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Tube Thoracostomy: Increased angle of insertion is associated with complications

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Abstract

Introduction—Tube thoracostomy (TT), considered a routine procedure, has significant complications. Current recommendations for placement rely on surface anatomy. There is no information to guide operators regarding angle of insertion relative to chest wall. We aim to determine if angle of insertion is associated with complications of TT.

Methods—We performed a retrospective review of adult trauma patients who necessitated TT at a level I trauma center over a 2 year period (January 2012 – December 2013). TT performed intraoperatively or using radiological guidance were excluded. Thoracic anteroposterior (AP) or posteroanterior (PA) radiographs were reviewed to determine the angle of insertion of TT relative to the thoracic wall. A previously validated classification method was utilized to categorize complications. Descriptive and univariate statistics were used to compare angle of insertion and complicated vs uncomplicated TT.

Results—Review identified 154 patients who underwent a total of 246 TT placed for emergent trauma. All patients had a post-procedural chest x-ray. We identified 90 complications (37%) over the study period. 144 of the TT's reviewed had an angle of insertion less than 45 degrees of which there were 27 complications (19%). 102 of the TT's had an angle greater than 45 degrees and 63 complications (62%), $P < 0.0001$.

Conclusions—Tube thoracostomy insertion is inherently dangerous. Placement of TT using a higher angle of insertion greater than 45 degrees is associated with increased complications. Further prospective studies quantifying TT angle of insertion on outcomes are needed.

Level of Evidence—Level IV therapeutic study.

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Author Contribution

All authors have contributed to the manuscript. Matthew C. Hernandez (literature search, data collection, data analysis, data interpretation, writing). Danuel V. Laan (data analysis, data interpretation, writing, critical revision). Stacey Zimmerman (literature search, study design, data collection, data analysis). Nimesh D. Naik (literature search, study design, data collection, critical revision). Henry J. Schiller (data analysis, data interpretation, writing, critical revision). Johnathon M. Aho (data analysis, data interpretation, writing, critical revision)

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Keywords

tube thoracostomy; angle of insertion; chest drain; chest tube; emergency general surgery

Introduction

Tube thoracostomy (TT) may be a lifesaving procedure in emergent chest trauma or for space occupying lesions within the pleural cavity, if cardio-pulmonary function is compromised¹. The commonly accepted approach recommends access to the pleural space through the British Thoracic Society (BTS) triangle of safety²; an area bordered by the axillary fold superiorly, the level of the nipple or inframammary fold inferiorly, latissimus dorsi posteriorly and the lateral border of the pectoralis major anteriorly (Figure 1). Contemporary case series have highly variable methods of complication classification. Due to the variable classification methodologies used, complication rates for this procedure range widely from 20-40%³⁻⁸. Current recommendations from both the BTS and Advanced Trauma Life Support (ATLS)⁹ provide minimal information for procedural performance and lack data for insertion angle relative to chest wall and surface anatomy. Angle of insertion may be of importance given that TTs are a semi-rigid tube and placement perpendicularly to the thoracic wall may allow for increased force on the TT. This may lead to subsequent injury from this force during placement on underlying structures, kinking of the TT leading to obstruction, or a TT position leading to poor drainage. We recently have developed a TT complication classification method which is robust, validated, successfully categorizes, and classifies complications of TT¹⁰.

In this study we aim to determine if angle of insertion during tube thoracostomy placement is associated with complication rates.

Methods

We performed a retrospective review of a prospectively collected database of adult trauma patients who necessitated TT at a level I trauma tertiary referral center over a 2 year period (January 2012 – December 2013). Inclusion criteria included age greater than 15 years old, TT size greater than 20 French, who underwent TT placement. Exclusion criteria included TT performed intraoperatively or using radiological guidance. Post-procedural chest anteroposterior (AP) or posteroanterior (PA) radiographs were reviewed (by author MH) to determine the angle of TT from skin structure to thoracic wall and measured relative to the thoracic wall (Figure 2). A previously validated complication classification method (Appendix 1)¹⁰ was utilized to categorize complications. Primary endpoints were TT complications, which were grouped into major categories including: insertional, positional, removal, infective/immunologic or equipment failure (Appendix 1). Secondary outcomes included patient demographics, Body Mass Index (BMI), intercostal space of TT placement, laterality of TT, and placement location (trauma bay, ICU, prehospital).

Complication categories¹⁰ included:

- **Insertional** – Placement of TT into an intra or extrathoracic location with injury to a structure within 24 hours of placement. Injuries include, but not limited to, the lung parenchyma, esophagus, liver, great vessels, subcutaneous space etc. or other organ.
- **Positional** - Placement of a TT into the pleural space or other organ space, erosion or compression of structures greater than 24 hours after placement, or TT non-functional due to kinking, or distal obstruction.
- **Removal** - Removal of a TT resulting in a post removal pneumothorax, bleeding, requiring intervention, retained foreign body, or inadequate securement of TT and dislodgement.
- **Infective and immunologic**, - Site infection, empyema or any resulting localized or systemic inflammation due to infection or immunologic reaction
- **Instructional or equipment failure** – Malfunction or improper equipment use, such as not connecting the TT to water seal correctly, Heimlich valve connected backwards, or failure to secure TT adequately, not resulting in dislodgement but requiring intervention.

