Predictors of retained hemothorax in trauma: Results of an Eastern Association for the Surgery of Trauma multi-institutional trial

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BACKGROUND: The natural history of traumatic hemothorax (HTX) remains unclear. We aimed to describe outcomes of HTX following tube thoracostomy drainage and to delineate factors that predict progression to a retained hemothorax (RH). We hypothesized that initial large-volume HTX predicts the development of an RH.

METHODS: We conducted a prospective, observational, multi-institutional study of adult trauma patients diagnosed with an HTX identified on computed tomography (CT) scan with volumes calculated at time of diagnosis. All patients were managed with tube thoracostomy drainage within 24 hours of presentation. Retained hemothorax was defined as blood-density fluid identified on follow-up CT scan or need for additional intervention after initial tube thoracostomy placement for HTX.

RESULTS: A total of 369 patients who presented with an HTX initially managed with tube thoracostomy drainage were enrolled from 17 trauma centers. Retained hemothorax was identified in 106 patients (28.7%). Patients with RH had a larger median (interquartile range) HTX volume on initial CT compared with no RH (191 [48–431] mL vs. 88 [35–245] mL, $p = 0.013$) and were more likely to be older with a higher burden of thoracic injury. After controlling for significant differences between groups, RH was independently associated with a larger HTX on presentation, with a 15% increase in risk of RH for each additional 100 mL of HTX on initial CT imaging (odds ratio, 1.15; 95% confidence interval, 1.08–1.21; $p < 0.001$). Patients with an RH also had higher rates of pneumonia and longer hospital length of stay than those with successful initial management. Retained hemothorax was also associated with worse functional outcomes at discharge and first outpatient follow-up.

CONCLUSION: Larger initial HTX volumes are independently associated with RH, and unsuccessful initial management with tube thoracostomy is associated with worse patient outcomes. Future studies should use this experience to assess a range of options for reducing the risk of unsuccessful initial management. (*J Trauma Acute Care Surg.* 2020;89: 679–685. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/care management study, level III.

KEY WORDS: Hemothorax; trauma; empyema; tube thoracostomy.

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Thoracic injuries represent a major source of both morbidity and mortality in trauma patients. Approximately 60% of polytrauma patients suffer an injury to the chest wall or to an intrathoracic structure, and these injuries are responsible for up to 25% of trauma-related mortality.[1–3]

In trauma patients with blunt or penetrating thoracic injuries, acute traumatic hemothorax (HTX) is one of the most common findings on initial evaluation. Traumatic HTX occurs in an estimated 300,000 patients in the United States annually. It is often associated with rib fractures, pulmonary contusion, pneumothorax, and diaphragmatic injuries.[4] Although many of these injures can be managed nonoperatively with either observation or tube thoracostomy, incomplete HTX evacuation resulting in a retained hemothorax (RH) independently predicts complications such as empyema and other poor outcomes such as pneumonia and prolonged hospital admission.[5–8] Recognition of the importance of adequate initial drainage has prompted development of several new techniques including bedside evacuation with a Yankauer suction device (Yankauer-assisted evacuation [YATS])[9,10] and irrigation of the chest cavity with warm saline.[11] However, it is not fully known what effect patient characteristics or interventions employed for HTX management may have on the development of RH or on overall patient outcomes. With this study, we sought to delineate factors that predict progression to an RH. We hypothesized that a large-volume HTX on initial computed tomography (CT) scan would predict the development of an RH and lead to worse patient outcomes.

PATIENTS AND METHODS

This was a prospective, observational, multicenter study conducted with the approval of the EAST Research Division and Multicenter Trials Committee. Each participating center either obtained approval from their individual institutional review board or relied upon the principle investigator site's institutional review board. Adult trauma patients, 18 years or older, diagnosed with an HTX between January 2016 and February 2018 were enrolled. Patients who presented after blunt or penetrating trauma that resulted in an initial diagnosis of HTX of any size identified on CT scan with volumes calculated at time of diagnosis followed by tube thoracostomy drainage within 24 hours of presentation were included. Subjects diagnosed with HTX by chest radiograph only, who underwent operative intervention as the initial management strategy; those transferred from a referring facility with any thoracic interventions already performed; and those who died in the emergency department before admission were excluded.

