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Is observation for traumatic hemothorax safe?

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BACKGROUND

Thoracic trauma accounts for up to 25% of traumatic deaths in the United States, and the incidence of traumatic hemothoraces is estimated to approach 300,000 cases each year¹. Patients who develop traumatic hemothoraces are at risk for serious complications including respiratory failure, retained hemothorax, empyema, fibrothorax, need for thoracoscopic or open surgical intervention, and prolonged hospitalization. To prevent these complications, current consensus guidelines from the Eastern Association for the Surgery of Trauma recommend consideration of evacuation of all hemothoraces with tube thoracostomy (TT)¹. This recommendation is supported by Level III evidence. However, the decision to proceed with tube thoracostomy must be balanced against the risk of complications that may arise from thoracostomy tube placement. Data suggests that tube thoracostomy placement carries up to a 21% risk of complications².

Given this risk of complications, some patients with traumatic hemothorax might be more safely managed with observation rather than tube thoracostomy. However, a subset of observed patients may fail observation and ultimately require delayed TT. It is unknown whether patients who fail observation have inferior outcomes compared to patients who receive early TT without initial observation. Furthermore, few data are available to help clinicians distinguish between patients who can be successfully observed and those who are likely to fail observation and ultimately require TT.

To address this paucity of data, we aimed to determine the safety of selective observation in patients with traumatic hemothorax and identify predictors of failed observation. We hypothesized that the majority of patients with small hemothoraces can be successfully observed and that a subset of patients with large hemothoraces may also be successfully observed. We also

hypothesized that patients who fail observation have similar outcomes to patients who receive early TT. Finally, we hypothesized that predictors of failed observation could be identified.

METHODS

All trauma patients in a tertiary care, Level I trauma center from January 2000 through December 2014 were retrospectively reviewed in this IRB-approved study. To identify patients with traumatic hemothorax, an electronic health record query was placed with our institutional clinical data registry, the Partners Healthcare Research Patient Data Registry, using International Classification of Diseases 9th revision (ICD-9) codes 860.2 and 860.3. The Research Patient Data Registry is a centralized data warehouse that extracts clinical information from the electronic health records of hospital systems within the Partners Healthcare Network. The institutional trauma registry was also queried using these ICD-9 codes to ensure that all eligible patients were identified.

All patients with traumatic hemothorax from January 2000-December 2014 at our Level I trauma center were included in this study, and the electronic health record of each patient was reviewed. Patients who did not receive a chest CT-scan (CT) or received TT prior to CT were excluded. Patients less than 18 years of age were also excluded. Analysis was conducted on a per-patient basis. For patients with bilateral hemothoraces, only the larger hemothorax was included. We also conducted an analysis in which bilateral hemothoraces were treated as separate cases, but the results were very similar. Given the possibility that bilateral hemothoraces may be correlated and may cause confounding in a per-hemothorax analysis, we have only reported the per-patient analysis.

Hemothorax size

Digital CT images were manually reviewed to measure the size of each hemothorax and to determine the presence of concurrent pneumothorax at the time of presentation. Hemothorax size was calculated using a previously validated formula³: $V = d^2 * L$ where V is the volume in cubic centimeters, d is the greatest depth of the hemothorax on axial CT images in centimeters (a line drawn perpendicular to the chest wall in the largest fluid collection on axial imaging), and L is the greatest craniocaudal length of the hemothorax in centimeters. The greatest craniocaudal length of the hemothorax was calculated by multiplying the number of CT slices on which the hemothorax was visualized by the thickness of each CT slice. This calculation therefore accounted for differences in the CT slice thickness when different CT scanners were used. Each hemothorax was categorized as small (<300cc) or large (≥ 300 cc)⁴.

Intervention groups

Medical records were reviewed to determine whether patients were observed successfully or required surgical intervention. Intervention was categorized as: early TT (TT <24hr after CT) or initially observed (no surgical intervention within 24hr of CT). The initially observed cohort was further sub-categorized as successful observation (neither TT nor video-assisted thoracoscopic surgery/thoracotomy) or failed observation (TT or video-assisted thoracoscopic surgery/thoracotomy ≥ 24 hr after CT, including during re-admissions). Patients who did not receive TT but died within 7 days of admission were categorized separately as inevaluable due to early mortality, because they could not be observed long enough to be considered successfully observed. These patients were excluded from analyses comparing successful versus failed observation.

Patient characteristics and outcomes

Patient characteristic data included demographics (age, sex), co-morbidities, medications, mechanism of injury, Injury Severity Score (ISS), 30-day ventilation-free days, and date of injury. Medication lists were used to determine recent anticoagulant use, which was defined as warfarin use up to 2 years prior to the current hospitalization or during the current hospitalization. The Charlson Comorbidity Index was calculated for each patient.