Descriptive summary, unpaired sample two tailed t-tests, ANOVA, and nominal logistic regression analyses were performed to compare complicated vs uncomplicated tube thoracostomy. Alpha level was set at 0.05. AUROC analysis was performed based on angle of insertion and complications. All data analyses were performed using JMP (SAS Institute, Inc. Cary NC)

Results

A total of 154 patients underwent 246 emergent TT during the study period. Interventions occurred in the trauma bay (n=123, 50%), surgical intensive care unit (n=105, 43%) or pre-hospital (n=18, 7%). Mean (SD) age for patients was 53 (± 21.4) years. Mean (SD) BMI for patients was 29 (± 7.8). Mean (SD) for TT intercostal space insertion location was 5.46 (± 2.15) overall. Patients who had a BMI greater than 30 had a mean TT intercostal space location of 5.52 (± 1.3)

Overall there were 90 complications (37%) for TT insertion. TT complications included insertional (n=13, 14.4%), positional (n=62, 68.9%) and removal (n=15, 16.7%) subtypes.

Complications included:

- **Insertional**- TT placement occurred in a variety of organs and anatomical spaces including liver (n=5), abutting the esophagus and causing dysphagia (n=2), mediastinum (n=4), and subcutaneous tissues (n=2) which were recognized within 24 hours.
- **Positional**- Extrathoracic placement (n=50, 81%) occurred typically with a proximal hole exposed. Positional Intrathoracic complications included

(n=12, 19%) kinking of the TT leading to obstruction and non-functional TT.

- **Removal**– All complications except one were due to post-removal pneumothorax requiring second TT, the additional complication in this group was TT spontaneously dislodging secondary to improperly securing with only medical tape.
- **Infective and immunologic, or equipment failure** had no recorded complications.

Unpaired two tailed t-tests were conducted to compare complications based upon angle of insertion. Uncomplicated TT mean angle of insertion 37.3 ($\pm$ 12.4 degrees, n = 156) was significantly less than complicated 59.8 ($\pm$ 25.3 degrees, n = 90) ($p < 0.0001$). (Figure 3).

Using univariate ANOVA analysis, only a BMI ≥ 30 was associated with increased complications or increasing angle of insertion $p = 0.04$ (Table 1). On nominal logistic regression, only an angle of greater than 45 degrees was associated with increased complications independent of BMI ($p < 0.0001$),

Insertion of TT into various rib interspaces were not significantly associated with increased angle of insertion or complications.

The ROC curve analysis of the angle of insertion is shown in Figure 4. The area under ROC (AUROC) curve of the angle of insertion was 0.79 (95% confidence interval (CI) 0.68–0.82, $P < 0.001$). When the cutoff value was set at 48.5 degrees, the Youden's index (sensitivity + specificity – 1) reached the largest value (0.48) (Appendix 2).

Discussion

Despite placement of TT in the putative anatomic triangle of safety,² increased TT angle of insertion greater than 45 degrees, viewed on post procedure chest radiograph is associated with increased complications. Our complication rate over the study period is comparable to other contemporary experiences at 37%⁴⁻⁶, which remains far from ideal. Tube thoracostomy placement by junior operators is often less than ideal⁸, possibly due to an increased angle of insertion as well as improper depth. Extrathoracic placement of the tube often left the proximal hole superficial to the skin rendering the TT ineffective.

Using our previously developed standardized methodology (Appendix)¹⁰, we were able to uniformly identify and report this data and correlate with angle of insertion as measured on radiographs. To our knowledge, this is the first association found between TT angle of insertion, elevated BMI > 30 and complications. Complications from improper placement impact patient outcomes, often necessitating TT reinsertion, delaying management, and increasing cost to the patient and rarely leads to organ damage during placement.

We have shown that an angle of insertion greater than 45 degrees is associated with increased rates of TT complications. The complications found are typically obstruction secondary to kinking, intrathoracic organ placement or placement to an inappropriate depth due to the

proximal hole incompletely inserted into the thorax. We hypothesize this may be due to TT, though not rigid, is relatively inflexible, and the force during insertion may either lead to TT kinking, penetration into organs or an inappropriate depth. An additional possibility is that when kinking does occur, this may lead a junior operator to believe, based on resistance during tube insertion that the TT is at the thoracic apex. As such, reduction of the angle of insertion may allow less force to be put on the TT and allow it to slide between the thoracic cage and organs into the apex of the pleural space and this may be reflective of a more experienced operator. Based on our results, consideration should be given during development of future ATLS and BTS guidelines on TT insertion angle.

