Thoracic cavity irrigation prevents retained hemothorax and decreases surgical intervention in trauma patients

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INTRODUCTION: Retained hemothorax (HTX) is a common complication following thoracic trauma. Small studies demonstrate the benefit of thoracic cavity irrigation at the time of tube thoracostomy (TT) for the prevention of retained HTX. We sought to assess the effectiveness of chest irrigation in preventing retained HTX leading to a secondary surgical intervention.

METHODS: We performed a single-center retrospective study from 2017 to 2021 at a Level I trauma center, comparing bedside thoracic cavity irrigation via TT versus no irrigation. Using the trauma registry, patients with traumatic HTX were identified. Exclusion criteria were TT placement at an outside hospital, no TT within 24 hours of admission, thoracotomy or video-assisted thoracoscopic surgery (VATS) prior to or within 6 hours after TT placement, VATS as part of rib fixation or diaphragmatic repair, and death within 96 hours of admission. Bivariate and multivariable analyses were conducted.

RESULTS: A total of 370 patients met the inclusion criteria, of whom 225 (61%) were irrigated. Patients who were irrigated were more likely to suffer a penetrating injury (41% vs. 30%, $p = 0.03$) and less likely to have a flail chest (10% vs. 21%, $p = 0.01$). On bivariate analysis, irrigation was associated with lower rates of VATS (6% vs. 19%, $p < 0.001$) and retained HTX (10% vs. 21%, $p < 0.001$). The irrigated cohort had a shorter TT duration (4 vs. 6 days, $p < 0.001$) and hospital length of stay (7 vs. 9 days, $p = 0.04$). On multivariable analysis, thoracic cavity irrigation had lower odds of VATS (adjusted odds ratio, 0.37; 95% confidence interval [CI], 0.30–0.54), retained HTX (adjusted odds ratio, 0.42; 95% CI, 0.25–0.74), and a shorter TT duration ($\beta = -1.58$; 95% CI, −2.52 to −0.75).

CONCLUSION: Our 5-year experience with thoracic irrigation confirms findings from smaller studies that irrigation prevents retained HTX and decreases the need for surgical intervention. (*J Trauma Acute Care Surg.* 2024;97: 90–95. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level III.

KEY WORDS: Retained hemothorax; thoracic irrigation; traumatic hemothorax; tube thoracostomy ; video-assisted thoracoscopic surgery.

Traumatic hemothorax (HTX) is a common complication of thoracic trauma with an annual incidence of 300,000 cases in the United States.[1] Most HTXs are managed with tube thoracostomy (TT) placement to evacuate the blood.[2,3] In approximately 20% to 25% of cases, TT fails to clear the blood, leading to a retained HTX. Retained HTX, defined as residual blood remaining in the thorax for more than 72 hours, increases length of stay (LOS), the risk of a fibrothorax and empyema, and the need for chest surgery.[4] To prevent these complications, secondary interventions directed at removing the retained HTX, such as video-assisted thoracoscopic surgery (VATS) or intrapleural tissue plasminogen activator (TPA), are performed, with associated resource utilization and expose the patient to additional morbidity.[5]

Approximately 15% to 20% of retained HTX require a secondary intervention.[6,7] Over the past decade, multiple studies have focused on optimizing the management of a retained HTX, but a limited number of studies have explored prophylactic strategies to reduce the risk of retained HTX.[2,4,8–10] Prior work assessed the effectiveness of tube positioning and direct Yankauer suction evacuation at time of TT placement in preventing retained HTX; however, both techniques failed in reducing rates of retained HTX.

Recently, thoracic cavity irrigation was studied to reduce retained HTX and the need for VATS. A pilot study and a small propensity-matched prospective study demonstrated the efficacy of thoracic cavity irrigation in decreasing the incidence of retained HTX and the need for VATS.[6,7] In light of these findings, our trauma division established the use of thoracic cavity irrigation for the prevention of retained HTX as a standard. The aim of this study is to review our 5-year experience with thoracic irrigation. This is the largest single-center retrospective review assessing the effectiveness of thoracic cavity irrigation in reducing rates of retained HTX and surgical intervention. We hypothesized that thoracic irrigation would be associated with a lower rate of secondary intervention.

