Safety of the Anterior Approach Versus the Lateral Approach for Chest Tube Insertion by Residents Treating Spontaneous Pneumothorax: A Propensity Score Weighted Analysis

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Abstract

Background Chest tube malposition (i.e., failure in inserting a chest tube to the functional sites) is the most common complication during chest tube insertion. Chest tube insertion into the thoracic cavity generally involves two approaches: the anterior approach and the lateral approach. To our knowledge, no report has compared the safety of the anterior approach with that of the lateral approach. In the present study, we compared the risk of chest tube malposition with the anterior or lateral approach for thoracostomy performed for patients with spontaneous pneumothorax by junior and senior residents. Methods We retrospectively included patients aged ≥20 years who exhibited primary or secondary spontaneous pneumothorax without pleural adhesion and underwent chest tube drainage performed by junior or senior residents at tertiary care hospital. We collected data on the patients' age, sex, and body mass index (BMI); setting of chest tube insertion; department where the chest tube was inserted; and other relevant background information. The study exposure involved insertion of the chest tube in the midclavicular line (anterior approach) or the anterior or midaxillary line (lateral approach). The primary outcome was the number of chest tube malpositions. Multiple imputation was used for missing data. The propensity score within each imputed dataset was calculated by using the collected variables. The inverse probability of treatment weighting (IPTW) method was used to adjust for baseline confounders. Results We identified 34 and 219 patients who underwent thoracostomy using the midclavicular and lateral approaches, respectively. IPTW analysis revealed that the estimated odds ratio for chest tube malposition in the anterior approach group versus the lateral approach group was 0.61 (95% confidence interval, 0.17–2.11). Conclusions In patients being treated for primary or secondary pneumothorax by junior or senior residents, the risk of chest tube malposition in thoracostomies performed using the midclavicular approach may not be lower than that in thoracostomies performed using the lateral approach.

Background

Tube thoracostomy is a standard treatment for pneumothorax.[1] Thoracostomy is an essential procedure that junior and senior residents must perform.[2] A tube thoracostomy is performed after a physician evaluates a plain chest radiograph or chest computed tomography (CT) image of the pneumothorax.[1] However, complications sometimes occur in patients who have undergone a thoracostomy by a resident, even though the resident is supervised by attending doctors. Ten percent of patients have complications after thoracostomy performed by junior residents under the supervision of attending doctors.[3]

Chest tube malposition (i.e., failure in inserting a chest tube to the functional sites) is the most common complication during chest tube insertion.[1] In fact, chest tubes may not be placed in the optimal position even when senior pulmonary residents perform the thoracostomy.[3] If patients exhibit the complication of chest tube malposition, repositioning or removal of the chest tube will be necessary. In the worst case scenario, additional tube replacement or surgery will be required. Chest tube insertion into the thoracic cavity generally involves two approaches: the anterior approach and the lateral approach.[4] The anterior approach is defined as chest tube insertion in the interspace between the first and second ribs or the second and third ribs in the midclavicular line.[5] The lateral approach is defined as chest tube insertion in the interspace between the fourth and fifth ribs in the anterior axillary line or midaxillary line. The British Thoracic Society recommends the lateral approach, which involves tube insertion from the midaxillary line (i.e. the 'safe triangle') because it reduces the risk of damage to the blood vessels, muscles, and breast tissue.[6] However, from an anatomical view, if no adhesions exist, then insertion of the tube from the midclavicular line using the anterior approach could be the better method because the tube is directed to the upper side of the thorax without coming in contact with the lungs.[7] To our knowledge, no report has compared the safety of the anterior approach with that of the lateral approach. The aim of this study was to elucidate the better of the two approaches (i.e., anterior or lateral approach) for junior and senior residents required to insert a chest tube without chest tube malposition during thoracostomy under the supervision of attending doctors in a teaching hospital.

Methods

Study Design and Participants

This retrospective cohort study was conducted between November 2018 and March 2019 and was approved by the Institutional Review Board (IRB) of Kameda Medical Center (approval number, 18–120). Kameda Medical Center is a tertiary care teaching hospital in a rural area that records 28,000 emergency department visits per year. The need for written informed consent was waived by IRB because of the retrospective nature of the study.