Hemothorax was defined as a fluid collection consistent with blood density on initial CT imaging. Size of HTX was calculated using the previously validated method for estimation of pleural effusions by Mergo et al.[12] (estimate = V [in mL] = $d^2 \cdot L$, where d is the greatest depth of HTX from the chest wall to lung on any CT image in cm and L is the craniocaudal length of the HTX obtained by multiplying the number of slices where the HTX is present by the thickness of the CT cuts in cm) (Supplemental Digital Content 1, Supplementary Fig. 1, http://links.lww.com/TA/B767). Hemothorax was further classified by volume as small (<300 mL), moderate (300–900 mL), or large (>900 mL).[8] Retained hemothorax was defined as blood-density fluid identified on follow-up CT scan or need for additional intervention after initial tube thoracostomy placement for HTX. Patients were subsequently managed according to the attending surgeon's discretion with observation, tube thoracostomy, image-guided percutaneous drainage, YATS, suction-catheter evacuation, or operative evacuation with either video-assisted thoracoscopy (VATS) or open thoracotomy.

A customized RedCAP[13] database was used to securely collect, store, and transfer patient data. Patient demographics, admission physiology, mechanism of injury, volume of initial HTX on CT imaging, and management of initial HTX and RH were recorded. In addition, we recorded Injury Severity Score, Abbreviated Injury Scale (AIS) of chest, and associated thoracic injuries. Intensive care unit (ICU), length of stay (LOS), hospital LOS, ventilator days, mortality, and complications were collected. Patients were followed until discharge from the outpatient clinic at which time Glasgow Outcomes Scale and postdischarge imaging results were also recorded.

The primary outcome of this study was to identify predictors leading to the development of an RH. Secondary outcomes included ICU and hospital LOS, development of empyema or complicated pleural effusion, number of additional interventions needed after initial management of HTX, discharge disposition, and functional outcome on initial follow-up after discharge.

Risk factors for RH were assessed using univariable and multivariable analysis. Continuous variables were compared using Student t test and the Mann-Whitney U test. The Fisher's exact test was used to compare categorical variables. All variables with a p value of <0.2 on univariable analysis and all clinically significant variables were entered into a multivariable logistic regression analysis, taking into account clustering by facility using random effects, to identify independent risk factors for RH. For the variables included in the multivariable regression analysis, 9.5% of cases had missing data. Missing values were imputed using fully conditional specification at 20 imputations in SAS version 9.4 (SAS Institute Inc., Cary, NC; 2014).[14] Data were reported as an adjusted odds ratio (OR) with 95% confidence interval (CI). A p value of <0.05 was considered statistically significant. Analyses were performed with IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY; 2019), and SAS version 9.4 (SAS Institute Inc., 2014).

RESULTS

During the 2-year study period, 1,033 patients with an HTX on initial presentation were enrolled from 17 centers within the United States and Canada. A total of 369 patients were managed with a tube thoracostomy as the initial management strategy after identification of HTX on CT imaging. These patients were further followed for development of RH (Fig. 1 and Supplemental Digital Content 2, Supplementary Fig. 2, http://links.lww.com/TA/B768).