PATIENTS AND METHODS

Study Design

This is a single-center retrospective study (2017–2021) conducted at a Level I trauma center comparing thoracic cavity irrigation versus no irrigation in traumatic HTX. All trauma patients requiring a TT placement for a traumatic HTX or a HPTX were eligible for inclusion. Exclusion criteria were TT placement at an outside hospital, no TT within 24 hours of admission, thoracotomy or VATS prior to or within 6 hours after TT placement, patients undergoing rib fixation or diaphragmatic repair, and death within 96 hours of admission. The primary outcome of this study was the development of a retained HTX requiring a secondary intervention. Secondary intervention was defined as placement of a second TT, VATS, use of TPA, or thoracotomy. Secondary outcome measures included development of pulmonary complications (pneumonia, empyema, abscess), LOS, TT duration, 30-day mortality, and 30-day readmission. This study was approved by the institutional review board (PRO30430). This retrospective study was conducted following the STROBE guidelines (Supplementary Table 1, http://links.lww.com/TA/D677).

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Thoracic Cavity Irrigation

In line with previously published data, our Level I trauma center instituted thoracic cavity irrigation as the standard of care for the management of traumatic HTX. The thoracic irrigation involves a four-step procedure whereby the HTX is initially drained by placing a bedside TT using sterile technique. The TT is directed toward a posterior and apical intrathoracic position, and suction is applied to the TT using a sterile Yankauer to evacuate the HTX. The thoracic cavity is then irrigated with 1,000 mL of warmed saline using a Toomey syringe as a funnel. Suction is again applied to the TT to remove as much fluid/blood as possible, and then the TT is connected to the pleural drainage system.[6,7] As per institutional guideline and in compliance with previously published data, routine preprocedural antibiotics were administered prior to TT placement.

HTX Volume

Hemothorax volume (V) in cubic centimeters was calculated using the previously validated Mergo's formula ($V = d^2 \cdot L$). d is the greatest anteroposterior depth on axial imaging measured by drawing a perpendicular from the chest wall to the mediastinum, and L is the number of slices on CT scan containing an HTX multiplied by the thickness of the slice.[11]

Data Collection

Using the trauma registry, patients with thoracic trauma were identified based on the chest Abbreviated Injury Scale. Electronic medical records were used to identify patients meeting the inclusion criteria and to collect further data. Data collected included demographics (age, race, sex, body mass index), pulmonary comorbidities (chronic obstructive pulmonary disease and smoking), admission findings (laboratories, vitals, imaging), TT characteristics (type, duration, initial volume output, irrigation, volume irrigated), pulmonary complications (retained HTX, pneumonia, empyema, abscess, pulmonary embolism), surgical intervention, hospital LOS, intensive care unit LOS, discharge status, and discharge disposition.

Data Analysis

Continuous variables were expressed as median (interquartile range), while categorical variables were expressed as counts (percentages). The χ^2 test was performed to determine differences in categorical variables across both cohorts, while the Student's t test was used to determine differences in continuous variables. To control for potential confounders, multivariable logistic regressions were constructed to assess the association between thoracic cavity irrigation and retained HTX, VATS, LOS, and TT duration. Variables that had a p value of <0.1 were included in the multivariable logistic regression. The following variables were included in the multivariable analysis: age, injury type, Injury Severity Score (ISS), chest Abbreviated Injury Scale score, initial output, and type of TT. Statistical significance was defined as a $p < 0.05$. Besides pre-TT placement HTX volume, overall data missingness was low (<5%). All statistical analyses were performed using StataCorp 2021 (Stata Statistical Software: Release 17; StataCorp LLC, College Station, TX).

RESULTS

Study Population

A total of 370 patients met the inclusion criteria, of whom 225 (61%) were irrigated (Fig. 1). The median age was 43 (27–60) years, and the majority was male (78%). The median ISS and chest AIS were 17 (11–26) and 3 (2–3). The majority of patients suffered a blunt injury (63%) with motor vehicle collision being the most common mechanism of injury. Approximately 85% of patients had a concurrent PTX, and 11% presented with a bilateral HTX. The most common type of TT placed was a 28 Fr, while 13% of patients had a 14-Fr pigtail inserted. The median pre-TT placement HTX volume and initial output after TT placement were 271 (132–470) mL and 200 (71–400) mL, respectively. Patients who were irrigated were more likely to suffer from a penetrating injury (41% vs. 30%, $p = 0.03$) and less likely to have a flail chest (10% vs. 21%, $p = 0.01$). Within the irrigated cohort, 85% had a total of 1,000 mL of normal saline (NS) instilled into the thoracic cavity with a median total evacuated volume of 1,000 (800–1,100) mL (Table 1).