The study included patients aged ≥20 years who were diagnosed with primary or secondary spontaneous non-tension pneumothorax without pleural adhesion and underwent chest thoracostomy performed by junior (postgraduate years 1–2) or senior (postgraduate years 3–5) residents between April 2001 and February 2019. The resident could choose which approach to use. Plain chest radiographs or CT images acquired before thoracostomy were independently evaluated by two senior pulmonology residents (A. Shiroshita and YT), who determined the presence or absence of pleural adhesion. The residents excluded patients via consensus if thoracostomy could be performed only by the anterior approach or the lateral approach because of dense pleural adhesions. We also excluded patients if they were judged to have pneumothorax under mechanical ventilation or required concomitant fluid drainage before thoracotomy. The patients' medical records provided data on the patients' background, insertion site, and clinical course during hospitalisation.

Exposure of interest

Junior and senior residents performed thoracostomy under the supervision of attending doctors. The study exposure, which involved chest tube insertion via the anterior route (interspace between the first and second ribs or the second and third ribs in the midclavicular line) or the lateral route (interspace between the fourth and fifth ribs in the anterior axillary line or midaxillary line), was determined at the discretion of the attending physician. Chest tubes were inserted anteriorly or laterally at the discretion of the attending physician.

Other than the insertion routine, the procedure was mostly standardized. Standard chest tubes with diameters ranging from 4.0 to 9.3 mm (i.e., 12 Fr to 28 Fr) were used. The insertion site was determined using plain chest radiography or chest CT performed before thoracostomy. The insertion site was marked before the puncture. Adequate analgesia, which included topical 1% lidocaine or oral or intravenous acetaminophen, was used as premedication for all patients. Aspirating air with a small needle was attempted before inserting the chest tube. In our hospital, small-bore chest drains with a diameter of <20 Fr are usually inserted with blunt dissection using forceps, following an aseptic technique. After chest tube insertion, plain chest radiographs or CT images were used to confirm the position of the chest tube. Patients with re-expansion pulmonary edema were assessed daily for wound infection, evidence of swinging in the water seal chamber, air leak, and position of the chest tube.

Outcomes

The number of chest tube malpositions reported in the medical records were assessed as the primary outcome. Chest tube malposition was defined as clinical evidence of chest tube malfunction or failure to place the chest tube between the visceral and parietal pleural space. Malposition includes lung parenchymal, mediastinal, intrafissural, intraparenchymal, or subcutaneous insertion of a chest tube, necessitating further improvements in its position or the insertion of another drainage tube.8 The secondary outcomes were the duration of chest tube drainage (i.e., the number of days between the first chest tube insertion and chest tube removal on the resolution of the pneumothorax); the number of operations performed because of a bubbling chest tube, regardless of drainage; in-hospital mortality; and cause of death. The frequency of other complications (e.g. other organ injury, wound infection, and re-expansion pulmonary edema) were assessed as other outcomes. Other organ injury included the perforation of organs other than the lungs due to tube insertion. Infection was defined as pneumonia, empyema, and infection at the insertion site that required antibiotic treatment. Clinicians judged whether re-expansion pulmonary edema had occurred. Doctors and nurses reported data regarding complications in the patients’ medical records.

Covariates

The patients’ age, sex, and BMI; the setting where the chest tube was inserted (i.e., emergency room, clinic, or hospital); the department where the chest tube was inserted (i.e., emergency department, pulmonology department, or thoracic surgery department); and background information (i.e., chronic obstructive pulmonary disorder, interstitial pneumonia, bronchiectasis, lung cancer, and lung metastases from other origins) were considered potential confounders.

Statistical Analysis

We used the following statistical analyses for assessing the primary and secondary outcomes: (1) multiple imputation for missing data and (2) propensity score weighting.

Multiple imputation: This study had substantial missing data. Therefore, we conducted multiple imputations for the missing data. Missing data were imputed by generating 100 complete datasets using multiple imputation by chained equations approach on the assumption of data missing at random. Variables used for estimating the missing data were the patients' age, sex, and BMI; the setting where the chest tube was inserted (e.g., emergency room, clinic, or in hospital); the department where the chest tube was inserted (e.g., emergency department, pulmonology department, or thoracic surgery department); and background information (i.e., chronic obstructive pulmonary disorder, interstitial pneumonia, bronchiectasis, lung cancer, and lung metastases from other origins).

