

Validation of a safe volumetric cut-off for observation of traumatic hemothorax: A Western Trauma Association multicenter study

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BACKGROUND:	Traumatic hemothorax (HTX) contributes significantly to trauma morbidity and is frequently managed with tube thoracostomy (TT). However, TT placement has complications and some HTXs can be successfully observed. Optimal observation criteria remain unclear, and management practices vary. This multicenter study aimed to characterize current practices, determine observation failure rates, and identify predictors of safe observation.
METHODS:	We conducted a prospective observational study from July 2023 to June 2025 across 16 trauma centers. Adult patients with computed tomography-confirmed HTX were included. Exclusions included age under 18 years, TT before computed tomography, concurrent pneumothorax > 35 mm, death within 48 hours, or observation failure due to operative intervention. HTX volume was calculated using Mergo's formula ($V = d^2 \times L$). Each hemithorax was analyzed independently. The primary outcome was observation failure. HTX > 300 mL was evaluated as a predictor of failure in a multivariable logistic regression model.
RESULTS:	Among 962 HTXs in 932 patients, 68% (n = 657) were initially observed. The observation group had shorter hospital (7 vs. 9 d) and intensive care unit stays (1 vs. 3 d) compared with immediate TT ($p < 0.001$). Observation failure rate was 22% (n = 141), most commonly from HTX progression (54%). Failed observation patients had longer hospital stays (13 vs. 9 d, $p < 0.001$) but similar complication rates, secondary intervention needs, and 30-day outcomes compared with early TT. HTX volume > 300 mL strongly predicted observation failure (adjusted odds ratio, 16.01; 95% confidence interval, 8.25–31.06). Management practices varied: 52% received antibiotics with TT, 16% underwent irrigation, and thoracostomy tube sizes ranged from 8 to 36 Fr.
CONCLUSIONS:	Initial observation of HTX is frequently successful, with HTX volume > 300 mL being the strongest predictor of failure. Failed observation patients experience longer stays but similar outcomes to early TT placement. Notable practice variation highlights opportunities for research and standardization through unified practice management guidelines. (<i>J Trauma Acute Care Surg.</i> 2026;00: 00–00. Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Therapeutic/Care Management; Level III.
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Thoracic injuries are a significant source of morbidity following trauma and are present in about 60% of polytrauma patients. Traumatic hemothorax (HTX) is one of the main components of thoracic trauma, with an estimated 300,000 cases occurring annually in the United States.^{1–4} Tube thoracostomy (TT) has been the mainstay of management; however, the procedure is not completely benign and management varies between institutions. TT placement has been associated with multiple complications, including empyema, post-removal pneumothorax (PTX), mispositioning, and organ injury, with overall complication rates reported around 20%.^{5,6}

While guidelines have previously advocated for draining all hemothoraces regardless of size, the evolution of the diagnostic landscape has affected this decision-making process.⁷ The widespread use of computed tomography (CT) has improved the identification of hemothoraces that may have previously gone undetected on plain radiography.^{3,8} The ability to detect a wide range of hemothorax volumes has raised the question whether TT placement is truly indicated for every identified hemothorax. Currently, guidelines from the Eastern Association for the Surgery of Trauma (EAST) and the Western Trauma Association (WTA) are variable. EAST was not able to make a recommendation for or against routine drainage of small HTX (defined as <500 mL) and the WTA recommends observation for small hemothorax, defined as volume of 300 to 500 mL.^{9,10} The variance in size and undefined thresholds for intervention ultimately result in variability in practice patterns.

Multiple single-center studies have explored the question of observing smaller hemothoraces, and while there is variation in the volume measurement methods and size definitions, they have largely demonstrated that selective observation is safe.^{11–17} Building upon these findings, this multicenter study aimed to characterize current management practices, determine observation failure rates, and validate volume-based predictors of safe observation. We hypothesized that a hemothorax volume of 300 mL represents a safe cutoff for observation and that successful observation is associated with a shorter hospital length of stay (LOS).