Outcomes

Fifty-four patients (15%) developed a retained HTX, of whom 42 (11%) underwent a VATS, 17 (5%) received intrapleural TPA, 15 (5%) required an additional TT placement, and a total of 14 patients (4%) required multiple interventions. The median time to VATS was 96 hours; however, no significant difference in timing to intervention was observed between irrigated/nonirrigated groups. Compared with the nonirrigated cohort, thoracic cavity irrigation was associated with lower rates of retained HTX (10% vs. 21%, $p = 0.01$) and VATS (6% vs. 19%, $p < 0.001$). The irrigated cohort had a shorter TT duration (4 vs. 6 days, $p < 0.001$) and hospital LOS (8 vs. 10 days, $p = 0.04$) (Table 2). No significant differences in need for a secondary TT placement, TPA instillation, 30-day mortality, and readmission rates were detected. After controlling for age, ISS, chest AIS, injury type, initial TT output, and type of TT

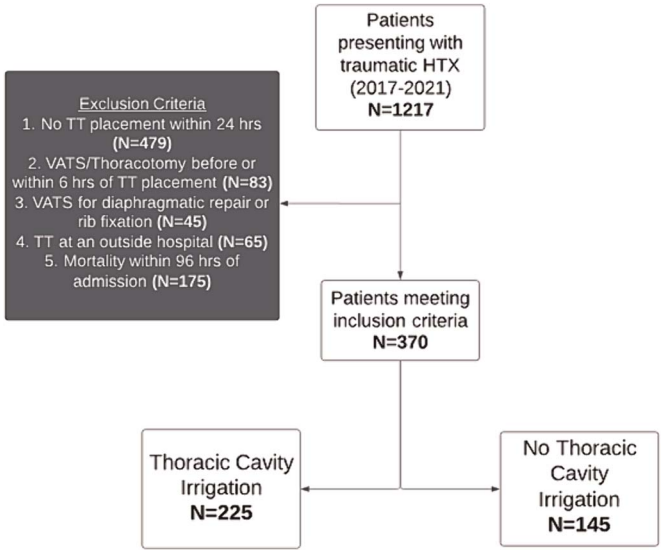

Figure 1. Consort diagram of patients meeting inclusion criteria.

TABLE 1. Baseline and Admission Characteristics Across Both Cohorts

Demographics and Admission Characteristics	Irrigation 225 (61)	No Irrigation 145 (39)	Total 370	*p*
Age, median (IQR), y	39 (26–60)	44 (31–61)	43 (27–60)	0.24
Sex				0.87
Male	177 (79)	113 (78)	290 (78)	
Female	48 (21)	32 (22)	80 (22)	
Race				0.38
White	106 (47)	76 (52)	182 (49)	
Black	103 (46)	63 (43)	166 (45)	
Other	16 (7)	6 (4)	22 (6)	
Underlying lung disease				
Current smoker	53 (24)	41 (28)	94 (25)	0.31
COPD	9 (4)	8 (6)	17 (5)	0.52
Injury type				0.03
Blunt	132 (59)	101 (70)	233 (63)	
Penetrating	93 (41)	44 (30)	137 (37)	
ED GCS, median (IQR)	15 (14–15)	15 (14–15)	15 (14–15)	0.88
ISS, median (IQR)	17 (11–25)	18 (10–32)	17 (11–27)	0.39
AIS chest, median (IQR)	3 (2–3)	3 (1–3)	3 (2–3)	0.25
SBP <90 mm Hg	25 (11)	15 (10)	40 (10)	0.45
Shock Index >0.9	32 (14)	22 (15)	54 (14)	0.54
Bilateral HTX	25 (11)	19 (14)	44 (12)	0.51
Ipsilateral rib fx, median (IQR)	3 (1–5)	3 (1–6)	3 (1–5)	0.24
Flail chest	23 (10)	29 (21)	52 (14)	0.01
Pulmonary contusion	143 (64)	88 (62)	231 (63)	0.78
Diaphragmatic injury	25 (11)	16 (11)	41 (11)	0.96
Abdominal injury	66 (30)	49 (35)	115 (32)	0.29
Concurrent PTX	185 (83)	120 (85)	305 (84)	0.53
Type of TT				0.15
24–28 Fr	160 (73)	98 (69)	258 (70)	
32–36 Fr	41 (19)	23 (16)	64 (17)	
<20 Fr PG	19 (9)	22 (15)	41 (13)	
Initial output, median (IQR), mL	200 (100–400)	200 (35–438)	200 (71–400)	0.51
HTX volume, median (IQR), mL	285 (150–500)	245 (120–450)	271 (132–470)	0.2
NS volume irrigated				NA
<1,000 mL	24 (10)	NA	NA	
1,000 mL	187 (85)	NA	NA	
>1,000 mL	10 (5)	NA	NA	
Volume evacuated, median (IQR), mL	1,000 (800–1,100)	NA	NA	NA
Post-ED disposition				0.22
Floor	69 (33)	38 (26)	107 (30)	
ICU	117 (56)	82 (56)	199 (56)	
OR	20 (10)	22 (15)	42 (12)	