Propensity Score Weighting: The inverse probability of treatment weighting (IPTW) method, based on the propensity score, was used in each imputed dataset and subsequently averaged with Rubin's rule over datasets to estimate the treatment effects.[9,10] To perform a propensity score analysis, the probability that a patient underwent chest tube insertion anteriorly versus laterally was calculated using multivariate logistic regression analysis. The covariates introduced in the logistic regression were the clinically important confounders mentioned above. Chest wall thickness was an independent predictor of thoracostomy failure. However, chest CT imaging is needed to determine the exact thickness of the chest wall. Therefore, we used BMI as a covariate because it is correlated with the thickness of the chest wall.[11,12] Propensity score weights were stabilized by trimming the non-overlapping tails of the distributions. Age, sex, and BMI; the department where the chest tube was inserted; and a medical history with or without bronchiectasis were not well balanced after IPTW. Accordingly, we introduced these variables into the logistic regression of each database as a double-adjustment, and the data were summed and averaged.[13]

The matching weight method was used for sensitivity analysis for the primary outcome by using the same covariates used for the IPTW method with multiple imputation.[14,15] A P-value of <0.05 was considered statistically significant. All data were analyzed with R, version 3.5.0 (R Core Team, Vienna, Austria).

Results

We identified 316 patients with primary or secondary non-tension pneumothorax in whom chest tubes were inserted by junior or senior residents between April 2001 and July 2018. Among these patients, 63 patients were excluded from this study because of pleural adhesions. In the unweighted data, junior or senior residents performed chest thoracostomy during the study period in 253 patients who were ≥20 years old and had primary or secondary spontaneous pneumothorax without pleural adhesions. The midclavicular approach was used in 34 (13.4%) patients and the lateral approach was used in 219 (86.6%) patients. The patients' characteristics are summarized in Table 1.

Several differences were observed between the anterior and lateral approach groups. The differences were particularly notable in terms of the department where the chest tube was inserted. The lateral approach was commonly used in the emergency department while the anterior approach was preferred in the pulmonology department. Of the 253 patients, 69 (27.3%) had missing data. Data for BMI were lacking for 66 (26.1%) patients.

Multiple imputation, propensity scoring, and IPTW adjustment revealed that age, sex, BMI, the department where the chest tube was inserted, and a medical history of bronchiectasis were not well balanced, with a standardized mean difference of <0.1 (Table 1). After conducting multiple imputation and IPTW, the estimated odds ratio for chest tube malposition in the anterior approach group versus the lateral approach group was 0.61 (95% confidence interval, 0.17–2.11; Table 2). In the IPTW-weighted sample, the absolute risks of chest tube malposition with the anterior and lateral approaches were 11.8% and 15.5%, respectively.

For sensitivity analysis, the primary outcome was assessed using the matching weight method. The standardized mean difference between treatment groups were well balanced, with values of <0.1, after application of multiple imputation and the matching weight method. The estimated odds ratio for chest tube malposition in the anterior approach group versus the lateral approach group was 0.57 (95% confidence interval, 0.18–1.82; Table 2).

Multiple imputation and IPTW findings revealed that the duration of chest tube drainage and the number of operations for persistent air leaks were not significantly different between the anterior and lateral approaches (Table 3). The number of other complications was small in both groups (Table 4).

Discussion

This study aimed to assess whether the anterior approach is a safer method than the lateral approach for junior or senior residents to use when treating spontaneous pneumothorax. The number of chest tube malpositions was comparable between the anterior and lateral approaches, although the point estimate was in the favorable direction (odds ratio, 0.61; 95% confidence interval, 0.17–2.11). Thoracostomy is a procedure that junior and senior residents should learn. However, no studies have evaluated the safety of thoracostomy performed by residents for the treatment of spontaneous pneumothorax. We found that the anterior approach was not superior to the lateral approach in terms of the number of chest tube malpositions, in-hospital mortality, the duration of chest tube drainage, and the length of hospitalization.

According to a previous meta-analysis,[16] needle aspiration using the lateral approach in patients with trauma can be more effective than needle aspiration using the anterior approach. However, that meta-analysis was characterized by high heterogeneity. In addition, needle aspiration differs from tube thoracostomy because, unlike needle thoracentesis, tube thoracostomy requires the guidance of a tube toward an optimal position into the thorax.[1]. Thoracostomy for non-tension spontaneous pneumothorax is performed in urgent situations rather than emergent situations.[1] Therefore, patients can be placed in Fowler's position, in which air anatomically accumulates in the upper lung areas. Therefore, it is natural to insert a chest tube into a larger space. Accordingly, we hypothesized that the anterior approach would be safer than the lateral approach.