METHODS

Study Design

This was a WTA multicenter prospective, observational study from July 15, 2023, to June 30, 2025. Adult trauma patients with a hemothorax confirmed on CT scan were included. Patients were excluded from analysis if they were under 18 years of age, had a thoracostomy tube (TT) or pleural intervention before initial CT scan, had a concurrent PTX > 35 mm, died within 48 hours of admission, or had a TT placed due to operative rib fixation or diaphragm repair. Each hemothorax was treated as a single entity if patients had bilateral HTX. The decision to place a TT, technique, and management were all done according to the practices of the

individual sites. The primary outcome was observation failure, defined as placement of a TT after an initial decision to observe and after a minimum of 4 hours of observation. Secondary outcomes included reasons for observation failure, TT duration, hospital LOS, complications, and need for secondary procedures. This study was approved by the institutional review board of the coordinating site, and all participating sites received approval via their individual institutional review boards. Sample size estimation was based on the precision of the primary outcome. Based on prior data, an expected observation failure rate of 20% was assumed. To achieve a 95% confidence interval (CI) with a margin of error of $\pm 4\%$, a sample size of 384 patients was required. This observational study was conducted following the STROBE guidelines (Supplemental Table 1, Supplemental Digital Content 1, <http://links.lww.com/TA/F375>).¹⁸

Data Collection

Eligible patients were identified prospectively by screening the trauma census, and individual center data were collected by each participating site and entered in a Research Electronic Data Capture (REDCap) database hosted by the coordinating site. Variables included demographic information, trauma related information [mechanism of injury, injury severity score (ISS), chest abbreviated injury scale (AIS) score, associated thoracic injuries], management details (initial management of HTX, observation failure, reason for failure, TT size, irrigation details, antibiotic use with TT placement, duration of TT), CT volume measurement of HTX and PTX size, hospital outcomes, and 30-day outcomes. The associated traumatic thoracic injuries and number of rib fractures were counted if present on the ipsilateral side of the hemothorax being analyzed. Flail chest was classified by the radiologic definition of fractures of three or more consecutive ribs in at least two places.

Hemothorax volume was calculated using the previously validated Mergo's formula: $d^2 \times L$ (d = depth, L = length, in centimeters).¹⁹ This formula was originally developed by Mergo and colleagues for rapid quantification of effusions, identifying the best correlated equation based on the principle that pleural fluid approximates a half cylinder or half cone shape. The formula demonstrated strong correlation with volumetric measurements, and has since been utilized in multiple trauma studies.^{11,12,14,15} Depth was measured as the greatest pocket of the hemothorax measured anteroposterior from the visceral pleura to the chest wall, on any axial image. Length was measured by multiplying the consecutive number of axial images with hemothorax present by the thickness of each slice. PTX size was measured by obtaining the maximum radial distance of the largest air pocket between the parietal and visceral pleural on any axial image.^{20,21} Hemothorax measurements reflect the calculated volume using Mergo's formula, measured on initial CT scan or volume at failure if repeat cross-sections were obtained.

tional imaging was available.

Statistical Analysis

Descriptive statistics were calculated, with categorical variables reported as counts and percentages and continuous data reported as median with interquartile range (IQR). Comparisons of categorical variables were performed using χ^2 or Fisher exact test as appropriate, and continuous variables were compared with Mann-Whitney U tests. Statistical significance was set at $p < 0.05$. To identify predictors of observation failure, a multivariable logistic regression model was constructed. Candidate variables were first evaluated using univariable logistic regression. Variables demonstrating statistical significance on univariable analysis and deemed clinically relevant were considered for inclusion in the multivariable model, to avoid model overfitting. Final model selection was guided by clinical judgment and a priori hypotheses, with particular emphasis on evaluating hemothorax volume > 300 mL as a predictor of failure of nonoperative management. The final multivariable model included hemothorax volume > 300 mL, number of rib fractures, flail chest, pulmonary contusion, and PTX size. Statistical analysis was performed with Stata v18 (StataCorp, College Station, TX).

RESULTS

Study Cohort

A total of 962 hemothoraces in 932 patients across 16 trauma centers met the inclusion criteria (Fig. 1). The majority were initially observed ($n = 657$, 68.2%), and the remaining 305 (31.8%) received a TT as initial management. The cohort had a median age of 58 years and was predominantly White (59.6%), non-Hispanic (89%), and male (73.1%). The most common injury type was a blunt mechanism (83.9%). Compared with observation patients, patients who initially underwent TT placement were younger, had a higher proportion of penetrating injuries, higher median ISS scores and larger hemothorax volumes and PTX sizes (Table 1). Of note, most of the cohort had a volume < 300 mL, with 174 hemothoraces (18.1%) measuring over 300 mL. Of the hemothoraces measuring > 300 mL, 117 (67.2%) received an immediate TT. In the initial observation group, 57 hemothoraces measured over 300 mL (9%), compared with 117 (38%) in the immediate TT group.

