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Abstract

Background: During therapeutic thoracentesis (TT), pleural fluid is typically drained to completion. Fluid removal improves oxygenation, and the amount of fluid removed is directly associated with the risk of serious complications. A relationship between the amount of fluid removed during TT and the change in oxygenation has not been found in the literature. A direct relationship was hypothesized in this study. Differences in the change in oxygenation between sexes, age, and pre-procedure oxygen support were secondarily hypothesized. This information would assist in the guidance of future TT protocols.

Methods: Subjects of this retrospective cohort study were males and females aged 26-74 years. Of the 166 patients who underwent inpatient TT between February 4, 2020, and December 10, 2022, at Berkshire Medical Center (BMC), 16 met the inclusion criteria. They were identified using CPT codes in the electronic medical record (EMR). Demographics, amount of fluid removed, and type of oxygen support were recorded. Pre and post-TT arterial oxygen partial pressure (PaO2) and fraction of inspired oxygen (FiO2) values were collected to calculate the P/F, a metric for oxygenation status. T-test and correlation coefficient were calculated to analyze the change in the P/F ratio versus the amount of pleural fluid removed. Correlation coefficients or ANOVA were calculated to compare oxygenation changes to sex, age, and supplemental oxygen types.

Results: There was no statistical significance ($p=0.87$) in the linear relationship between the amount of pleural fluid drained (mean=660 mL, range=150-1500 mL) and the change in oxygenation (mean=162, range=34-300). There were no statistically significant differences in oxygenation changes between sex ($p=0.60$), age ($p=0.81$), or types of oxygen support pre-procedure ($p=0.07$). There was a statistically significant difference in pre and post-procedure P/F ratio ($p<0.001$).

Discussion: We found a statistically significant change in oxygenation before and after TT, with no evidence of a direct relationship between amount of fluid removed and improvement in oxygenation. There were no complications when removing up to 1500 mL of fluid. A protocol that halts pleural fluid drainage once it is complete or when the amount removed reaches 1500 mL, whichever occurs first, may be optimal.

Keywords

pleural effusion, thoracentesis, pneumothorax

Conflict of Interest Statement

Hannah Zazulak and Ryanne Burke are 3rd-year medical students from the University of New England College of Osteopathic Medicine (UNECOM) who are on clinical rotation at Berkshire Medical Center in Pittsfield, MA. Andrea Bodine is an American College of Obstetrics and Gynecology fellow, Associate Clinical Professor at UNECOM, and research mentor. We do not have conflicts of interest or financial disclosures.

ARTICLE

Comparing Pleural Fluid Removal Volume and Oxygenation Change in Therapeutic Thoracentesis: Is There a Relationship?

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Abstract

Background: **During therapeutic thoracentesis (TT), pleural fluid is typically drained to completion. Fluid removal improves oxygenation, and the amount of fluid removed is directly associated with the risk of serious complications. A relationship between the amount of fluid removed during TT and the change in oxygenation has not been found in the literature. A direct relationship was hypothesized in this study. Differences in the change in oxygenation between sexes, age, and pre-procedure oxygen support were secondarily hypothesized. This information would assist in the guidance of future TT protocols.**

Methods: **Subjects of this retrospective cohort study were males and females aged 26–74 years. Of the 166 patients who underwent inpatient TT between February 4, 2020, and December 10, 2022, at Berkshire Medical Center (BMC), 16 met the inclusion criteria. They were identified using CPT codes in the electronic medical record (EMR). Demographics, amount of fluid removed, and type of oxygen support were recorded. Pre and post-TT arterial oxygen partial pressure (PaO2) and fraction of inspired oxygen (FiO2) values were collected to calculate the P/F, a metric for oxygenation status. T-test and correlation coefficient were calculated to analyze the change in the P/F ratio versus the amount of pleural fluid removed. Correlation coefficients or ANOVA were calculated to compare oxygenation changes to sex, age, and supplemental oxygen types.**

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Discussion: **We found a statistically significant change in oxygenation before and after TT, with no evidence of a direct relationship between amount of fluid removed and improvement in oxygenation. There were no complications when removing up to 1500 mL of fluid. A protocol that halts pleural fluid drainage once it is complete or when the amount removed reaches 1500 mL, whichever occurs first, may be optimal.**

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1. Introduction

Therapeutic thoracentesis (TT) is a procedure performed to alleviate symptoms of respiratory distress from pleural effusions. It is typical practice to drain the fluid until it slows or stops, essentially to completion. Complications associated with the procedure include pneumothorax and re-expansion pulmonary edema (REPE). Both complications are related to the amount of pleural fluid drained.[1,2] Though these complications are relatively rare, they can be taxing on the patient and costly to the healthcare system. For example, an iatrogenic pneumothorax can add 4.4 days to

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hospital length of stay and $18000 in additional healthcare expenditures.[3]

