Thoracic irrigation for prevention of secondary intervention after thoracostomy tube drainage for hemothorax: A Western Trauma Association multicenter study

CONTINUING MEDICAL EDUCATION CREDIT INFORMATION

Accreditation

In support of improving patient care, this activity has been planned and implemented by CineMed and the American Association for the Surgery of Trauma. CineMed is jointly accredited by the Accreditation Council for Continuing Medical Education (ACCME), the Accreditation Council for Pharmacy Education (ACPE), and the American Nurses Credentialing Center (ANCC), to provide continuing education for the healthcare team.

AMA PRA Category 1 Credits™

CineMed designates this enduing material for a maximum of 1 *AMA PRA Category 1 Credit(s)™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

JOINTLY ACCREDITED PROVIDER™
INTERPROFESSIONAL CONTINUING EDUCATION

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, CineMed must ensure that anyone in a position to control the content of the educational activity (planners and speakers/authors/discussants/moderators) has disclosed all financial relationships with any commercial interest (termed by the ACCME as "ineligible companies", defined below) held in the last 36 months (see below for definitions). Please note that first authors were required to collect and submit disclosure information on behalf all other authors/contributors, if applicable.

Ineligible Company: The ACCME defines an "ineligible company" as any entity producing, marketing, selling, re-selling, or distributing health care goods or services used on or consumed by patients. Providers of clinical services directly to patients are NOT included in this definition.

Financial Relationships: Relationships in which the individual benefits by receiving a salary, royalty, intellectual property rights, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest, excluding diversified mutual funds), or other financial benefit. Financial benefits are usually associated with roles such as employment, management position, independent contractor (including contracted research), consulting, speaking and teaching, membership on advisory committees or review panels, board membership, and other activities from which remuneration is received, or expected.

Conflict of Interest: Circumstances create a conflict of interest when an individual has an opportunity to affect CME content about products or services of a commercial interest with which he/she has a financial relationship.

The ACCME also requires that CineMed manage any reported conflict and eliminate the potential for bias during the session. Any conflicts noted below have been managed to our satisfaction. The disclosure information is intended to identify any commercial relationships and allow learners to form their own judgments. However, if you perceive a bias during the educational activity, please report it on the evaluation. All relevant financial relationships have been mitigated.

AUTHORS/CONTRIBUTORS

Thomas W. Carver, InnoVital/Cytovale, Inc, Grant/Consulting fees, PI/Consultant, Sharon Gautschy. Allison E. Berndtson, Allison G. McNickle, KLS Martin, Honoraria, Lecturer, Sharon Gautschy. Kelly A. Boyle, James M. Haan, Eric M. Campion, Walter L. Biffl, Alexion/UpToDate/Various Attorneys, Grant/Honoraria/Money, PI/Lecturer/Expert Witness, Sharon Gautschy. Alyssa N. Carroll, Michael J. Sise, Kelsey S. Berndt, Jennifer M. Burris, Tammy R. Kopelman, Jaqueline J. Blank, Mark J. Seamon, Wolters Kluwer/Springer/Main Line Health/Multiple, Royalties/Honoraria/Money, Associate Editor/Editor/Lecturer/Expert Testimony, Sharon Gautschy. Jacob R. Peschman, Intuitive, Travel funds, Course Participant, Sharon Gautschy. Rachel S. Morris, Nathan W. Kugler, Ryan D. Conrardy, Aniko Szabo have nothing to disclose, and Marc A. de Moya, Boston Scientific/Medical Expert, Consulting Fees/Money, Consultant/Testimony, Sharon Gautschy.

EDITOR-IN-CHIEF/DEPUTY EDITORS/ ASSOCIATE EDITORS

Conflict of Interest forms for all Journal of Trauma and Acute Care Editors have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D55).