Observation Versus Immediate TT placement

The observation failure rate was 21.5%, with 141 initially observed hemothoraces requiring TT placement. The most common reason for failure was progression of hemothorax ($n = 79$, 56%), followed by new or progression of PTX. Table 2 details outcome comparisons between the two initial management cohorts. The initial observation group had lower rates of empyema (0.2% vs. 2%, $p < 0.01$) and any pulmonary complication (8.7% vs. 18.0%, $p < 0.001$), compared with the initial TT cohort.

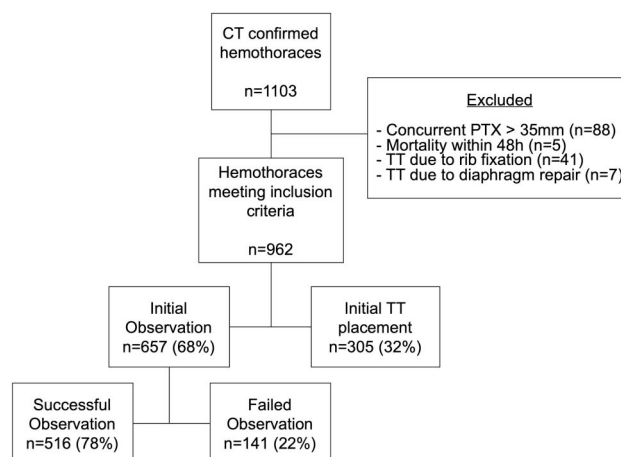


Figure 1. Patient inclusion flowchart. CT, computed tomography; PTX, pneumothorax; TT, tube thoracostomy.

They also had shorter overall (7 d vs. 9 d, $p < 0.001$) and intensive care unit (ICU) LOSs (1 d vs. 3 d, $p < 0.001$).

Observation Failure Versus Immediate TT Placement

Among patients who underwent TT placement, tube sizes ranged from 8 to 36 Fr, with the most common size used being a 28 Fr (53.4%). The largest size used was 36 Fr, which four patients received. The most common tube utilized in the observation failure cohort was a pig-tail TT (Table 3). Antibiotics were administered around the time of TT placement in just over half of cases (52.4%), and irrigation at the time of placement was performed in 16.3% of cases. When comparing the initial TT group to those who failed observation, there were similar demographic findings as compared with the whole observation cohort. The initial TT group was younger and had a higher proportion of penetrating injury; however, there were no longer differences in ISS or AIS chest scores. The time to TT placement from presentation was significantly longer in the failed observation group (52.5 h vs. 2.5 h, $p < 0.001$). Hospital LOS (13 d vs. 10 d, $p < 0.001$) and ICU LOS (5 vs 3 d, $p = 0.003$) were also longer in the failed observation group compared with initial TT. There was no difference in chest tube duration; both groups had a median duration of 4 days (IQR, 3–7, $p = 0.84$). The failed observation group had a longer time to secondary intervention from admission if required (6.5 vs. 3 d, $p < 0.001$). However, there was no statistically significant difference in the overall rate of secondary intervention, including the need for operative thoracic intervention (video-assisted thoracoscopic surgery or thoracotomy). There were also no differences in overall complications, 30-day readmission, or need for 30-day interventions (Table 3).