The median (interquartile range) age of patients managed with tube thoracostomy drainage for initial HTX was 43 (27–58) years, 78.3% were male, and 30.1% sustained penetrating injury. Median Injury Severity Score was 21 (13–30), with a chest AIS of 3 (3–4). About 75.3% of HTX managed with tube thoracostomy had associated rib fractures, with a median number of 5 (0–9) ribs fractured. More than half (62.9%) were found to have pulmonary contusion, 19.0% had a flail chest, and

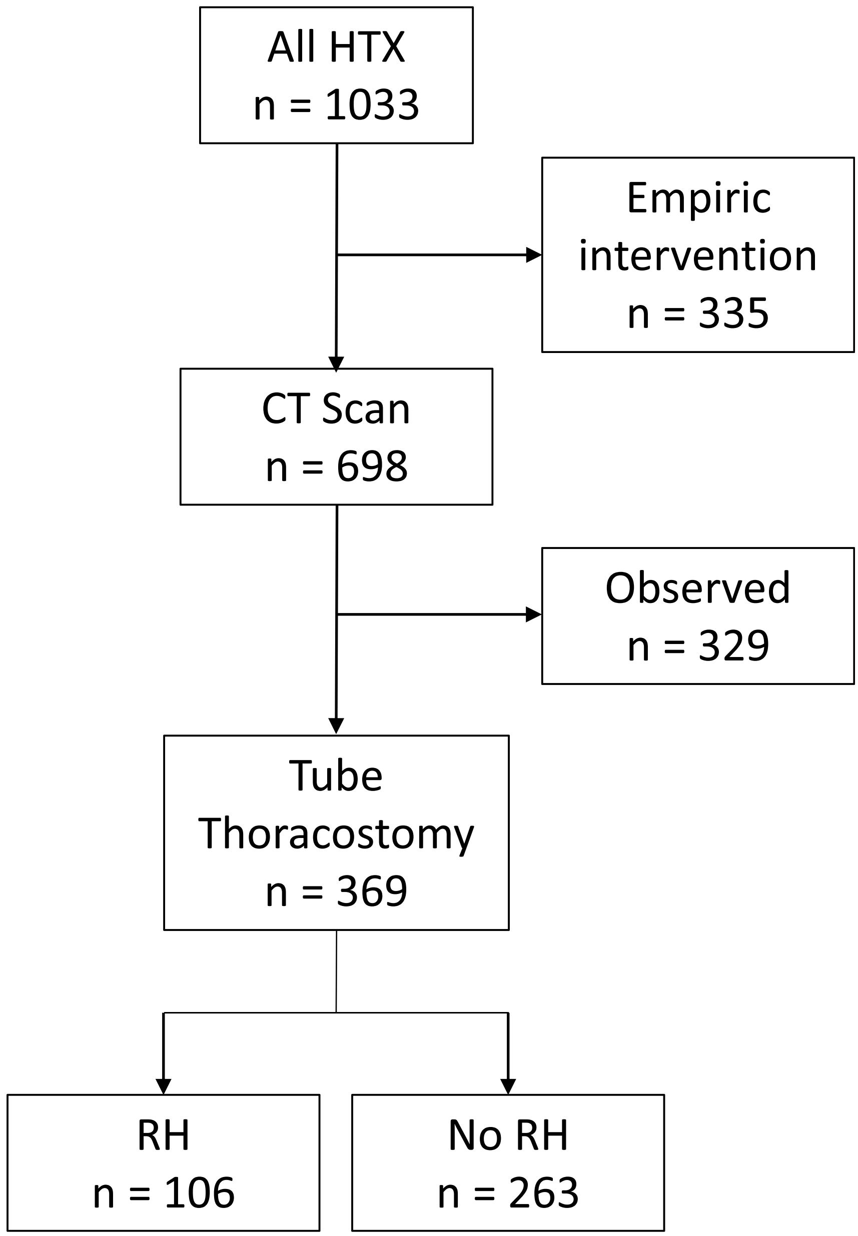

Figure 1. Study outline for patient selection and inclusion criteria.

10.3% had a diaphragm injury. Median volume of HTX on admission CT was 101 (39–317) mL (Table 1). Hemothorax size was small in 72.4% (n = 267), moderate in 21.4% (n = 79), and large in 6.2% (n = 23) of patients treated with tube thoracostomy drainage (Table 1).

