Risk factors of iatrogenic pneumothorax after thoracentesis in a clinical setting

James Pribila BS, MS, Beth Veale PhD, RT(R) (QM)

ABSTRACT

Pleural effusion is a pathology that affects 1.5 million people in the United States every year. The treatment for pleural effusion is typically thoracentesis, which has several risks, such as pneumothorax, that can be life threatening and can pose a significant financial burden on patients and their families. Isolating and identifying the risk factors associated with pneumothorax after thoracentesis will help improve patient safety. The research for this literature review came from the referenced peer-reviewed scholarly articles that included other literature reviews, research papers, and research studies. Numerous articles were initially reviewed and several were excluded from this review due to their date of publication. Identifying risk factors had a positive impact on patient outcomes. Pneumothorax following thoracentesis was associated with increased morbidity, mortality, and the length of hospital stay. Patients with pneumothorax were also more likely to require additional procedures such as invasive mechanical ventilation, hemodialysis, tracheostomy, and chest tube placement. Pathologies such as cystic fibrosis (CF), chronic obstructive pulmonary disease (COPD), malignancies, and congestive heart failure (CHF) can contribute to in increased risk of iatrogenic pneumothorax following thoracentesis. Intra-procedural ultrasound use, clinician experience, patient positioning, and needle gauge also affect the rate of pneumothorax. Proper risk management includes education, better training, use of ultrasound intra-procedurally and proper patient workups help minimize these risks. Pneumothorax is a significant complication of thoracentesis that warrants careful consideration. There is not enough research to narrow down actual risk factors, and research in this area would benefit mid-level providers such as physician assistants and radiology assistants who are becoming the main performers of these services.

Keywords: Pleural effusion, thoracentesis, pneumothorax, iatrogenic

INTRODUCTION

Pleural effusion is an accumulation of fluid within the pleural space surrounding the lung. Every year it is estimated that 1.5 million people in the United States develop pleural effusions, and 178,000 thoracenteses are performed.[1] Thoracentesis, also referred to as a pleural tap, is the drainage of this fluid. The procedure is performed in a hospital or clinical setting in which the patient can be closely monitored. Thoracentesis has several complications like pneumothorax (PTX), a condition in which air enters the pleural space surrounding the lung, exerting force against the lung, causing a partial or full collapse of the lung. Hospital-acquired (iatrogenic) pneumothorax (IP) has the potential to be life-threatening. Computed tomography (CT) scans and conventional radiography are modalities of choice for identifying pneumothorax. Ultrasound and magnetic resonance imaging (MRI), while not ideal, can also detect pneumothorax. Symptoms of pneumothorax include sudden onset chest pain often localized to one side, dyspnea, and dry cough. Clinical indications can include tachypnea, tachycardia, decreased oxygen saturation, decreased breath sounds over the affected lung, and hyperresonance during auscultation.

Corresponding author: **Beth Veale**
Contact Information: Beth.Veale@msutexas.edu
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This literature review analyzes risk factors associated with iatrogenic pneumothorax post-thoracentesis and risk management.

Methods

A formal search of the referenced peer-reviewed scholarly articles, including literature reviews, research papers, and research studies, was conducted using Midwestern State University's (Wichita Falls, TX) online library database search engine as well as Google Scholar. Keywords used in the search were thoracentesis, pleural effusion, pneumothorax, risk factors of thoracentesis, and pneumothorax after thoracentesis. Numerous articles were initially reviewed and several were excluded from this review due to outdated dates of publication, except three articles that were directly relevant. The search was refined to include the years 2020–2025. Eighteen articles were chosen related to the topic, and one Radiopaedia entry was used for definition.