TABLE 1. Baseline Characteristics

Patient and Clinical Characteristics	Observation n = 657	TT Placement n = 305	Total n = 962	p
Age at admission, median (IQR)	61 (44–75)	51 (36–64)	58 (41–72)	<0.001
Male sex	467 (71.1)	236 (77.4)	703 (73.1)	0.04
Race				<0.001
White	427 (65.0)	146 (47.9)	573 (59.6)	
Black	151 (23.0)	105 (34.4)	256 (26.6)	
Other	79 (12.0)	54 (17.7)	133 (13.8)	
Non-Hispanic ethnicity	580 (90.1)	263 (86.8)	843 (89.0)	0.13
BMI, median (IQR)	26.7 (23.4–31.3)	27.3 (22.4–32.3)	26.8 (23.2–31.8)	0.84
Injury type				<0.001
Blunt	606 (92.2)	201 (65.9)	807 (83.9)	
Penetrating	51 (7.8)	104 (34.1)	155 (16.1)	
ISS, median (IQR)	14 (10–22)	17 (10–25)	14 (10–22)	0.01
AIS chest, median (IQR)	3 (3–3)	3 (3–4)	3 (3–3)	<0.001
No. rib fractures, median (IQR)	5 (2–7)	3 (1–7)	4 (2–7)	<0.001
Associated injuries				
Flail chest	85 (12.9)	36 (11.8)	121 (12.6)	0.62
Pulmonary contusion	271 (41.2)	162 (53.1)	433 (45.0)	<0.001
Diaphragm injury	16 (2.4)	51 (16.7)	67 (7.0)	<0.001
Abdominal injury	163 (24.8)	94 (30.8)	257 (26.7)	0.05
Concurrent pneumothorax	275 (41.9)	169 (55.4)	444 (46.2)	<0.001
HTX volume (mL), median (IQR)	28 (10–76)	180 (53–562)	41 (13–180)	<0.001
PTX size (mm), median (IQR)	0 (0–5)	5 (0–16)	1.7 (0–8.3)	<0.001

Bold values indicate statistical significance $p < 0.05$.

Categorical variables are presented as number (percentage).

AIS, abbreviated injury scale; BMI, body mass index; HTX, hemothorax; IQR, interquartile range; PTX, pneumothorax.

Predictors of Observation Failure

On univariable logistic regression analysis among initial observation patients, several injury-related factors were significantly associated with failure of nonoperative management. Increasing injury severity was associated with higher odds of failure, including ISS [odds ratio (OR), 1.04 per point; 95% CI, 1.02–1.06; $p < 0.001$] and AIS (OR, 1.65; 95% CI, 1.24–2.19; $p = 0.001$). Larger hemothorax volume (OR, 1.004/mL; 95% CI, 1.003–1.006; $p < 0.001$), rib fractures (OR, 1.22 per fracture; 95% CI, 1.14–1.30; $p < 0.001$), flail chest (OR, 3.08; 95% CI, 1.90–4.98; $p < 0.001$), pulmonary contusion (OR, 1.92; 95% CI, 1.32–2.80; $p = 0.001$), diaphragm injury (OR, 6.49; 95% CI, 2.32–18.18; $p < 0.001$), abdominal injury (OR, 1.72; 95% CI, 1.15–2.59; $p = 0.009$), and PTX size (OR, 1.05/mm; 95% CI, 1.03–1.08; $p < 0.001$) were also significantly associated with observation failure. Age, sex, and injury type (blunt vs. penetrating) were not significantly associated with observation failure.

In multivariable logistic regression adjusting for associated thoracic injuries (rib fractures, flail chest, pulmonary contusion, and PTX size), hemothorax volume > 300 remained the strongest independent predictor of observation failure (adjusted OR, 16.01; 95% CI, 8.25–31.06; $p < 0.001$). The associated thoracic injuries, aside from flail chest, were also associated with failure (Table 4). The multivariable model demonstrated good discrimination, with an area under the receiver operating characteristic curve of 0.79.

DISCUSSION

This multicenter prospective observational study demonstrates that selective observation of HTX is often successful, with nearly 70% of hemothoraces initially managed without intervention, and an observation failure rate of 22%. Initial observation patients, compared with immediate TT placement, have shorter hospital and ICU lengths of stay and lower rates of pulmonary complications. A hemothorax volume > 300 mL emerged as the strongest independent predictor of observation failure. While patients who ultimately failed observation experienced longer lengths of stay, they had similar complication rates, need for secondary interventions, and 30-day outcomes compared with those who received immediate TT, supporting the safety of selective observation with appropriate monitoring.

Our findings expand on prior single-center studies by prospectively examining a large, multi-center cohort of patients. In comparing prior investigations, they have varied in measurement technique and patient selection. Some used the greatest lamellar fluid strip depth^{16,17} while others used the Mergo formula, $V = d^2 \times L$.^{11,12,19} With regards to the study populations, some limited inclusion hemothorax volumes to those under 300 mL, excluded patients with a concurrent PTX, or restricted study population to those with an ISS > 12 .^{11,12,15} In contrast, our study utilized Mergo's formula across all sites and included patients with concurrent PTX up to 35 mm, which

