiding the use of suction in management of pleural drains. Most guidelines advocate for suction if initial management fails and advise caution when instituting this intervention [3,6,7]. The caution advised is due to risk of re-expansion pulmonary oedema, tissue damage or prolong air leaks.

We present a review of current literature, guidelines and relevant textbooks that are currently used to guide the management of pneumothorax and provide an understanding of the safety concerns raised.

Methods

Database searches were conducted using keywords of 'Pneumothorax, Suction, Thoracostomy, Chest tube, Chest drain'. Any case reports without attached literature reviews were immediately excluded, as were any articles related to specific medical conditions. Articles compiled were sourced from PubMed, Up-to-date, Cochrane Library and Google Scholar.

Also included were textbooks on the Australasian Cardiothoracic Surgery Training reading list. The studies used to write the chapters dealing with pneumothorax were sourced and included.

Further literature includes Guidelines from the British Thoracic Society, the American College of Chest Physicians, Belgian Society of Pneumology and the Australian Emergency Care Institution.

Articles were reviewed and assessed for relevance to the topic and impact on clinical practice. Each piece of relevant literature will be discussed with the aim to review if relevance to and impact on the topic. Any articles that did not directly address the topic, involved the addition of an extra piece of equipment or involved a case report of a specific, unrelated condition were excluded.

Results & discussion

A large volume of literature was reviewed from the sources outlined. Database searches found 583 articles which were reviewed. A large percentage or articles were excluded as they related to a particular condition or procedure. A final total of 19 articles were deemed suitable for review based on the criteria.

In 1968, Clifford F Storey, a founding member of the Society of Thoracic Surgeons, published an editorial in the Annals of Thoracic surgery titled 'Intrapleural Suction: Is It Being Used to Best Advantage?. Storey discusses that at the time, routine use of suction was agreed to be good practice with only the level of suction being under debate. He goes on to state that level of suction should be increased after 24 hrs if the desired result is not achieved and his opinion was based on using this technique in 2500 patients. Furthermore, he also reports that 300 patients with spontaneous pneumothorax were treated with tube insertion and high-level suction. There was no failure of treatment in any of those 300 patients [8]. As no demographics or patient information was supplied in this article, it is purely an opinion piece and thus caution must be exercised when considering these results.

There are many clinical practice guidelines published that are used world wide as a reference for clinicians, such as Up-to-date, that provide guidance on the management of chest drains. The Up-to-date article on management of pneumothorax does not recommend suction as routine for initial management of pneumothorax without tension physiology. Suction may be applied if the lung fails to re expand with underwater seal only [9]. This article reports that despite this recommendation, there is no evidence to suggest either method is more effective. Its only caution for initial suction is an increased risk of Re-expansion Pulmonary Oedema (RPO). This is based on evidence from an article by S. Sherman in 2003 [10].

Sherman published a case report and literature review in the Journal of Emergency Medicine on the dangers of re-expansion pulmonary oedema secondary to suction. Sherman noted that there had been no prospective studies conducted on humans and that the risk quoted in most studies is based on a study of 12 Rhesus monkeys. The largest study reviewed in this article had a sample size of 21 patients treated for spontaneous pneumothorax and re-expansion pulmonary oedema occurred in 3 patients (14%). Sherman reported that other, similar studies found no fatalities, but did not discuss these studies further [10].

The first study cited by Sherman in his article was by Miller et al in 1972. 12 monkeys were given a unilateral pneumothorax and left untreated for 3 days. 6 monkeys were then treated with underwater seal and low level suction (-10 cm H_2O) and 6 were treated with underwater seal only. RPO was found in 5 patients (80%) of the suction group. This result was reduced in a second study when the treatment was initiated less than 72 hrs post pneumothorax and RPO was absent in all subjects if the lung was re-expanded within 1 hour [11]. More recent studies have found incidence of RPO is ~1% of clinical cases and is more prevalent in cases where the lung has been down for >7 days [12]. The pathophysiology of the development is likely due to cytokine and interleukin release once there has been endothelial damage to lung tissue from poor prefusion [12]. This is not an immediate process and takes this time to develop. Most cases of spontaneous pneumothorax present early, especially the larger cases requiring drainage, and thus the risk of RPO is much lower in the common clinical setting of treating a spontaneous pneumothorax.

The second review article discussed by Sherman is from 1988 by Mahfood et al who reported a 20% mortality from RPO [13]. Mahfood reviewed the reported cases of 53 patients with RPO. Some of these were reported as case series, the largest of these was n=5. `There was an heterogenicity in this article as minimal demographic information was included, there was no information about the aetiology of the pneumothorax and only 3 of the patients with adverse outcomes did not have chronically (>72hrs) deflated lungs. 12 patients were reported as having a pneumothorax for >10 days. 5 of the mortalities included occurred in patients who were treated without suction. This

level of mortality has not been reported in any other literature. Furthermore, only 47 cases of 53 were from pneumothorax. When calculating the mortality, Mahfood included 6 cases of RPO from thoracocentesis for chronic pleural effusion of which 3 died [13]. Thus his figure of 20% is falsely elevated when dealing with a pneumothorax, nor does this correlate to the common clinical scenario of an acute pneumothorax.