Primary outcomes included 30-day hospital free-days, discharge disposition, and mortality. Secondary outcomes included complications (empyema, iatrogenic pneumothorax) and need for tissue plasminogen activator (tPA) administration. Empyema was defined as pleural fluid culture demonstrating bacterial growth. Iatrogenic pneumothorax was defined as a pneumothorax that was not present on initial CT but was seen on subsequent imaging after TT was placed.

Statistical analysis:

Patient characteristics and outcomes were compared across intervention groups using descriptive, univariate, and multivariable regression analyses. Outcomes were compared between patients who received TT (either early TT or failed observation) and those who did not receive TT (successful observation). Patients were followed through time of discharge and during any subsequent re-admissions before being categorized as successful observation. Outcomes were also compared between patients who received early TT and those who received delayed TT due to failed observation. Unadjusted univariate analyses were performed with χ^2 test for categorical variables, Student's *t* test for normally-distributed continuous variables, and Mann-Whitney U test for non-normally distributed continuous variables.

To identify independent predictors of failed observation among patients who were initially observed, adjusted analyses were performed with logistic regression. First, potential predictors of failed observation were identified using univariate analyses. The five most statistically significant variables on univariate analysis were included in the multivariate model: age, Charlson Comorbidity Index, hemothorax size >300cc, concurrent pneumothorax, and ventilation-free days. Furthermore, a variable denoting year of the injury was included to adjust for the possible confounding effect of changes in trauma care practice over the study period. Statistical significance was defined as $p < 0.05$. Stata version 13.1 (Stata Corp., College Station, TX, USA) was used for statistical analyses.

RESULTS

Study population

During the study period, 810 patients with traumatic hemothoraces were identified. Within this population, 340 patients met the inclusion criteria. Overall patient demographics and clinical characteristics are presented in Table 1. Average age was 55 (SD 21 years). Most patients were male (72%). The median Charlson Comorbidity Index was 2 (IQR 1-5) and 13% of patients had a history of recent anticoagulant use. The majority of patients (88%) suffered blunt injury, and the median ISS was 20 (IQR 16-29). 25% of hemothoraces were large (≥ 300 cc) and 33% involved a concurrent pneumothorax. 36% of patients required mechanical ventilation, and the median ventilation-free days was 30 (IQR 25-30)

156 of the 340 patients (46%) were treated with early TT. Of the 184 patients who were initially observed, 121 (66%) were successfully observed, 53 (29%) failed observation, and 10

(5%) did not receive TT but died within 7 days of admission and thus were unable to be observed sufficiently (Figure 1). Almost all of the successfully observed patients had small hemothoraces (119/121, 98%). However, only 11/85 (13%) of patients with large hemothoraces were initially observed and thus were eligible for successful observation. In total, 209 patients (61%) were treated with TT. 12 hemothoraces were ultimately treated with VATS and 9 hemothoraces were treated with open thoracotomy. All patients who received either VATS or open thoracotomy also received TT. Indications for VATS included retained hemothorax (75%) and hemothorax evacuation during repair of a concurrent injury (25%).

Differences in outcomes:

i) TT vs. no TT

Table 2 summarizes differences in outcomes between patients who received TT (early TT and failed observation) and those who did not receive TT. Those who received TT were more likely to have a fewer hospital-free days (19 [IQR 2-24] vs. 26 [IQR 16-28] days, $p<0.001$), be discharged to a rehabilitation facility (49% vs. 31%, $p=0.001$) and receive tPA (17% vs. 0%, $p<0.001$). Patients who did not receive TT were more likely to be discharged to their own homes (60% vs. 41%, $p=0.001$). There was no difference in mortality between those who received TT and those who did not (8% vs. 8%, $p=0.932$). All empyemas occurred in patients who received TT (4/209 vs. 0/131, $p=0.111$). In patients who received TT, the rate of iatrogenic pneumothorax was 20% (41/209).

ii) Early TT vs. delayed TT (failed observation)

Table 3 summarizes the sub-analysis comparing hemothoraces that were treated with early TT (<24 hours after CT) and those that required delayed TT due to failed observation. This

comparison demonstrated no difference in number of hospital-free days (19 [IQR 3.5-24.5] vs. 17 [IQR 0-21], $p=0.062$, mortality (8% vs. 9%, $p=0.689$), rate of empyema (2% vs. 2%, $p=0.987$), rate of iatrogenic pneumothorax (22% vs. 13%, $p=0.174$), or need for tPA administration (18% vs. 15%, $p=0.634$). Patients who received early TT were more likely to be discharged to their own homes (47% vs. 25%, $p=0.004$). Patients who required delayed TT due to failed observation were more likely to be discharged to a rehabilitation facility (64% vs. 43%, $p=0.010$)

Predictors of failed observation:

On multivariate analysis, age (OR per year older 1.03, 95% CI 1.01-1.05, $p=0.013$), ventilation-free days (OR 0.93 per ventilation-free day, 95% CI 0.89-0.97, $p=0.003$), hemothorax size ≥ 300 (OR 8.51, 95% CI 1.56-46.28, $p=0.013$), and presence of a concurrent pneumothorax (OR 4.6, 95% CI 1.94-10.94, $p=0.001$) were independent predictors of failed observation while Charlson Comorbidity Index (OR 1.05, 95% CI 0.94-1.16, $p=0.417$) and date of injury (1.08 per 5 years, 95%CI 0.65-1.79, $p=0.778$) were not (AUROC 0.80, 95% CI 0.73-0.87, Hosmer-Lemeshow goodness-of-fit 5.01, $p=0.756$)

DISCUSSION

In this study of patients presenting with traumatic hemothorax at a Level I Trauma Center, we have found that selective observation of traumatic hemothorax is safe and may result in better outcomes. The only difference in outcomes between patients who received Early TT and those who required delayed TT due to failed observation was an increased likelihood of discharge to a rehabilitation facility rather than to home in patients who failed observation. We have further found that older age, fewer ventilation-free days, hemothorax size ≥ 300 , and

presence of a concurrent pneumothorax independently predict delayed TT placement due to failed observation.

These findings are largely consistent with other papers in the literature that have investigated predictors of TT placement. For example, in a retrospective study of 749 hemothoraces published in 2015, Wells et al. found that concomitant ipsilateral flail chest, concomitant pneumothorax, and larger hemothorax size independently predicted TT placement⁵. These findings confirmed the results of previous smaller retrospective studies⁶⁻⁹. The role of mechanical ventilation in predicting TT placement has been controversial in the literature as some studies^{7,9} have found mechanical ventilation to predict TT drainage while other studies^{5,8} have not. Some of this discrepancy may be due to small cohort sizes and the lack of multivariate analyses in some studies.

Our analysis of patients who received TT (early TT or failed observation) versus those who were successfully observed confirms the findings by Wells et al., who demonstrated the association of TT with longer hospital LOS and high rates of empyema but no difference in mortality⁵. Our study additionally suggests that TT is associated with higher rates of discharge to a rehabilitation facility rather than discharge to home. Taken together, these findings suggest that avoiding unnecessary TT in patients with small hemothoraces without concurrent pneumothoraces or need for mechanical ventilation may help these stable patients leave the hospital safely and return home sooner.

We investigated differences in outcomes between patients who received early TT versus those who failed observation to determine if delay to TT had adverse consequences. Our results suggest that there was no difference in hospital-free days, mortality, rate of empyema, tPA

administration or rate of iatrogenic pneumothorax. The only difference found was an increased likelihood of being discharged to a rehabilitation facility rather than to home in the group that failed observation.

This study has several limitations. This was a single center study, and the small sample size and low number of event rates (such as rate of empyema) increases the possibility of a type two statistical error in our analyses. Furthermore, given the retrospective design of this study, our analyses cannot differentiate association from causation. Our analyses are also limited due to potential unmeasured confounders. For example, we did not specifically collect information regarding concurrent traumatic brain injury or extremity fractures, and such concurrent injuries may have influenced whether patients were discharged to a rehabilitation facility versus to their homes. Additionally, unmeasured concurrent injuries such as rib fractures and flail chest may have contributed to the success or failure of observation. Finally, the decision to perform a tube thoracostomy varies significantly among physicians and is directed not only by the patient's clinical status but also physician preference and perhaps physician experience level. Thus, one limitation of this study is that it was difficult to know whether TT was objectively required in each case, and the indication for each TT was unknown. For example in some patients, TT may have been placed due to physician preference rather than acute clinical decompensation, while in other patients, a large concurrent pneumothorax may have been the actual indication for TT placement. Furthermore, due to the retrospective nature of this study, the indication for delayed surgical intervention in patients who failed observation is unknown. Although only 2 large hemothoraces were successfully observed, only 14% of large hemothoraces were initially observed and thus eligible for successful observation. Many of these hemothoraces may have been successful observed had they not been treated immediately with TT.

Looking forward, we recommend that future studies aim to prospectively determine a set of objective criteria for placement of TT in the setting of traumatic hemothorax. Such criteria must balance the clinical risks of observation against the known complications of TT placement.

CONCLUSION

We have found that a subset of patients with traumatic hemothorax can be safely observed without tube thoracostomy. Factors that predict failed observation include older age, fewer ventilation-free days, hemothorax size ≥ 300 , and presence of a concurrent pneumothorax. Avoidance of unnecessary TT may result in better outcomes for patients who are successfully observed, with little additional risk to patients who ultimately fail observation. The results of this study have the potential to improve clinical decision-making by helping clinicians predict which patients will require TT and understand better possible risks that may be associated with initial observation.

Author Contribution Statement:

L. Demetri: study design, data acquisition, analysis and interpretation of data, manuscript development

M. Martinez Aguilar: study design, data acquisition, manuscript development

J. Bohnen: study design, analysis and interpretation of data, manuscript development

R. Whitesell: data acquisition, analysis and interpretation of data, manuscript development

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