TABLE 2. Comparison of Initial Observation versus Initial TT Placement Cohorts

Patient and Clinical Characteristics	Observation n = 657	TT Placement n = 305	Total n = 962	p
Observation failure	141 (21.5)	NA	NA	
Reason for observation failure				
Progression of hemothorax	79 (56.0)			
New/progression of pneumothorax	39 (27.7)			
Worsening respiratory symptoms	18 (12.8)			
Other	5 (3.5)			
Any pulmonary complication*	55 (8.4)	54 (17.7)	109 (11.3)	<0.001
Empyema	1 (0.2)	6 (2.0)	7 (0.7)	0.005
PNA	28 (4.3)	20 (6.6)	48 (5.0)	0.13
Post-pull PTX	4 (0.6)	10 (3.3)	14 (1.5)	0.002
Retained HTX	21 (3.2)	27 (8.9)	48 (5.0)	<0.001
Other	8 (1.2)	4 (1.3)	12 (1.2)	1.0
Hospital LOS (d), median (IQR)	7 (3–13)	9 (5–15)	7 (4–14)	<0.001
ICU LOS (d), median (IQR)	1 (0–5)	3 (0–7)	2 (0–6)	<0.001
Need for mechanical ventilation	108 (16.4)	95 (31.1)	203 (21.1)	<0.001
Duration of MV (d), median (IQR)	0 (0–2)	0 (0–5)	0 (0–3)	<0.001
Discharge status				0.24
Alive	635 (96.7)	290 (95.1)	925 (96.2)	
Dead	22 (3.3)	15 (4.9)	37 (3.8)	
Discharge disposition				0.06
Home	399 (60.7)	197 (64.6)	596 (62.0)	
Rehab/facility	206 (31.4)	73 (23.9)	279 (29.0)	
Morgue	21 (3.2)	13 (4.3)	37 (3.8)	
Other	31 (4.7)	22 (7.2)	50 (5.2)	

Bold values indicate statistical significance $p < 0.05$.

Categorical variables are presented as number (percentage).

*Includes empyema, pneumonia, post-pull pneumothorax, retained hemothorax, and other.

FR, French (catheter size); ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; MV, mechanical ventilation; NA, not applicable; TT, tube thoracostomy.

is the current WTA recommended cutoff for TT placement for a PTX, allowing for a more comprehensive assessment of real-world hemothorax management.⁹

Of the patients observed in this study, the failure rate was 22%, with the primary reason for failure being progression of the hemothorax. This is consistent with prior HTX studies and aligns with the pooled failure rate from a systematic review and meta-analysis on occult hemothorax management.^{12,22} Given that a portion of observed hemothorax patients will fail, evaluating the risks of failure and outcomes is critical. While patients who failed observation had longer hospital and ICU stays (13 vs. 10 d, 5 vs. 3 d, respectively), this appears to correspond to the delay in TT placement. There was a ~2-day delay in placing a TT in the failed observation group. Once tubes were in place, both groups had the same duration (median, 4 d), suggesting perhaps the increased LOS is attributable to the observation period before failure rather than complications. The reason for increased ICU LOS is less clear, as we did not capture specific indications for ICU admission or discharge criteria, and the presence of a TT alone does not typically necessitate ICU-level care. Despite the increased LOS, we did not find a difference in complication rates, mortality, or 30-day outcomes. In addition, despite the delay to TT in the failed observation group, there was no difference in

the need for operative thoracic intervention. However, we recognize that ICU admission has potential for additional complications and risks not captured in this data. These findings suggest that a trial of observation with appropriate monitoring does not appear to adversely affect major clinical outcomes and support the role of observation as an initial management strategy in selected patients, with the understanding that there may be a tradeoff with regard to LOS.

We observed variation in management practices across multiple aspects. Chest tube sizes spanned a wide range, with tubes up to 36 Fr being utilized, while current recommendations per the WTA recommend sizes between 14 and 28 Fr.⁹ Adjunctive practices also varied: peri-procedural antibiotics were administered in approximately half of the cases, and tube irrigation at the time of placement was performed 16% of the time. While WTA recommends antibiotic prophylaxis,⁹ and EAST conditionally recommends a dose of antibiotic prophylaxis before thoracostomy tube placement,²³ the heterogeneity seen in this study may reflect ongoing uncertainty and lack of consensus regarding optimal practice. In addition, the median hemothorax volume in the immediate chest tube group was 180 mL, suggesting that many patients in the TT group may have been suitable for initial observation, and further highlights differences in local practice patterns.