Although this observational study did not demonstrate statistically significant superiority for the anterior approach, the point estimate (odds ratio, 0.61) was in the favorable direction. Our current estimates of the absolute risk (11.8%) can help in determination of the sample size required for a randomized controlled trial in a similar patient population and setting (where residents perform thoracostomy for primary or secondary spontaneous pneumothorax without pleural adhesion). If randomized controlled trials with a randomization ratio of 1:1 are conducted in the future, we believe that 2614 patients would be needed to detect an absolute risk reduction of 3.5% (i.e., from 15.5% to 11.8%) in chest tube malposition with the anterior approach, assuming α is set at 0.05 and power is set at 0.8.[3]

This study has several limitations. First, this observational study was conducted in a single center. Strategies for thoracostomy could differ between hospitals and between doctors. In our hospital, thoracostomy with the anterior approach is commonly used, although this method may not be used in other institutions. Second, in this study, the pain scale and dose of anesthetic medications were not assessed because most medical records lacked this information. The anterior approach requires chest tube insertion through the pectoralis muscle, which can be painful for patients. However, in this study, small-bore catheters were used. In most (97.1%) patients who underwent thoracostomy with the anterior approach, a catheter of <20 Fr was used. This catheter size may reduce pain at the insertion site. At our clinical site, higher anesthetic doses are generally used with the anterior approach than with the lateral approach. Third, we used propensity score analysis to minimize confounding; however, unmeasured confounders such as the trainees' past experience in thoracostomy could have altered the results.

In conclusion, our findings suggest that thoracostomy with the anterior approach is not significantly superior to that with the lateral approach when performed by junior or senior residents for the treatment of primary or secondary non-tension pneumothorax without adhesion.

Abbreviations

BMI = body mass index; CT = computed tomography; IPTW = inverse probability of treatment weighting, IRB = Institutional Review Board

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Boards of Kameda Medical Center (approval number, 18–120). The requirement for written informed consent from the patients was waived because of the retrospective nature of this study.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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No funding was received for this study.

Authors' contributions

All of the authors contributed substantially to the study design, data analysis and interpretation, and the writing of the manuscript. Akihiro S, Y.T, K.Y, K. N. had full access to all of the data in the study and took responsibility of data curation. Akihiro S. and K. Y. performed statistical analysis and interpret the result.

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Tables

TABLE 1 Baseline Patient Characteristics

Parameter	Anterior Approach (N=34)	Lateral Approach (N=219)	Patients with Missing Data (N=69)	Standardized Mean Difference Before Multiple Imputation and IPTW* Method	Standardized Mean Difference After Multiple Imputation and IPTW* Method
Median age (y), no. (IQR‡, 25-75)	72.0 (55.8-80.5)	62.0 (36.5-76.0)	0 (0%)	0.307	0.105
Sex			0 (0%)	0.110	0.173
Men, no. (%)	30 (88.2%)	185 (84.5%)			
Women, no. (%)	4 (11.8%)	34 (15.5%)			
Body mass index, no. (SD§)	21.1 (20.0-22.6)	19.5 (18.4-23.0)	66 (26.1%)	0.267	0.103
Setting where the chest tube was inserted			2 (0.79%)	0.351	0.001
Emergency room, no (%)	21 (61.8%)	166 (57.8%)			
Clinic, no (%)	9(26.5%)	41 (18.7%)			
In hospital, no (%)	4(11.8%)	10(4.57%)			
Department where the chest tube was inserted			2 (0.79%)	0.642	0.117

Emergency department, no (%)	8 (23.5%)	50 (%)				
Pulmonology department, no (%)	16 (47.1%)	49 (22.4%)				
Thoracic surgery department, no (%)	9 (26.5%)	119 (54.3%)				
Chronic obstructive pulmonary disease, no. (%)	13 (38.2%)	48 (21.9%)	0 (0%)	0.362		0.035
Medical history						
Interstitial lung diseases, no. (%)	5 (14.7%)	15 (6.85%)	0 (0%)	0.255		0.059
Cancer, no. (%)	2 (5.88%)	9 (4.11%)	0 (0%)	0.081		0.012
Bronchiectasis, no. (%)	0 (0%)	6 (2.73%)	0 (0%)	0.237		0.220

The characteristics are presented with missing values and standardized mean differences for evaluating the balance between the treatment groups after multiple imputation and inverse probability of treatment weighting.

* IPTW = inverse probability of treatment weighting

‡ IQR = interquartile range

- SD = standard deviation

TABLE 2 Estimated Hazard Ratios for Chest Tube Malposition

Model	Estimated Odds Ratio [no. (95% CI*)]
Inverse probability of treatment weighting method	0.61 (0.17-2.11)
Matching weight method	0.58 (0.18-1.82)

The hazard ratios are calculated after using multiple imputation and the inverse probability of treatment weighting method and the matching weight method.

* CI = confidence interval

TABLE 3 Estimated Hazard Ratios for the Number of Operations and Estimated Duration of Chest Tube Drainage

	Estimation [no. (95% CI*)]
In-hospital mortality, odds ratio	2.50 (0.47-13.5)
Duration of chest tube drainage (estimated difference)	−1.88 (−3.56-0.20)
Length of hospitalization (estimated difference)	−3.86 (−8.09-0.37)

Values are calculated after using multiple imputation and the inverse probability of treatment weighting method.