Procedure Overview

The first recordings of draining pleural fluid dates to the fifth century BCE, when Hippocrates reported on "empyema" located in the thorax. He drew the pus out of the body using an incision and inserting a hollow tin drainage tube. The tube was removed once the output ceased.[2] During the next 1,600 years, procedural techniques and knowledge of pathology advanced so that thoracentesis was considered to be one of the simplest of procedures performed.[2] As described on Radiopaedia, thoracentesis is typically performed bedside with the patient in the upright, lateral decubitus, or supine position.[3] Ultrasound is used to find the most appropriate needle insertion site. After the area is prepped and draped according to sterile standards and hospital protocol, the skin is anesthetized using a local anesthetic. A centesis needle is advanced into the pleural space, and after the needle is removed, the catheter is attached to suction or gravity drainage. There are two clinical applications for thoracentesis, diagnostic and therapeutic. Diagnostic thoracentesis samples are sent to the laboratory and processed to determine the root cause of the effusions. Therapeutic thoracentesis is performed to provide patient comfort, alleviating symptoms such as dyspnea. Nicholson et al. describe the various etiologies that cause pleural effusion.[4] These included heart failure, pneumonia, systemic inflammatory disorders, and malignancies. Krishnaet noted that the management of this condition involves addressing the underlying cause, draining the accumulated fluid, and managing complications like infection and pleural fibrosis.[5]

Risk Factors

Identifying risk factors has a positive impact on patient outcomes. Shechtman et al. reported that pneumothorax following thoracentesis was associated with increased morbidity, mortality, and the length of hospital stay.[6] Increased hospital stay led to a significant economic burden. Patients with iatrogenic pneumothorax following thoracentesis stayed in hospitals for an average of 4.4 extra days.[7] Another study by Nasrullah et al. found that patients with iatrogenic pneumothorax after COVID-19 incurred significantly higher hospitalization costs and longer hospital stays, 15 days longer on average and a cost difference of $435,508 vs. $96,668.[8] This study also found that patients with pneumothorax were more likely to require additional procedures such as invasive mechanical ventilation, hemodialysis, tracheostomy, and chest tube placement.

Pathology/Comorbidities

Several diseases increase the risk of developing iatrogenic pneumothorax post-thoracentesis, and diseases that disrupt the normal lung parenchyma increase the risk.

Fibrotic diseases

Cystic fibrosis (CF) is a respiratory disease commonly identified by the production of thick mucus that accumulates in the lungs. This mucus leads to airway inflammation, infections, and structural damage. The chronic issues associated with CF can potentially lead to the formation of cysts and blebs, which are air-filled spaces within the lungs. These ruptures cause air to leak into the pleural space, resulting in a pneumothorax. Chronic inflammation caused by CF weakens lung tissue, making it more fragile during lung re-expansion post-thoracentesis. This delicate

tissue is more susceptible to tearing.[6] Patients with cystic fibrosis are also treated with airway clearance techniques. These procedures have the potential to cause trauma to the lung parenchyma. Mechanical chest physiotherapy and heavy coughing can lead to the rupture of cysts due to increased intrathoracic pressure.[8] These factors increase the risk of pneumothorax in patients with cystic fibrosis.

Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) is another respiratory disease that causes similar damage to the lungs. The chronic inflammation of COPD leads to the breakdown of lung tissue. The walls between alveoli become weak and break down. This breakdown causes the formation of large air sacs in the lungs.[9] Along with the larger air sacs, the inflammatory response also breaks down elastin, which gives the lungs their elasticity. These sacs have the potential to rupture into the pleural cavity, which in turn causes air leaks and a subsequent pneumothorax. The risk is increased during procedures such as thoracentesis.[6]

Malignancy

Cancer is another disease that poses an increased risk for pneumothorax after thoracentesis. Malignant tumors can erode the lung tissue, creating a fistula, which allows air to travel between the bronchus or alveoli and the pleura. Tumors can also weaken lung tissue, leading to bleb rupture.[1] Sagar et al. found that malignant pleural effusion in breast and lung cancer is associated with a higher risk of pneumothorax when compared with non-malignant pleural effusions.[10]