Existing literature supports that large amounts of fluid removal are associated with an increased risk for complications of pneumothorax and REPE. In a retrospective analysis of ultrasound-guided thoracentesis, volume of pleural fluid drained was significantly associated with the development of pneumothorax.[1] A 12 year cohort study of 9320 thoracenteses demonstrated that iatrogenic pneumothorax was significantly associated with removal of >1500 mL fluid, and also indicated a direct relationship between amount of fluid removed and increased risk of REPE.[2] Of note, it has been demonstrated that no specific technical aspects of the procedure confer greater risk of complication in the current standard of care.[4] Existing literature tells us that there is an increase in oxygenation with pleural fluid removal. Oxygenation status is commonly described using the P/F ratio. This is the partial pressure of oxygen (PaO2) divided by the fraction of inspired oxygen (FiO2). A lower number indicates worse oxygenation. Less than 300 is the cutoff for hypoxic respiratory failure. A systematic review and meta-analysis of 1124 thoracenteses demonstrated that there is a significant difference in the PaO2/FiO2 ratio before and after thoracentesis.[5]

Removing fluid improves oxygenation and the amount removed is directly related to increased complication risk. [4] However, literature looking at the relationship between amount of fluid removed vs how much oxygenation improves was not able to be located. Given the risk of major complications with increased fluid removal, it would be helpful to have this information to make commentary on the benefit gained versus the risk increase.

The goal of this study was to determine if there is a relationship between change in oxygenation requirement and pleural effusion drainage amount. The primary outcome was oxygenation status pre/post thoracentesis. Secondary outcomes examined sex differences, age differences, and differences based on type of oxygen support pre-procedure. We hypothesized that there would be a direct relationship between the amount of fluid removed and the improvement in oxygenation. We secondarily hypothesized differences in change in oxygenation between sexes, age cohorts, and pre-procedure oxygen support type. The importance of this study is to explore the risk/benefit of the standard practice of draining a pleural effusion to completion. Complete drainage may be no more beneficial than partial. This could guide future thoracentesis protocols.

2. Methods

2.1. Patients

This retrospective cohort study of inpatient therapeutic thoracentesis (TT) was conducted at Berkshire Medical Center (BMC) in Pittsfield, Massachusetts. Data was collected from February 4, 2020, to December 10, 2022. IRB exemption was obtained. The purpose was to investigate the change in oxygenation requirement with drainage of pleural fluid. All information was collected from BMC's electronic medical record system (EMR). Inclusion criteria for this study were male and female patients aged 18 to 75 who had undergone ultrasound guided TT in the inpatient setting, required supplemental oxygen before TT, and had arterial blood gasses (ABG) performed both pre and post procedure. Exclusion criteria were patients aged less than 18 or greater than 75, procedures without ultrasound guidance, and those performed in the outpatient setting. Patients who did not require supplemental oxygen before TT or did not have ABG pre and post procedure were excluded. Patients were also excluded if the procedure was solely a diagnostic thoracentesis, if it was an incomplete tap, or if it resulted in a dry tap. The cutoff age of 75 was used as it is the standard age for screening cessation for many diseases (breast cancer, lung cancer, colon cancer).

Patient records were identified using the procedure codes CPT 32555 for "thoracentesis with imaging guidance" and CPT 32557 for "pleural drainage with image guidance". The EMR was reviewed to select patients who met the stated inclusion criteria. From selected patient records, information was recorded including patient sex, age, amount of pleural fluid drained, type of supplemental oxygen used, FiO2 pre and post TT, and PaO2 from pre and post TT ABG. The data was extracted from records and de-identified. PaO2 and FiO2 values were collected to calculate the P/F. For patients on regular nasal cannula or room air, FiO2 was estimated at 0.21 for room air, and an additional 0.04 for every additional mL per nasal cannula of oxygen.

2.2. Procedure

Each patient underwent standard procedural consent for thoracentesis. TT may have been performed bedside or in the interventional radiology suite. Pleural effusion location was confirmed with ultrasound. Once the fluid was identified, the site for catheter insertion was determined, as well as the

angle and depth of insertion. This site was then sterilized, and local anesthetic was injected. With ultrasound guidance and sterile technique, a scalpel was used to incise the skin and an over-the-needle catheter was inserted through the incision. Once fluid was flowing, the needle was removed, and the catheter remained in place. The catheter was connected to a collection container. Once the fluid was removed, the catheter was removed and the incision was covered with a clean dressing.

2.3. Definitions

Therapeutic thoracentesis: A technique for removing large volumes of pleural fluid with the intent of symptom improvement. Fluid is usually drained until flow slows or stops. Therefore, we assume the amount drained is equal to the amount of effusion present.

Diagnostic thoracentesis: A technique for removing only a small sample of pleural fluid with the intent of determining the nature and potential etiology of effusion.