* CI = confidence interval

TABLE 4 Other Complications with the Anterior and Lateral Approaches for Chest Tube Insertion

	Anterior Approach (N=34)	Lateral Approach (N=219)
Other organ injuries	0 (0%)	0 (0%)
Wound infection	0 (0%)	0 (0%)
Re-expansion pulmonary edema	0 (0%)	1 (0.45%)

The data are presented as number (percentage).

Figures

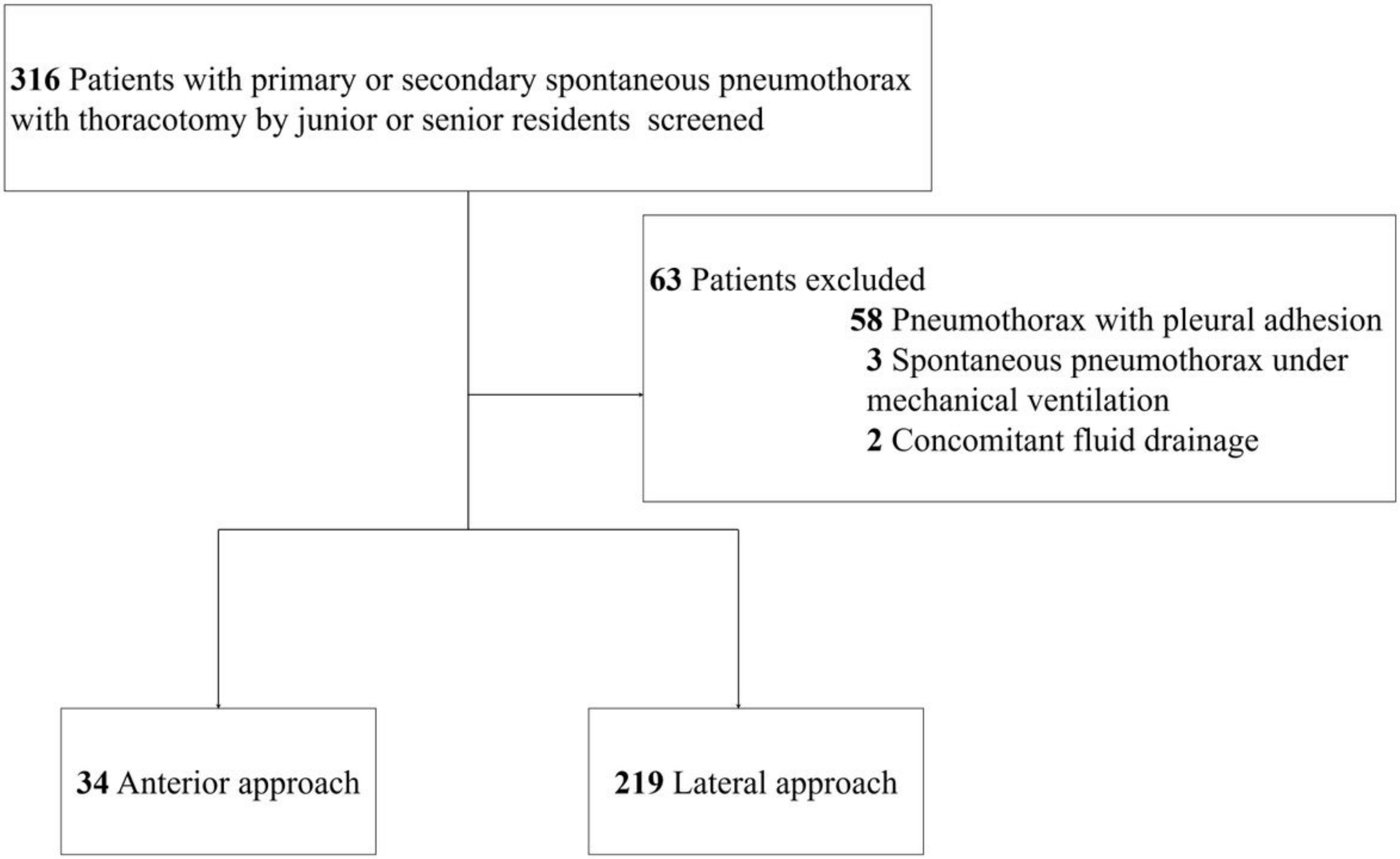

Figure 1

Patient selection flowchart