Congestive heart failure

While there is no direct correlation between congestive heart failure (CHF) and pneumothorax, CHF is a leading factor of pleural effusion. Individuals who suffer from CHF often have other associated conditions such as COPD and pulmonary fibrosis. These diseases increase the risk of developing a pneumothorax.[11] Shechtman et al. found that the incidence of congestive heart failure is significantly higher among patients who develop pneumothorax compared to patients who do not develop pneumothorax.[6]

Age

Age does not appear to have a direct link to pneumothorax; however, older patients are likely to have COPD, lung cancer, and CHF. The presence of these disorders greatly increases the risk of pneumothorax after thoracentesis. Older patients often need longer hospital stays due to their reduced lung function. Shechtman, et al. found that older males have a higher rate of pneumothorax following thoracentesis.[6]

Non-expandable lung

Petersen et al. described non-expandable lung (NEL) as a condition in which the lung does not fully expand after pleural fluid is removed.[13] Furthermore, these authors indicated pneumothorax *ex vacuo* as the term for this specific type of pneumothorax, in which the lung fails to expand after fluid removal from the pleural space. Pleural inflammation, scarring, and malignant pleural effusion (MPE) are the main causes of non-expandable lungs, leading to the formation of fibrotic tissue on the lung surface.[13] The authors noted that this mesh-like structure restricts the lungs' ability to expand. Malignant tumors pose a risk of blocking airways, potentially preventing air from reaching parts of the lungs; without airflow, these sections remain deflated and do not re-expand. Saha et al. reported that drainage of pleural effusion in patients with NEL due to trapped air can lead to hydropneumothorax or pneumothorax *ex vacuo*.[14] According to Petersen et al., malignant pleural effusion is the leading cause of non-expandable lung.[13] They also stated that some studies suggest up to 30% of patients with MPE are at risk of developing NEL.

Technique/Experience

Point-of-care ultrasound

Dancel et al. stated that the use of intraprocedural ultrasound influenced the outcome of the thoracentesis and reduces complications, including pneumothorax.[15] According to these authors, direct

needle stick injury is a cause of pneumothorax during thoracentesis. If the needle punctures the lung parenchyma, air escapes and accumulates in the pleural space. This can be avoided by using live ultrasound guidance during the procedure, referred to as point-of-care ultrasound (POCUS). Point-of-care ultrasound is performed directly by a physician during the procedure to provide real-time imaging. A thoracentesis is performed with a blind needle stick or with POCUS. In a blind stick, the preferred needle-accessed site is pre-marked by the physician or an ultrasound technologist. The site is anesthetized, and the centesis catheter is inserted while drawing back, until pleural fluid is aspirated. Once the pleural fluid is aspirated, the catheter is advanced, and the needle is withdrawn. Complications using this technique include vessel injury, lung laceration, multiple sticks due to encountering ribs, and organ injury such as diaphragm perforation. Patient shifting can cause the pre-marked site to become less than ideal, as stated by Dancel et al.[15]; therefore, they advised for little to no delay between site marking and needle stick. Point-of-care ultrasound allows the observation of respiratory cycles and diaphragmatic motion, preventing liver perforation and reducing the number of needle passes. There is an increased occurrence of pneumothorax with more than one needle pass through the skin.[10] Blind stick thoracentesis has an increased risk of dry tap, in which no effusion is sampled in at least one stick for the procedure. A dry tap is likely to increase the risk of pneumothorax and is an indicator of incorrect needle positioning.[16]