Tube thoracostomy was used more often in moderate- and large-volume HTX when compared with small-volume HTX (89.5% [102 of 114 patients] vs. 45.7% [267 of 584 patients], $p < 0.001$) (Fig. 2*A*). Hemopneumothorax was the most common indication for tube thoracostomy placement (60.2%), followed by HTX alone (26.0%), pneumothorax (11.7%), and other unspecified indications (1.6%) (Table 2). The median volume (mL) of HTX drained in patients who received a tube thoracostomy for pneumothorax was statistically lower when compared with those with hemopneumothorax and HTX (30 [9–70] vs. 93 [37–274] vs. 280 [87–681], $p < 0.001$). Of the 267 small HTX managed with tube thoracostomy, hemopneumothorax (63.3%) was cited as the predominant reason for drainage, followed by HTX (15.6%) and pneumothorax (15.6%). Median chest tube size used for evacuation of initial HTX was 32 (28–36) Fr, with chest tube size not statistically significant among patients who developed an RH when compared with those who did not (Table 2).

About 71.3% (263 of 369 patients) of patients were successfully treated with tube thoracostomy drainage for initial HTX and did not require further intervention. Progression from

TABLE 1. Patient Demographics

	All Patients (N = 369)	RH (n = 106)	No RH (n = 263)	*p*
Age, y	43 [27–58]	51 [36–64]	38 [26–56]	0.004
Male sex	289 (78.3)	89 (84.0)	200 (76.3)	0.068
Penetrating mechanism	111 (30.1)	27 (25.5)	84 (31.9)	0.135
GCS	15 [11–15]	15 [12–15]	15 [10–15]	0.019
ISS	21 [13–30]	21 [17–29]	21 [11–33]	0.411
Chest AIS	3 [3–4]	3 [3–4]	3 [3–4]	0.015
Anticoagulant/antiplatelet use	47 (12.7)	19 (17.9)	28 (10.8)	0.051
COPD/home oxygen	11 (3.0)	6 (5.8)	5 (1.9)	0.062
Hypothermic (temp. <95°F)	22 (6.0)	2 (2.1)	20 (8.3)	0.024
Heart rate, beats/min	100 [85–113]	97 [85–113]	101 [83–113]	0.735
Hematocrit, %	38.8 [35.7–42.6]	37.8[35.6–42.0]	39.0 [35.8–43.0]	0.220
INR	1.1 [1.0–1.2]	1.1 [1.0–1.3]	1.1 [1.0–1.2]	0.590
Lactate, mmol/L	3.0 [1.8–4.6]	2.7 [1.8–4.3]	3.0 [1.9–4.8]	0.148
Rib fractures present	278 (75.3)	85 (80.2)	193 (73.7)	0.117
No. rib fractures	5 [0–9]	6 [2–9]	5 [0–8]	0.113
Flail chest	70 (19.0)	26 (24.5)	44 (16.9)	0.063
Pulmonary contusion	232 (62.9)	68 (64.2)	164 (62.8)	0.455
Diaphragm injury	38 (10.3)	20 (17.9)	18 (6.8)	0.001
Visible on CXR	122 (33.1)	41 (38.7)	81 (30.8)	0.092
Initial volume on CT scan, mL	101 [39–317]	191 [48–431]	88 [35–245]	0.013
Small (initial volume <300)	267 (72.4)	62 (58.5)	205 (77.9)	<0.001
Moderate (initial volume 300–900)	79 (21.4)	35 (33.0)	44 (16.7)	
Large (initial volume >900)	23 (6.2)	9 (8.5)	14 (5.3)	

*Values are listed as n (%) or median [IQR].
GCS, Glasgow Coma Scale; ISS, Injury Severity Score; COPD, chronic obstructive pulmonary disease; INR, international normalized ratio; CXR, chest x-ray.