TABLE 3. Comparison of Treatment Characteristics and Outcomes in Observation Failure Versus TT Placement

Characteristics and Outcomes	Observation Failure n = 141	TT Placement n = 305	Total n = 446	p
Age at admission, median (IQR)	61 (43–75)	51 (36–64)	54 (37–68)	<0.001
Male sex	103 (73.0)	236 (77.4)	339 (76.0)	0.32
Injury type				<0.001
Blunt	129 (91.5)	201 (65.9)	330 (74.0)	
Penetrating	12 (8.5)	104 (34.1)	116 (26.0)	
ISS, median (IQR)	20 (12–26)	17 (10–25)	17 (10–25)	0.17
AIS Chest, median (IQR)	3 (3–4)	3 (3–4)	3 (3–4)	0.32
No. rib fracture, median (IQR)	6 (4–9)	3 (1–7)	4 (1–7)	<0.001
Flail chest	35 (24.8)	36 (11.8)	71 (15.9)	<0.001
Pulmonary contusion	76 (53.9)	162 (53.1)	238 (53.4)	0.88
Diaphragm injury	10 (7.1)	51 (16.7)	61 (13.7)	0.01
Abdominal injury	47 (33.3)	94 (30.8)	141 (31.6)	0.60
Concurrent PTX	78 (55.3)	169 (55.4)	247 (55.4)	0.99
Time to TT placement (h), median (IQR)	52.5 (24–120)	2.5 (1–4)	4 (2–24)	<0.001
Type of TT placed				<0.001
36 Fr	0 (0.0)	4 (1.3)	4 (0.9)	
32 Fr	8 (5.7)	45 (14.8)	53 (11.9)	
28 Fr	54 (38.3)	184 (60.3)	238 (53.4)	
Pigtail	71 (50.4)	44 (14.4)	115 (25.8)	
Other	8 (5.7)	28 (9.2)	36 (8.1)	
Irrigation with TT placement	26 (18.4)	45 (15.3)	71 (16.3)	0.40
Antibiotics with TT placement	72 (51.1)	158 (51.8)	230 (52.4)	0.88
Duration of TT (d), median (IQR)	4 (3–7)	4 (3–7)	4 (3–7)	0.84
Any pulmonary complication*	35 (24.8)	54 (17.7)	89 (20.0)	0.08
Pneumonia	12 (8.5)	20 (6.6)	32 (7.2)	0.46
Empyema	1 (0.7)	6 (2.0)	7 (1.6)	0.44
Retained HTX	20 (14.2)	27 (8.9)	47 (10.5)	0.14
Post-pull PTX	4 (2.8)	10 (3.3)	14 (3.1)	1.00
Other	3 (2.1)	4 (1.3)	7 (1.6)	0.68
Required secondary intervention	35 (24.8)	57 (18.7)	92 (20.6)	0.14
TPA	3 (2.1)	5 (1.6)	8 (1.8)	0.72
Additional TT	16 (11.3)	30 (9.8)	46 (10.3)	0.63
VATS/thoracotomy	23 (16.3)	34 (11.1)	57 (12.8)	0.13
Days to secondary intervention, median (IQR)	6.5 (4.5–11.5)	3 (2–6)	5 (3–7)	<0.001
Reason for secondary intervention*				
Worsening/retained HTX	25 (17.7)	46 (15.1)	71 (15.9)	0.48
Worsening PTX	5 (3.5)	8 (2.6)	13 (2.9)	0.59
Other	4 (2.8)	6 (2.0)	10 (2.2)	0.56
Hospital length of stay (d), median (IQR)	13 (8–20)	10 (5–15)	11 (6–17)	<0.001
ICU length of stay (d), median (IQR)	5 (2–10)	3 (0–7)	4 (0–8)	0.003
Discharge status				0.52
Alive	136 (96.5)	290 (95.1)	426 (95.5)	
Dead	5 (3.5)	15 (4.9)	20 (4.5)	
30 d ED visit	23 (16.5)	85 (28.1)	108 (24.5)	0.008
Thoracic reason for ED visit	7 (5.1)	28 (9.7)	(7.8)	0.05
30 d readmission	16 (11.3)	42 (13.8)	58 (13.0)	0.48
30 d secondary intervention	2 (1.4)	9 (3.0)	11 (2.5)	0.33
TPA	0	0	0	
VATS	0 (0)	1 (0.3)	1 (0.2)	0.50
Thoracotomy	1 (0.7)	0 (0.0)	1 (0.2)	0.14
Additional TT	1 (0.7)	8 (2.7)	9 (2.0)	0.18

Bold values indicate statistical significance $p < 0.05$

Categorical variables are presented as number (percentage).