Patient positioning

Poor patient positioning is another cause leading to increased iatrogenic pneumothorax. According to Cantey et al., the ideal positioning and needle insertion site is with the patient sitting upright and with the needle insertion at the mid-axillary line between the 5th and 7th intercostal spaces.[17] They argued that that site minimizes the risk of damaging underlying structures, adding that the intercostal neurovascular bundle sits on the inferior side of each corresponding rib. Needle insertion below this is important to avoid vessel laceration, reducing the risk of hemothorax and pneumothorax. The midscapular line is a viable approach when entering posteriorly from the patient's back. Williams and Lerner had a different opinion, stating that the lateral decubitus was the position of choice for non-ultrasound-guided procedures.[18] The authors reported that with the arm extended forward, the patient is placed in a position that exposes the "triangle of safety," a region that reduces the risk of injuring internal organs or blood vessels during the insertion of chest tubes or centesis catheters for the removal of pleural effusions. The "triangle of safety" is bordered by the edge of the pectoralis major muscle on the anterior edge, the anterior edge of the latissimus dorsi muscle posteriorly, and the superior aspect of the 5th rib inferiorly.[18] This triangular area provides direct access to the pleural cavity while avoiding major organs, vessels, and nerves.

Experience

Several studies showed an association between experience levels and rates of iatrogenic pneumothorax. A report by Çelik et al. found a correlation between the provider's experience and the rate of pneumothorax during thoracentesis.[19] Their study showed that less experienced practitioners have a higher risk of pneumothorax due to improper technique and misidentification of anatomical landmarks. Dancel et al. found that the iatrogenic pneumothorax rate is not significantly different between interventional radiologists and internists (2.8% and 2.9%, respectively).[15] In their study, 132,472 thoracenteses were performed over 3 years across 234 hospitals, with 33.1% of those thoracenteses performed by interventional radiologists, 20.3% by pulmonologists, and 16% by internists and hospitalists. However, Dancel et al. found discrepancies between experienced providers and residents.[15] Experienced physicians showed an incidence rate of 3.9% compared to 8.5% for resident physicians after 6,605 thoracenteses. Shechtman et al. also found that operator experience correlated with the rate of iatrogenic pneumothorax following thoracentesis, revealing an incidence rate of 3.9% in procedures performed by experienced operators and 8.5% performed by less skilled operators.[6]

Risk Management

Point-of-care ultrasound during every thoracentesis makes one of the biggest differences in iatrogenic

pneumothorax rates. A study by Shechtman et al. found that live ultrasound guidance reduces the rate of pneumothorax occurrence from 4–30% without guidance to 1.3–6.7% with live ultrasound guidance.[6] Williams and Lerner found that iatrogenic pneumothorax was discovered in 0.3–1.5% of cases using ultrasound to guide the needle versus 5.7–15% in cases that did not use ultrasound.[18] Cho et al. did not find a correlation between live ultrasound guidance and reduced risk of pneumothorax.[16] They did state that live ultrasound guidance is beneficial for patients who have smaller collections of fluid.

Dancel et al. found that proper education led to an understanding of patient anatomy.[15] When combined with point-of-care ultrasound, educating physicians on ultrasound anatomy provides a better understanding of appropriate needle placement and areas to avoid. In a study by Dancel et al., instituting a formal ultrasound training program for ER physicians resulted in a reduction of PTX from 8.6% to 1.1%.[15]

Being mindful during preprocedural patient workups of comorbidities that increase the risk for PTX, such as malignant tumors involving the lung, COPD, and emphysema, would allow the clinician to tailor the technique to the patient's specific factors, as suggested by Dancel et al.[15] This also enables providers to have a more honest discussion with patients about the potential risks. The providers recognized the possible outcomes that were more accurate for their situation.

Immediate post-procedural imaging reduces the delay in patient care in situations in which the patient develops a pneumothorax. Many facilities omit immediate post-procedural chest x-rays as they may be considered unnecessary radiation. In high-risk patients, this poses a safety risk and can cause a delay in care.

Conclusion

Pneumothorax is a significant complication of thoracentesis that warrants careful consideration. While the procedure is generally safe, factors such as live ultrasound guidance, needle size, and patient comorbidities have critical roles in determining patient outcomes. Continued research and refinement of techniques are essential to minimize the risk of pneumothorax after thoracentesis. Further research can narrow actual risk factors. These findings could benefit mid-level providers, such as physician assistants and radiologist assistants, who are increasingly performing these services.

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