initial HTX to RH occurred in 28.7% (106 of 369 patients) of patients. Of patients who were initially managed with a tube thoracostomy, 107 subsequently underwent repeat CT scan. Retained hemothorax was diagnosed in 74 patients based on CT imaging. Thirty-two patients who underwent initial drainage procedure did not have a repeat CT scan but did have a subsequent procedure. Fourteen patients had a second chest tube placed, three underwent image-guided percutaneous drainage, two were administered thrombolytic therapy, eight had a VATS, and five had a thoracotomy performed. Development of an RH varied significantly by initial HTX volume. Small HTX had an RH rate of 23.2% (62 of 267 patients) as compared with 44.3% (35 of 79 patients) for moderate and 39.1% (9 of 23 patients) for large ($p < 0.001$) (Fig. 2*B*).

Management of RH is shown in Figure 2*C*. While 33.0% (35 of 106 patients) of RH did not undergo further drainage, 67.0% (71 of 106 patients) RH required subsequent intervention. Standard chest tube and percutaneous/pigtail catheters were used in 30.2% and 6.6% of RH, respectively. Thrombolytic therapy was only attempted in 1.9% of RH. Operative management was used in 28.3% (n = 30) of RH. Of those with an operative intervention, 76.7% (23 of 30 patients) had VATS, 3.3% (1 of 30 patients) had VATS converted to thoracotomy, and 20.0% (6 of 30 patients) had a thoracotomy. Those receiving operative evacuation for RH had a lower failure rate and were less likely to require additional procedures than those who were managed with tube thoracostomy or thrombolytic therapy (6.7% [2 of 30 patients] vs. 24.4% [10 of 41 patients], $p = 0.049$).

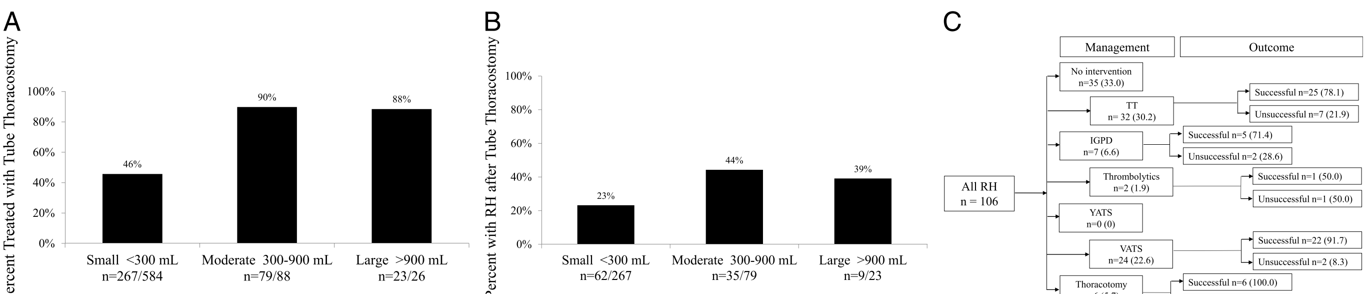

Figure 2. Management of initial HTX and RH based on CT-calculated volume. (*A*) Tube thoracostomy placement based on initial HTX volume. (*B*) Development of RH based on initial HTX volume. (*C*) Management and outcomes of RH.

TABLE 2. Chest Tube Management of Initial HTX

	RH (n = 106)	No RH (n = 263)	*p*
Standard chest tube	96 (90.6)	248 (94.3)	0.205
Percutaneous/pigtail catheter	5 (4.7)	13 (4.9)	
YATS	3 (2.8)	2 (0.8)	
Mean chest tube size, Fr	32 [28–36]	32 [28–36]	0.475
Location of placement			
Placed in ED	69 (65.1)	193 (73.4)	0.335
Placed in ICU	11 (10.4)	28 (10.6)	
Placed in OR	19 (17.9)	31 (11.8)	
Placed in inpatient ward	4 (3.8)	5 (1.9)	
Placed in IR	0 (0)	3 (1.1)	
Antibiotics given	56 (54.9)	131 (50.8)	0.278
Indication: HTX	33 (31.1)	63 (24.0)	0.099
Indication: PTX	12 (11.3)	31 (11.8)	0.529
Indication: HPTX	61 (57.5)	161 (61.2)	0.296
Indication: other	3 (2.8)	3 (1.1)	0.231

*Values are listed as n (%) or median [IQR].
OR, operating room; IR, interventional radiology; PTX, pneumothorax; HPTX, hemopneumothorax.