COPD, chronic obstructive pulmonary disease; ED, emergency department; fx, fracture; GCS, Glasgow Coma Scale; GSW, gunshot wound; ICU, intensive care unit; IQR, interquartile range; MCC, motorcycle collision; MVC, motor vehicle collision; OR, operating room; PG, pigtail; PTX, pneumothorax.

placement, thoracic cavity irrigation had lower odds of VATS (adjusted odds ratio, 0.37; 95% CI, 0.30–0.54) and retained HTX (adjusted odds ratio, 0.42; 95% CI, 0.25–0.74). In addition, it was associated with a shorter TT duration ($\beta = -1.58$; 95% CI, −2.52 to −0.75) (Table 3).

On subgroup analysis, comparing hospital complications between patients irrigated with NS <1,000 mL (n = 24) versus NS ≥1,000 mL (n = 105), no significant difference in retained HTX ($p = 0.74$), VATS ($p = 0.68$), hospital LOS ($p = 0.99$), intensive care unit LOS ($p = 0.74$), and TT duration ($p = 0.55$) was detected (Supplementary Table 2, http://links.lww.com/TA/D677).

DISCUSSION

This is the largest single-center retrospective study assessing the efficacy of thoracic cavity irrigation in the management of traumatic HTX. The results of this study confirm findings from smaller studies that thoracic cavity irrigation is

TABLE 2. Complications and 30-Day Outcomes Across Both Cohorts

Outcome	Irrigation 225 (61)	No Irrigation 145 (39)	Total N = 370	*p*
Hospital LOS, median (IQR)	7 (5–13)	9 (5–16)	8 (5–15)	0.04
ICU LOS, median (IQR)	2 (0–5)	3 (0–8)	2 (0–6)	0.13
Ventilation days, median (IQR)	0 (0–2)	0 (0–4)	0 (0–2)	0.08
TT duration, median (IQR)	4 (3–7)	6 (3–9)	5 (3–7)	<0.001
Pulmonary complications				
Retained HTX	23 (10)	31 (21)	54 (15)	<0.001
VATS	14 (6)	28 (19)	42 (11)	<0.001
Time to VATS	5 (2–10)	4 (2–7)	4 (2–8)	0.69
TPA	9 (4)	8 (6)	17 (5)	0.53
PNA	8 (4)	10 (7)	18 (5)	0.14
Empyema/parapneumonic effusion	6 (3)	9 (6)	15 (4)	0.11
ARDS	3 (1)	2 (1)	5 (1)	0.97
PE	4 (2)	4 (3)	8 (2)	0.53
30-d All cause readmission	9 (4)	6 (4)	15 (4)	0.95
Pulmonary-related readmission	5 (2)	5 (3)	10 (3)	0.35
30-d Mortality	9 (4)	7 (5)	16 (4)	0.75

ARDS, acute respiratory distress syndrome; ICU, intensive care unit; IQR, interquartile range; PE, pulmonary embolism; PNA, pneumonia.

associated with a lower incidence of retained HTX and decreased need for VATS. Based on the results of the present study, thoracic cavity irrigation was associated with a threefold decreased risk of surgical intervention for retained HTX. In the present study, a total of 225 patients underwent thoracic cavity irrigation compared with only 20 and 60, respectively, in two prior smaller studies conducted at our institution.

Retained HTX is a common complication following traumatic HTX with a reported incidence of 20%.[7,12] Prior research focused on preventing the progression to retained HTX shows that TT position does not impact need for intervention even when image-guided TT placement was explored.[13,14] One hypothesis to explain this finding is that a component of the HTX has already become a clot and therefore does not drain regardless of the size or location of the tube.[6,7] Thoracic cavity irrigation may work to prevent retained HTX by disrupting the clot while also diluting the intrapleural hemorrhagic component, thereby allowing for this blood to be removed.

Prior studies have identified several predictors of retained HTX, including penetrating injuries, type of TT, and size of the HTX.[15,16] In the current study, approximately 45% of patients presented with a penetrating injury and had a median initial output of 200 mL. Despite the presence of these risk factors, irrigation was associated with a decreased incidence of retained HTXs and reinforces the benefit of thoracic cavity irrigation at time of TT placement.