Bilal et al published an article in 2008 where 100 patients with traumatic pneumothorax were randomised to suction or non-suction. They demonstrated that placing chest tubes on continuous low pressure suction after penetrating chest trauma improved evacuation of blood, expansion of lung and prevented the development of clotted haemothorax. It also reduced time to removal of chest drains, hospital stay and requirement for surgery for clotted haemothorax or empyema [14].

Morales et al published a similar study in 2014 with 110 thoracic trauma patients. They found no benefit to introducing suction routinely, however they excluded all patients who were mechanically ventilated at any point during admission, any patients with underlying lung disease, any who had previous thoracic interventions and any who required pulmonary surgery admission [15]. The exclusion of patients with underlying lung disease and/or previous thoracic interventions increased the homogeneity of the sample population by reducing cofounder and thus improving the power of the study. This articles exclusion of patients who were mechanically ventilated is also unfortunate and the increased PEEP delivered would increase the intrathoracic pressure. If these patients were found to resolve over shorter duration, it would confirm the physiological basis for suction. Morales concluded that there was no benefit from applying suction in the setting of trauma, however in his study, which included both haemothorax and pneumothorax; no adverse outcomes such as RPO or bronchopleural fistula were recorded.

Sy et al., conducted a study in 1982 dedicated to investigating the use of suction for primary spontaneous pneumothorax [16]. They enlisted 23 patients and randomised them to suction or no suction. This study showed slightly higher resolution rates in the non-suction group. However, the authors commented that no patients experienced RPO and while there was a recurrence rate in only 1 (10%) of the non-suction group, who required repeat intervention. There was 0% recurrence in the suction group. This study also used 13Fr catheters and their standard level of suction was -8cm H_2O, below that of any current recommendation [16]. This study is a frequently cited article in the guidelines and textbooks discussed below, however given the small population size, it lacks the statistical power to provide a sound basis for clinical practice.

The British Thoracic Society published a consensus guideline in 2010 on the management of spontaneous pneumothorax. In this guideline, routine suction is not advised due to the risk of RPO. Sources used to provide this recommendation include the previously mentioned articles by Mahfood and Sherman [3].

In 2001, the American College of Chest Physicians published a consensus statement on the management of spontaneous pneumothorax. This statement reports that suction may be applied to a water seal device. This was based on 'some consensus' rather than 'good consensus'[6]. Application of a water seal to a lung that had failed to re-expand with simple aspiration was agreed upon with good consensus; however, the application of suction in this situation only achieved some consensus. The literature referenced for this section of the guideline was the above mentioned article from Sy et al., in 1982. No other studies or trials investigating the use of suction as a primary intervention were used in this guideline. Concerns raised in this guideline and again in the consensus statement from the German Thoracic Surgery Society include the risk of damage to fragile lung tissue due to suction [17]. There are rare cases of bronchopleural fistula formation post chest tube insertion however none of these have been proven to be due to the use of suction and has been demonstrated in cases where suction was not used [18]. In 1977, Stahly and Tench published an article regarding lung infarction and entrapment from use of suction. At the time only two cases were identified as a consequence of suction at -15cm H_2O. No intervention was required in either case [19].

The Emergency Care Institute of Australia recommends that suction not be employed due to risk of RPO. No references or evidence are provided as the basis for this recommendation [7]. The Guidelines on the management of spontaneous pneumothorax from The Belgian Society of Pneumology state that suction can be used if the lung fails to expand after 2 days [20], which is when the risk of RPO starts to increase [10]. It is listed as Level C evidence however no references are provided to determine where this evidence was derived from.

Sabiston and Spencer - Surgery of the Chest is one of the recommended textbooks for Cardiothoracic Surgery. On the topic of suction, it reads, "The efficacy of suction is debated, but there is no evidence that it speeds the resolution of spontaneous pneumothorax. If it is used, it should be used judiciously" [21]. The basis for this recommendation is the previously mentioned study by Sy et al., No further explanation is provided for this caution.