On univariable analysis, patients who developed an RH were more likely to be older (51 [36–64] vs. 38 [26–56], $p = 0.004$) and present with a higher chest AIS (3 [3–4] vs. 3 [3–4], $p = 0.015$). Those who developed an RH during hospital admission were also more likely to have an associated diaphragm injury when compared with those who did not develop an RH (17.9% [n = 20] vs. 6.8% [n = 18], $p = 0.001$) and have larger volume of HTX measured on initial CT scan (191 [48–431] mL vs. 88 [35–245] mL, $p = 0.013$). Those who had an initial CT-estimated volume of HTX >300 mL were more likely to progress to an RH compared with patients with a CT-estimated volume of HTX <300 mL (43.1% [44 of 102 patients] vs. 23.2% [62 of 267patients], $p < 0.001$) (Table 1).

After controlling for age, mechanism, Glasgow Coma Scale, chest AIS, temperature, antiplatelet and anticoagulant use, hematocrit, chronic obstructive pulmonary disease and home oxygen use, presence of rib fractures and flail chest, number of rib fractures, pulmonary contusion, diaphragm injury, and CT-estimated volume of HTX, multivariable analysis (Table 3) identified independent predictors of RH to include higher chest AIS (adjusted OR, 1.92; 95% CI, 1.34–2.77; $p < 0.001$), penetrating mechanism (adjusted OR, 2.14; 95% CI, 1.01–4.50; $p = 0.046$), and lower hematocrit on presentation (adjusted OR, 1.06; 95% CI, 1.02–1.11; $p = 0.008$). Computed tomography–estimated volume was also an independent predictor of RH, with a 15% increase in risk of RH for each additional 100 mL of HTX on initial CT imaging (adjusted OR, 1.15; 95% CI, 1.08–1.21; $p < 0.001$). The multivariable logistic regression model demonstrated a good fit as seen by the χ^2 statistics listed in Table 3.

TABLE 3. Multiple Variable Logistic Regression for Predictors of RH

	OR (95% CI)	*p*
Age	1.00 (0.98–1.02)	0.685
GCS	1.04 (0.97–1.12)	0.290
Chest AIS	1.92 (1.34–2.77)	<0.001
Antiplatelet/anticoagulant	1.28 (0.57–2.86)	0.544
Penetrating mechanism	2.14 (1.01–4.50)	0.046
Number of rib fractures	1.04 (0.97–1.12)	0.279
Decreased hematocrit, %	1.06 (1.02–1.11)	0.008
Pulmonary contusion	1.32 (0.77–2.27)	0.305
Volume per 100 mL	1.15 (1.08–1.21)	<0.001

$\chi^2 = 77.02$, $p = <0.001$.
GCS, Glasgow Coma Scale.

Outcomes of HTX and RH are shown in Table 4. Compared with patients who did not develop an RH, those who did develop an RH had a longer hospital LOS, longer ICU LOS, and increased ventilator days. Patients with an RH were also more likely to develop pneumonia but not an empyema. About 54.7% of patients with an HTX managed with tube thoracostomy on presentation were ultimately discharged directly home from the hospital, and those with an RH had worse functional outcomes as measured by Glasgow Outcomes Scale at time of discharge from the hospital (4 [3–5] vs. 4 [4–5], $p = 0.021$) and at first follow-up visit (5 [3–5] vs. 5 [4–5], $p = 0.043$). Patients had a median hospital LOS of 9 (5–14) days and were followed until discharge from the outpatient clinic. Median time to first follow-up visit was postinjury day 21 (15–31) with a median length of follow-up until discharge from clinic of 22 (14–38) days.