Incomplete tap: Pleural fluid removal is sometimes stopped before flow slows or stops if the patient develops intractable chest pain or hypotension. This is documented in the procedure note.

Dry tap: A thoracentesis which results in no pleural fluid return.

Supplemental oxygen: May include closed circuit ventilation with intubation, high flow nasal cannula, or regular nasal cannula.

P/F: The ratio of arterial oxygen partial pressure to fractional inspired oxygen. It is used to assess lung function and severity of respiratory distress.

2.4. Outcomes

The objective of this study was to determine the relationship between the change in oxygenation requirements and the amount of pleural fluid removed via TT. The primary outcome was the correlation between the change in P/F ratio and the volume of fluid. Secondary outcomes were the differences in the strength of this correlation between sexes, ages, and supplemental oxygen types.

2.5. Statistical analysis

We calculated the P/F ratio for each patient and used a T-test to compare the change in the P/F ratio to the volume of pleural fluid removed. A correlation coefficient was used to analyze the plotted data to determine if a nonlinear relationship was present. A T-test was performed to determine if there was a statistically significant difference in pre and post procedure P/F ratio. The significance level considered was $p \leq 0.05$. Correlation coefficients or ANOVA were calculated to analyze oxygenation changes compared to sex, age, and supplemental oxygen types.

3. Results

A total of 166 thoracentesis were performed between February 4, 2020, and December 10, 2022 at BMC. Of these, 22 were diagnostic and were excluded. Of the remaining 144, 128 were excluded for charts lacking data; 3 did not report volume of pleural fluid drained, and 125 did not report pre and/or post procedure ABG. There were 16 TT which met all inclusion criteria (Fig. 1). Subjects were 31% (5) female, and average age was 59 years with a range of 26–74 years. The type of oxygen support prior to TT was 38% (6) nasal cannula, 31% (5) high flow nasal cannula, 25% (4) ventilator, and 6% (1) bilevel positive airway pressure (Fig. 2).

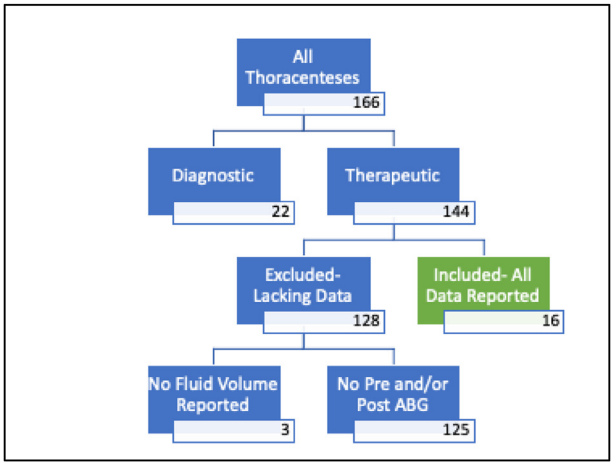

Fig. 1. Approach to data collection.

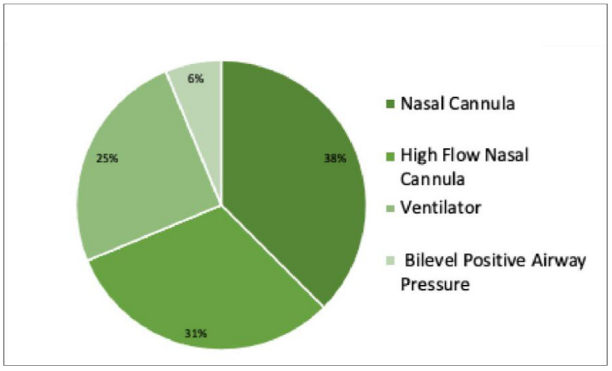

Fig. 2. Type of oxygen supplementation pre-procedure.

The amount of pleural fluid drained during TT ranged from 150 to 1500 mL with an average of 660 mL. There was a statistically significant difference in pre and post procedure P/F ratio ($p < 0.001$). The delta of the P/F ratio, which represented the change in oxygenation between pre and post TT, ranged from 34 to 300 with an average of 162. In assessing the linear relationship between the amount of pleural fluid drained and the change in oxygenation, there was no statistical significance ($p = 0.87$). r value was −0.046. A nonlinear relationship was not suggested by the plotted data (Fig. 3).

There were no statistically significant differences in oxygenation changes between sex ($p = 0.60$) or age ($p = 0.81$). There were no statistically significant differences in oxygenation changes between types of oxygen support pre-procedure ($p = 0.07$).

4. Discussion

Our study reported changes in oxygenation requirements for patients who underwent TT. We attempted to relate this change to the amount of pleural fluid removed. Sixteen TTs were assessed for this relationship. The findings demonstrated no statistical significance.