Based on the results of the current study, the irrigated cohort was three times less likely to undergo a VATS. This is lower than our historic VATS rate (15%) and also lower than the reported rates in the literature, which range from 12% to 15%.[4,6,7] In addition, the results of the current study showed a decrease in TT duration associated with irrigation. At our institution, a TT is removed when the 24-hour total output is less than 150 mL. There are many factors associated with chest tube duration, but this provides another potential benefit to performing thoracic irrigation.

In a recent retrospective study, Crankshaw et al.[17] investigated the association between volume irrigated and hospital outcomes in traumatic HTX. Those irrigated with an NS ≥1,000 mL had a statistically significant shorter hospital LOS but no difference in secondary intervention or infection rates.[17] At our institution, the irrigation protocol recommends irrigation with 1,000 mL. In the present study, noncompliance was detected in 11% of cases, a total of 24 patients with instilled volumes <1,000 mL. However, irrigation <1,000 mL was not associated with an increased secondary interventions rates or prolonged TT duration or LOS. Notably, the relatively small sample size in the <1,000 mL group might prohibit the detection of significant differences if one truly exists.

Multiple procedural options are available for managing retained HTXs, including intrapleural TPA, placement of a second TT, or VATS, all of which are associated with an increased hospital cost and LOS.[4,5] An Eastern Association for the Surgery of Trauma multicenter trial highlighted the superiority of VATS over an additional TT placement in the management of a retained HTX.[5] In the current study, approximately 80% of those who developed a retained HTX underwent a VATS, while 33% underwent TPA, 28% had a second TT placed, and 26% required multiple interventions. Fifty-three percent of people undergoing TPA instillation and 33% of patients who had a second TT placed failed these interventions and required a definitive VATS. A recent Eastern Association for the Surgery of Trauma practice management guideline conditionally recommended performing VATS over TPA for the management of retained HTXs,[18] but because of the retrospective nature of this study, we were unable to identify the rationale for why TPA was used in these cases.

This study has several limitations. First, the retrospective nature of the current study increases the risk of selection and confounding biases. Second, physician and specialty data were not collected, and the decision to irrigate the thoracic cavity at time of TT placement might differ across specialties (emergency medicine vs. trauma surgery). Despite thoracic cavity irrigation being a standard within the trauma division, the decision to perform irrigation is still at the discretion of the attending, and approximately 40% of patients with traumatic HTX were not irrigated. With the retrospective nature of the present study, reasons for noncompliance could not be evaluated. Some plausible assumptions include staff, resident, and faculty noncompliance due to unfamiliarity with the technique or the urgent need to transfer a patient to the operating room. Third, one potential

TABLE 3. Association Between Thoracic Cavity Irrigation and Outcomes: Multivariate Analysis

Outcomes	AOR/β (95% CI)	*p*
Retained HTX	0.42 (0.25–0.74)	0.01
VATS	0.37 (0.30–0.54)	0.001
Hospital LOS	1.15 (−0.68 to 2.45)	0.15
TT duration	−1.58 (−2.52 to −0.75)	0.01

AOR, adjusted odds ratio.

limitation of thoracic cavity irrigation is increased time required to place a TT. This can be particularly important in hemodynamically unstable patients. We usually do not perform thoracic irrigation in this patient group; however, omitting those who are hemodynamically unstable may lead to a treatment bias. In the present study, a similar rate of hemodynamic instability was observed across both cohorts. Fourth, quantitative assessment of HTX volume is not routinely done at our institution before placement of a TT. As part of this study, we quantified the pre-TT HTX volume, using the previously validated Mergo's formula to calculate the HTX volume when axial CT scans were available. However, significant number of patients had a TT placement prior to CT scan; accordingly, pre-TT HTX could not be quantified in these patients. Finally, approximately 10% of the irrigated cohort had a total instilled volume <1,000 mL, despite our standard being 1,000 mL. Altering the volume instilled could impact the results of the study, but there are currently no experimental data available to suggest that one volume is better than another.

CONCLUSION

Our 5-year experience with thoracic irrigation confirms findings from smaller studies that chest tube irrigation reduces retained HTXs, decreases the need for surgical intervention, and is associated with a decreased TT duration. Adoption of chest tube irrigation should be considered by centers and physicians who care for trauma patients. Further efforts are required to assess the cost-effectiveness of irrigation in thoracic trauma.

AUTHORSHIP

T.W.C. and A.H.A.T. contributed in the study concept and design. A.H.A.T., M.T., and M.M. contributed in the data collection. A.H.A.T., E.A.B., S.G., M.T., M.M., and T.W.C. contributed in the data analysis. A.H.A.T., E.A.B., S.G., M.T., M.M., J.G., J.R.P., P.B.M., R.S.M., A.E., M.A. d.M., and T.W.C. contributed in the manuscript preparation.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D678).

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