DISCUSSION

Acute traumatic HTX is common after thoracic injury and represents a major source of morbidity in polytrauma patients. The purpose of this prospective, observational, multicenter trial

TABLE 4. Outcomes

	All Patients (N = 369)	RH (n = 106)	No RH (n = 263)	*p*
Hospital LOS	9 [5–14]	13 [8–21]	6 [4–12]	0.002
ICU LOS	2 [0–8]	5 [1–10]	2 [0–5]	0.001
Ventilator days	0 [0–4]	1 [0–5]	0 [0–2]	0.044
Complications				
Mortality	32 (8.7)	9 (8.5)	23 (8.7)	0.127
Empyema	1 (0.3)	1 (0.9)	0 (0)	0.260
Pneumonia	57 (15.4)	32 (30.2)	25 (9.5)	<0.001
Discharge location				
Home	202 (54.7)	51 (48.1)	151 (57.4)	0.336
Acute/inpatient rehab	76 (20.6)	28 (26.4)	48 (18.3)	
Skilled nursing facility	25 (6.8)	7 (6.6)	18 (6.8)	
Long-term acute care facility	24 (6.5)	9 (8.5)	15 (5.7)	
Glasgow Outcome Score**				
At hospital discharge (n = 342)	4 [3–5]	4 [3–5]	4 [4–5]	0.021
At first follow-up appointment (n = 157)	5 [4–5]	5 [3–5]	5 [4–5]	0.043

*Values are listed as n (%) or median [IQR].
**Overall rating of functional outcome, ranging from 1 to 5, with 1 as death; 2, vegetative state; 3, severe disability; 4, moderate disability; and 5, good recovery.

was to describe patient characteristics associated with initial HTX management and to identify predictors of progression to an RH. In this study, 29% of patients with any HTX on admission had an RH on subsequent imaging, with a greater than 40% RH rate in those initially presenting with moderate and large HTX. Higher chest AIS, penetrating mechanism, lower presenting hematocrit, and larger initial HTX volume on CT scan were identified as independent predictors of RH, with a 15% increase in risk of RH for each additional 100 mL of HTX on initial CT imaging. Initial tube thoracostomy size was not associated with development of an RH. Patients with an RH had worse outcomes, including longer ICU and hospital LOS, prolonged ventilator days, and increased rates of pneumonia. Retained hemothorax was also associated with worse functional outcomes at discharge and first outpatient follow-up; however, only 0.3% with an HTX and 0.9% with an RH developed an empyema.

Historically, the rate of RH after thoracic injury was estimated at 5% to 30% based on single-center retrospective data.[15,16] Our study confirms that the rate of RH is near the upper end of this estimate, at 29%. Previously, RH has also been linked to development of empyema[5,6,17–19] and to fibrothorax.[20] In our study, only 0.3% of patients with an HTX and 0.9% of those with an RH went on to develop an empyema. This rate is considerably lower than historic rates and the 26.8% rate of empyema occurring after RH recently reported by Dubose et al.[7,8] Also in contrast to historic studies, no patients in this study progressed to a fibrothorax. Improved diagnostic imaging and earlier interventions could be partly responsible for these findings, although empyema or fibrothorax may have developed after discharge from clinic or in those who did not present for follow-up.

Patients with CT-estimated volumes of <300 mL were also less likely to progress to an RH. This is consistent with recent literature suggesting that selective observation of traumatic HTX is safe and may result in better outcomes, although HTX size of >300 mL independently predicts delayed tube thoracostomy placement because of failed observation.[21] Our low rates of subsequent empyema and fibrothorax development after initial HTX suggest that drainage of all hemothoraces may not be universally necessary, especially in patients who present with CT-estimated volumes of <300 mL. However, we did find that moderate- and large-volume HTX had increased rates of RH compared with small-volume HTX when initially treated with tube thoracostomy and larger volumes of HTX on initial imaging predicted development of an RH. Because CT-estimated volume of initial HTX predicts development of an RH, volume estimates on presenting imaging may be used to identify patients who benefit from earlier operative intervention, such as VATS, to mitigate progression to an RH and subsequent worse outcomes such as prolonged hospital and ICU LOS, ventilator days, and pneumonia.