We primarily hypothesized a direct relationship between change in oxygenation and amount of fluid removed. We are unable to reject the null hypothesis that there is no significant relationship between oxygenation changes and fluid amount. Our secondary hypothesis was that there would be differences between sexes, age cohorts, and pre-procedure oxygen support type. The comparisons within these groups were not statistically significant. The small sample size may be an explanation for these findings.

Our study investigated the relationship between oxygenation changes and fluid amount. It was unique in this aspect because no other study was able to be located that has examined this relationship. Some studies look at changes in the mean P/F ratio before and after TT, unrelated to fluid removal amount. Previous studies supported that there were changes in oxygenation pre and post TT using the same metric of P/F that our study used.[5,6] Though this was not an objective of this study, our data supports a statistically significant change in oxygenation before and after TT.

There were no complications with the maximum amount of 1500 mL fluid removed during TT in our study. This aligns with the results of a 12-year review on thoracentesis, which found that removing >1500 mL of pleural fluid was significantly associated with complications.[2] Our findings support this conclusion, and support that there is no statistically significant evidence that removing more fluid leads to better oxygenation. This may suggest a protocol that stops draining pleural fluid once it reaches completion or at a maximum of 1500 mL, whichever comes first, to reduce risks of complications.

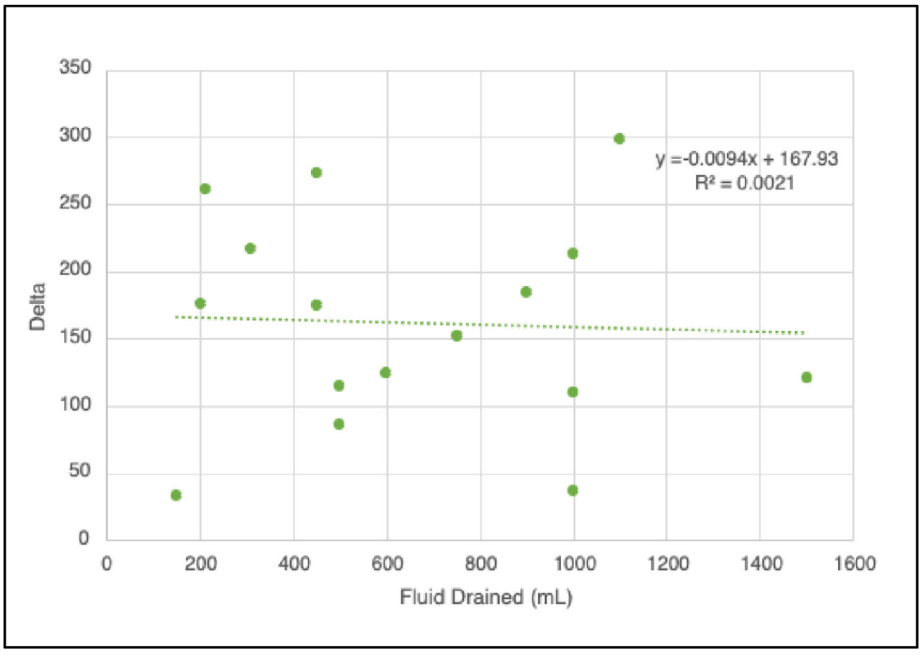

Fig. 3. Amount of pleural fluid drained vs. change in oxygenation.

Small sample size is a limitation of this study. Excluding patients with incomplete ABG data greatly reduced the sample size. This study was of retrospective design with inability to form a standardized protocol for obtaining pre and post procedure ABG. Some patients whose chart lacked ABG data did include venous blood gas (VBG) sampling. Considerations for future research would be to repeat this retrospective study allowing for inclusion of a calculated PaO2 using VBG and pulse oximetry to have a larger sample. Future studies with a prospective design may seek to create a protocol which includes obtaining pre and post procedure ABG. Other limitations include the opportunity for error with EMR documentation and retrieval of data. Our study population was selected from a single institution and geographic region, and we did not account for other health comorbidities, race, or socioeconomic status in our population. This reduces the ability for generalizability. This study did not examine the impact of underlying etiology of pleural effusion on the relationship between drainage volume and oxygenation. Future studies should explore this relationship further to better inform clinical decision-making. The strengths of this study are the easily replicated retrospective design and the ability to calculate the P/F if it was not specifically documented. Additional studies may be conducted to explore guiding future protocols regarding the amount of pleural effusion removed during TT using different criteria.

5. Conclusion

We found a statistically significant change in oxygenation before and after TT with no evidence indicating a direct correlation between the amount of fluid removed during the procedure and the improvement in oxygenation. There were no complications when removing up to 1500 mL of fluid in our study. A protocol that halts pleural fluid drainage once it is complete or when the amount removed reaches 1500 mL, whichever occurs first, may be optimal.

Conflict of interest

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