*Patients may have multiple complications or multiple reasons for secondary intervention.

AIS, abbreviated injury scale; ED, emergency department; Fr, French (catheter size); HTX, hemothorax; ICU, intensive care unit; IQR, interquartile range; ISS, injury severity score; PTX, pneumothorax; TPA, tissue plasminogen activator; TT, thoracostomy tube; VATS, video-assisted thoracoscopic surgery.

TABLE 4. Predictors of Observation Failure: Multivariable Model

Variable	Adjusted Odds Ratio (OR) (95% Confidence Interval)	p
Hemothorax volume > 300 mL*	16.01 (8.25–31.06)	< 0.001
No. rib fractures (per fracture)	1.17 (1.08–1.26)	< 0.001
Flail chest	1.77 (0.99–3.18)	0.05
Pulmonary contusion (presence)	1.78 (1.16–2.74)	0.008
Pneumothorax size (per mm increase)	1.06 (1.03–1.09)	< 0.001

*Reflects volume as measured by Mergo's formula on initial computed tomography scan or repeat imaging at failure if available.

This study is not without limitations. The observational nature introduces inherent selection bias, as management decisions were left to individual treating teams rather than being randomly assigned. The full breadth of factors that led clinicians to observe versus place a TT were not captured, and unmeasured confounding remains. This is highlighted in part by the hemothorax volumes in our cohorts. Many patients in the observation group had very small hemothorax volumes, yet 22% progressed to requiring a TT. In addition, only 38% of the hemothoraces in the immediate TT were > 300 mL. The decision to place a chest tube may be multifactorial and beyond volume alone. We cannot determine whether immediate TT patients with smaller volumes could have been safely observed, and while we captured generalized reasons for observation failure, there is an overall heterogeneity and lack of granularity to the data that limits our ability to understand the exact clinical contexts that played a role in providers opting to place a thoracostomy tube. As management practices are not standard across participating institutions, repeat imaging and the ability to obtain progressive hemothorax volumes were not always obtained. As a result, the true volume at which observation failed could not always be determined. This affects our ability to precisely define volume thresholds and may underestimate the true hemothorax burden. In addition, we did not capture other clinical factors that may have contributed to observation failure. Our data focused on thoracic trauma and injury characteristic findings and did not include factors such as anticoagulation status or markers of physiologic derangement, which may limit the comprehensiveness in identifying predictors for observation failure. Regarding hemothorax measurements, while Mergo's formula provides a validated and standardized approach to calculating volume, it is not a true volumetric measurement and may introduce measurement error. Measurements were also performed by individual sites, introducing potential variability that may affect volume accuracy. Lastly, the majority of hemothoraces > 300 mL received an immediate TT. The relatively small proportion of hemothoraces > 300 mL managed with observation, which reflects current

clinical practice, combined with the skewed distribution of our observed patients to smaller volumes, limits our ability to determine a safe observation cutoff with the current data. We focused on the 300 mL threshold based on prior literature, and additional data would be needed to make more definitive recommendations about ideal observation safety thresholds.

CONCLUSION

Initial observation of HTX is safe and frequently successful for appropriately selected patients. A hemothorax volume > 300 mL was the strongest predictor of observation failure, though associated thoracic factors, including rib fractures, pulmonary contusion, and PTX size, also contribute to risk. Successful observation is associated with fewer complications and shorter hospital stays. When observation fails, lengths of stay are longer, but outcomes do not differ compared with early intervention. Considerable practice variation exists in hemothorax management, highlighting the need for standardized, evidence-based guidelines. Our findings support current recommendations for selective observation of small hemothoraces, and further research should evaluate volume thresholds in a randomized manner to control for selection biases to better identify optimal management strategies.

AUTHORSHIP

A.H.A., A.T., and M.d.M. contributed to the study conception and design. A.H.A., A.T., D.W., and M.d.M. contributed to the literature review. A.T., D.W., A.H.A., and M.d.M. contributed to the drafting of the manuscript. All authors participated in data acquisition, analysis, and interpretation of results. All authors provided critical revisions.

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DISCLOSURE

Conflict of Interest: All JTACS COI Disclosure forms have been supplied and are provided as Supplemental Digital Content, <http://links.lww.com/TA/F374>.

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