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Credits can only be claimed online

Cost

For AAST members and Journal of Trauma and Acute Care Surgery subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

Thomas W. Carver, MD, FACS, Allison E. Berndtson, MD, FACS, Allison G. McNickle, MD, FACS, Kelly A. Boyle, MD, James M. Haan, MD, FACS, Eric M. Campion, MD, FACS, Walter L. Biffl, MD, FACS, Alyssa N. Carroll, MPH, Michael J. Sise, MD, FACS, Kelsey S. Berndt, MD, FACS, Jennifer M. Burris, MD, FACS, Tammy R. Kopelman, MD, FACS, Jaqueline J. Blank, MD, Mark J. Seamon, MD, FACS, Jacob R. Peschman, MD, FACS, Rachel S. Morris, MD, FACS, Nathan W. Kugler, MD, Ryan D. Conrardy, MS, Aniko Szabo, PhD, *and* **Marc A. de Moya, MD, FACS**, *Milwaukee, Wisconsin*

BACKGROUND: Retained hemothorax (rHTX) requiring intervention occurs in up to 20% of patients who undergo chest tube (TT) placement for a hemothorax (HTX). Thoracic irrigation at the time of TT placement decreases the need for secondary intervention in this patient group but those findings are limited because of the single-center design. A multicenter study was conducted to evaluate the effectiveness of thoracic irrigation.

METHODS: A multicenter, prospective, observational study was conducted between June 2018 and July 2023. Eleven sites contributed patients. Patients were included if they had a TT placed for a HTX and were excluded if: younger than 18 years, TT for pneumothorax, thoracotomy or video-assisted thoracoscopic surgery performed within 6 hours of TT, TT >24 hours after injury, TT removed <24 hours, or death within 48 hours. Thoracic irrigation was performed at the discretion of the attending. Each hemithorax was considered separately if bilateral HTX. The primary outcome was secondary intervention for HTX-related complications (rHTX, effusion, or empyema). Secondary intervention was defined as: TT placement, instillation of thrombolytics, video-assisted thoracoscopic surgery, or thoracotomy. Irrigated and nonirrigated hemithoraces were compared using a propensity weighted analysis with age, sex, mechanism of injury, Abbreviated Injury Scale chest, and TT size as predictors.

RESULTS: Four hundred ninety-three patients with 462 treated hemothoraces were included, 123 (25%) had thoracic irrigation at TT placement. There were no significant demographic differences between the cohorts. Fifty-seven secondary interventions were performed, 10 (8%) and 47 (13%) in the irrigated and non-irrigated groups, respectively ($p = 0.015$). Propensity weighted analysis demonstrated a reduction in secondary interventions in the irrigated cohort (odds ratio, 0.56 (0.34–0.85); $p = 0.005$).

CONCLUSION: This Western Trauma Association multicenter study demonstrates a benefit of thoracic irrigation at the time of TT placement for a HTX. Thoracic irrigation reduces the odds of a secondary intervention for rHTX-related complications by 44%. (*J Trauma Acute Care Surg.* 2024;97: 724–730. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

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

KEY WORDS: Chest tube; hemothorax; thoracic surgery; therapeutic irrigation.

Traumatic hemothorax (HTX) is reported to occur in approximately 300,000 people annually, and the vast majority are successfully managed with thoracostomy tube (TT) placement alone.[1,2] Thoracostomy tubes have been a staple of HTX management for decades, but when a TT fails to evacuate a HTX the resulting collection may lead to significantly increased length of stay (LOS), increased costs, and empyema or fibrothorax.[3–5] Generations of surgeons have debated the best way to treat a HTX. Studies regarding the appropriate size of TT, the number of TTs to place, and the use of image guidance have all been performed to reduce the rate of retained HTX (rHTX)[6,7] but the incidence of rHTX has remained around 20% for years.[1,7,8]

Out of concern for the aforementioned complications, the abundance of trauma research has focused on the treatment of the rHTX.[9–11] Compared with traditional thoracotomy, video-assisted thoracoscopic surgery (VATS) revolutionized the treatment of rHTX by decreasing the operative morbidity, which made early intervention more appealing.[11–13] Unfortunately, VATS has its own drawbacks including the need for general anesthesia, increased costs, and operating room availability. Given these limitations, surgeons began exploring different ways to improve the initial HTX drainage because once blood clots in the chest, it will not drain regardless of the number or size of the TT placed.[2]