General Thoracic Surgery by Shields et al is also a commonly referenced textbook in Thoracic Surgery. Chapter 58 addresses pneumothorax. It states that despite 4 sets of consensus guidelines (ACCFP, BTS, Belgian Society of Pneumonology and Australian Therapeutic guidelines), pneumothoraces are still treated with empiricism and most treatment is based on low levels of evidence [5]. Routine suction is not recommended based on the risk of RPO. The references provided as the basis for this warning are either individual case reports, the previously mentioned studies or based on post-operative surgical patients. The mortality quoted in this chapter is from Mahfood's study which had some limitations as previously discussed. This chapter goes on to recommend that in the case of ongoing pneumothorax or incomplete re-expansion, suction should be trialled.

Ayed AK conducted a prospective, randomised control trial on the use of suction in 100 primary pneumothorax patients from 1995-1999. This study only included post-operative patients who had undergone resection of blebs or bullae. All patients were placed on suction immediately post operatively for a period of 2 hours and then afterwards were randomised to continue suction or be changed to underwater seal only. This study found that while prolonged use of suction tended to cause longer hospital stays, the routine use of suction post operatively resulted in less air leaks, less days with drain in and shorter hospital stays than in patients treated with underwater seal only [22].

In 2010 Deng et al published a meta-analysis of all RCTs dealing with trials of suction in post-operative lung surgery patients. 6 RCTs were assessed and found that while routine use of suc-

tion post operatively did not impact the incidence of prolonged air leaks, it can reduce the occurrence of postoperative pneumothorax resulting from early air leak. As a result, the early use of postoperative suction might be crucial to specific patients to whom early elimination of residual space is very important [23]. Despite being focussed on post-operative patients, this was one of few studies that discussed the physiology and fluid mechanics underlying the use of suction demonstrated by Roe et al. in his paper describing the 'Physiologic principles of drainage of the pleural space with special reference to high flow, high vacuum suction'[24]. Roe's paper provides a discussion on the physiological basis of suction. While a strong advocate for the use of suction to eliminate a potential space for pneumothorax and ensure pleural apposition post operatively, Roe does not provide any evidence or outcomes of patients treated with or without suction.

In 2012, van Miert et al., published a Cochrane protocol for a review all current literature and practice. This protocol highlighted the discrepancy between physiology and standard practice of chest drain management [1]. Unfortunately, the study was not completed, though it does discuss the physiological basis and previous literature in detail. It also provides a framework for this research to be completed.

Marshall et al published a randomised prospective study which found that placing chest tubes on water seal after a brief period (20 minutes) of suction post pulmonary resection shortens the duration of the air leak and apparently decreases the time the chest tubes remain in place. Adoption of this practice may result in lower morbidity and lower hospital costs [25]. Once again, this study was limited to post-operative patients. Like Ayed in 2000, Marshall et al found that the routine use of suction immediately post operatively reduced the expected recurrence and air leak rates, despite improved outcomes ,with regards to days with drain in, in the group treated with underwater seal only [22,25].

In 2012, Coughlin et al found differing results. A systematic review and metanalysis of post-surgical patients identified no differences in terms of duration of air leak, incidence of prolonged air leak, duration of chest tubes and duration of hospital stay when chest tubes were placed on suction rather than water seal alone; though chest tube suction appeared to be superior to water seal in reducing the incidence of post-operative pneumothorax [26]. A retrospective analysis by Cerfolio et al., in 2005 found that 16% of post-operative patients failed to resolve pneumothorax or air leak with water seal alone and suction was required. This study also identified significant safety issues, such as recurrence and unrecognised tension pneumothorax, when leaving patients with a large pneumothorax on water seal only [27]. The most recent meta-analysis of this topic is by Zhou et al in January 2019. Like Coughlin in 2012, this study found no difference in air leak rates or hospital stay in post-operative lung surgery patients. However, like Cerfolio et al., they also identified that a large or expanding pneumothorax was best and more safely treated with suction. None of these three studies identified a safety issue when considering the use of suction.

Conclusion

In summary, despite a large body of literature surrounding this topic, there are very few studies that directly address the use of suction as a routine intervention in management of a pleural space, despite the physiological basis behind it. However, many of the clinical guidelines raise the possible dangers from the use of suction. Unfortunately the evidence used to draw these conclusions is either not representative of the clinical scenario i.e. Lung collapse of >72 hrs, or is based on very limited studies that have been propagated without further verification or scrutiny. This is evident in the guidelines from 4 different Thoracic societies using the same few studies to generate their consensus statements.

When assessing a pneumothorax, a clinician must accept that the physiology of a previously closed system has changed and thus an external force may be required to restore normal physiology, even if only for a brief period of time. There is little evidence to support avoiding suction due to concerns of RPO or tissue damage. While the evidence for the use of negative pressure suction when managing a pleural space remains limited and not yet definitive, this can be an effective tool with sound physiological basis. The trepidation surrounding the use of suction is a good example of how bias can be propagated throughout medical teaching and practice if evidence is not properly scrutinised or questioned.

Disclosure

The authors have no agreements, affiliations or sponsorships to disclose.

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