Historically, large-caliber tube thoracostomy was recommended as initial treatment of choice for traumatic HTX and pneumothorax,[22] although a prospective analysis in 2012 of tube thoracostomy size demonstrated no difference in outcomes based on size of chest tube placed.[23] Our study showed that tube thoracostomy size was not significantly different in patients who developed an RH in comparison with those who did not, keeping with current literature. Although size of tube thoracostomy used did not differ among groups, only 4.9% of initial HTX were managed with percutaneous or pigtail catheters. These smaller caliber tubes warrant further investigation because they may prove to be just as efficacious as larger caliber tubes in evacuation of blood from the thoracic cavity.

Despite efforts to improve primary management of traumatic HTX, rates of RH remain high.[1,10,24–27] For this reason, early identification of HTX on initial presentation and the selection of appropriate subsequent management represent important subjects of investigation. Specifically, selection criteria for initial observation should be delineated with further prospective studies based on our results. Patients with multiple risk factors for development of an RH, such as higher chest AIS, penetrating mechanism, lower hematocrit on admission, and large volume HTX on presentation may benefit from YATS,[9,10] irrigation with warm saline during initial insertion,[11] and early reimaging with CT. Finally, if an RH does develop, our results indicate a benefit to operative intervention compared with various nonoperative strategies; however, this should be further validated prospectively.

To our knowledge, this is the only prospective, observational, multicenter trial to investigate the management of traumatic HTX after initial presentation. Despite its prospective design, our present investigation has some important limitations. The study is observational only, based on a convenience sample of patients, which may not be reflective of all patients with an HTX on initial presentation. Not fully assessing the influence of pneumothorax on the decision to drain an HTX is also a noted limitation, although pneumothorax was cited as the indication or partial indication to place a tube thoracostomy in more than 70% of patients with HTX of any size and in almost 80% of small HTX. In addition, use of follow-up imaging varied among participating centers, possibly not capturing the true incidence of RH development, regardless of size or need for further intervention. Resources available at participating centers and individual surgeon experience also may have biased the strategies chosen for management of HTX, and various practice patterns and preexisting treatment protocols or lack of a protocol could have led to bias in preferred interventions.

This study highlights the need for continued work to reduce the rate of RH and to define the optimal management once an RH develops. Nearly 30% of HTX initially managed with a tube thoracostomy were incompletely evacuated, leading to longer hospital courses and increased infectious complications. Future work should seek to identify characteristics that predict successful observation and further evaluate adjuncts to initial thoracostomy insertion that will minimize RH rates. Finally, for management of an RH, patient selection for no intervention as compared with additional tube insertion, intrapleural thrombolysis, or operative intervention still needs to be defined. These data can serve to better define future randomized studies evaluating these various options.

In conclusion, this study sought to characterize the management and outcomes of initial traumatic HTX and identify risk factors leading to the progression of an RH. Higher chest AIS, penetrating mechanism, lower hematocrit, and larger-volume HTX on admission were identified as independent predictors of subsequent development of an RH, leading to increased hospital morbidity and worse functional outcomes. Further investigation is warranted to determine optimal management strategies that may mitigate the progression of these high risk patients to an RH.

AUTHORSHIP

This work represents the original efforts of the investigators. P.S.P., S.A.M., M.J.S., and J.W.C. performed literature search, study design, data collection, data analysis, data interpretation, article development, and critical revision. The remaining authors contributed to data collection, data interpretation, and critical revision.

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DISCLOSURE

The authors declare no conflicts of interest.

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