Triangle of safety and angle of insertion

The most common error in anatomic identification among junior physicians and trainees appears to be identifying the triangle to extend below the level of the transverse nipple line at approximately the 5th or 6th intercostal space; trainees outside of a surgical specialty identify a position outside the triangle of safety 45% of the time¹¹, however this has questionable influence on complications, both in recent data¹² and our own. In this cohort, however, identification of the triangle of safety was appropriate based on radiographic data. The mean TT placement was in the fifth rib interspace. TT inserted with a more perpendicular angle was associated with complications.

An increased BMI is associated with an increased angle of insertion and complications

To our knowledge, there is no literature commenting on increased BMI as a risk factor for TT complication or having an association with TT angle of insertion. While the association of increased BMI with complications appears obvious, the association with increased angle of insertion is unknown. To our knowledge the only detrimental effect of BMI previously shown has been a study assessing time to completion which was detrimental with increased BMI¹³. In our analysis, an increased BMI ≥ 30 is associated with an increased angle of insertion, as to which causes or contributes to complications remains unclear. While patients with BMI ≥ 30 often have unreliable surface anatomy, we found TT reliably occurred within the triangle of safety. Our data would suggest that guiding the TT in a more acute angle (towards the apex of the lung) may be beneficial and have fewer complications based on multivariate analysis. This is clearly not possible in all obese patients given limited exposure and increased chest wall thickness. Insertional and positional complications apparently arise in the obese TT procedural setting due to poor visualization. Operators may be more likely to favor a less acute angle of insertion to facilitate procedural visualization.

What can be learned from our complications?

The overwhelming majority of complications were classified as insertional, positional or during removal of the TT. At our institution the majority of TT are placed by emergency medicine or surgical resident operators, which historically have had more complications with more junior trainees⁸. In order to address our complications, our institution has introduced a TT workshop for surgical and emergency medicine trainees. The goal of the workshop is to simulate proper TT insertion technique. A thoracic wall model and standardized instruments are used to give the trainee hands on experience for TT. This

skillset is retested throughout residency in preparation for the emergent patient. The aim is to have trainees increase their number of repetitions in a simulated environment.

Limitations

This study has several limitations. Foremost it is a retrospective review of our institution's experience. The single center experience also limits the generalizability of our findings. It is possible due to the retrospective nature of this study that there were complications which were not reported.

Additionally, the measurement of the angle, post insertion, may vary based on chest wall movement before radiographic imaging due to the semi-rigid nature of the TT. Furthermore, the semi-rigidity of the TT may be subject to the deforming forces within the chest wall tract but we feel this is unlikely. If the tract were to have an effect on the TT, there should be angulation within the extrathoracic portions of the TT. We believe that use of an AP and PA radiographic angle measurements are appropriate and comparable as radiographic magnification should be similar as the TT is located mid thoracic on the chest wall. The semi rigid nature of TT is influenced by TT diameter, our trauma group utilizes 20 French tube or greater, these TTs favor a more rigid device, which may alter our results.

This study needs to be prospectively validated. We are in the process of performing this analysis on TT prospectively. We believe this information regarding angle of insertion is easily determined, readily generalizable to both trauma and acute care surgery patient populations, as to causality of the angle on complications, this is unclear.

Conclusion

Increased angle of insertion is associated with complications after tube thoracostomy. Increasing angle of insertion is additionally associated with increased patient BMI. Further studies aimed at determining optimal angle of insertion of TT may be a potential method for reduction of complications.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
British Thoracic Society triangle of safety detailing anatomic borders for placement of tube thoracostomy

Figure 2.
Radiographic measurement methodology for determination of tube thoracostomy angle of insertion

Figure 3.

Angle of insertion by individual tube thoracostomy event by complicated (Red) and uncomplicated (Blue) placements. Mean angle of insertion designated (Star)

Figure 4.
Area under the receiver operating characteristic curve for Angle of Insertion and Complications.

Table 1

Comparisons of Mean Angle for Variables of Interest

		Mean Angle	SD	p value
Angle of Insertion				<0.001
	Uncomplicated (n=156)	37.3	± 12.4	
	Complicated (n=90)	59.8	± 25.3	
BMI				<0.04
	<30 , Uncomplicated (n=115)	36.3	± 12.5	
	>30 , Complicated (n=30)	67.8	±31.6	
				<0.001
	< 30, Uncomplicated (n=115)	36.3	± 12.5	
	< 30, Complicated (n=60)	55.3	± 20.8	
				< 0.001
	>30, Uncomplicated (n=41)	41.1	± 11.6	
	>30, Complicated (n=30)	67.8	± 31.6	
Rib Interspace Inserted				0.4
	2 (n=1)	25	-	
	3 (n=9)	43.75	±22.5	
	4 (n=55)	42.4	±19.2	
	5 (n=79)	46.4	±20.7	
	6 (n=57)	45.2	±16.6	
	7 (n=30)	43.1	±19.5	
	8 (n=13)	51.3	±20.16	
	9 (n=1)	80	-	