Two techniques have been studied to decrease rHTX rates: Yankauer suction evacuation (YATS) of the chest before placement of the TT and thoracic irrigation with a liter of normal saline instilled via the TT. Yankauer suction evacuation was successful in a small pilot study,[14] but was not found to improve rHTX rates in a larger study.[15] In 2016, a pilot study on the use of thoracic irrigation was performed, and the results were confirmed by a larger, prospective comparison study.[16,17] That single-center study demonstrated a significantly lower secondary intervention rate when compared with the nonirrigated cohort, 5.6% versus 21.8%, respectively.[17] Given these promising results, a multi-center study was planned to further evaluate the

Submitted: January 23, 2024, Revised: March 21, 2024, Accepted: April 6, 2024, Published online: May 20, 2024.
From the Division of Trauma & Critical Care Surgery (T.W.C., K.A.B., J.R.P., R.S.M., N.W.K., M.A.d.M.), Medical College of Wisconsin, Milwaukee, Wisconsin; Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery (A.E.B.), UC San Diego Health, San Diego, California; Division of Acute Care Surgery (A.G.M.N.), Kirk Kerkorian School of Medicine at UNLV, Las Vegas, Nevada; Division of Trauma (J.M.H.), Ascension via Christi Hospitals, Wichita, Kansas; Division of Trauma (E.M.C.), Denver Health, Denver, Colorado; Division of Trauma (W.L.B.), Scripps Memorial Hospital La Jolla; Division of Trauma (A.N.C., M.J.S.), Scripps Mercy Hospital, San Diego, California; Division of Trauma, Acute Care Surgery, and Surgical Critical Care (K.S.B.), Regions Hospital Health Partners, St. Paul, Minnesota; Division of Trauma and Emergency General Surgery (J.M.B.), Methodist Health System, Dallas, Texas; Division of Trauma (T.R.K.), Mission Health, Ashville, North Carolina; Division of Trauma and Surgical Critical Care (J.J.B., M.J.S.), University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; and Division of Biostatistics (R.D.C., A.S.), Institute for Health & Equity, Medical College of Wisconsin, Milwaukee, Wisconsin.
Accepted for an oral podium presentation at the 2024 Western Trauma Association Annual Meeting, February 2024, in Snowmass, Colorado.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).
Address for correspondence: Thomas W. Carver, MD, FACS, Division of Trauma & Critical Care Surgery, Department of Surgery, Medical College of Wisconsin; email: tcarver@mcw.edu.

DOI: 10.1097/TA.0000000000004364

hypothesis that thoracic irrigation would lead to a significant decrease in reintervention rates for rHTX.

MATERIALS AND METHODS

The Western Trauma Association Multi-Center Trials Group performed a prospective, observational study comparing a nonirrigation control arm with a thoracic irrigation experimental arm from June 2018 to July of 2023. All trauma patients 18 years or older, presenting within 24 hours of blunt or penetrating injury resulting in traumatic hemothorax or hemopneumothorax, were eligible for enrollment. Patients were excluded from analysis if they were younger than 18 years of age, presented >24 hours after injury, had their TT placed >24 hours after injury, had TT placed for isolated pneumothorax, underwent thoracic surgery (either open or VATS) within 6 hours of TT placement, had an initial TT placed at a different institution, had the TT removed in <24 hours, or died within 48 hours of arrival.

Thoracostomy tube indications, procedural techniques, and management were left to the discretion of the individual sites in accordance with their institutional guidelines. Thoracic irrigation, when performed at the time of the initial TT placement, was done at the attending trauma surgeon's discretion. All sites were provided with detailed instructions on the irrigation technique, as described by Kugler et al.,[17] but monitoring for procedural compliance was not performed. While the general recommendation was to irrigate with 1,000 mL of warmed NS, patients were not excluded if a different volume was used.

The primary outcome for this study was the necessity of a secondary intervention to treat HTX-related complications (rHTX, recurrent/enlarging effusion, or empyema). Secondary intervention was a composite outcome defined as placement of an additional TT, replacement of a TT, instillation of thrombolytics, and/or performance of a VATS or thoracotomy. Secondary interventions were screened according to indication in collaboration with each site's principal investigator (PI). Only those directed at management of rHTX (or complication) were considered in the analysis as our primary outcome. Specifically, interventions performed for persistent air leaks or pneumothorax were not considered as a secondary intervention. Similarly, VATS or thoracotomy for rib stabilization or for diaphragm repair was not considered as a secondary intervention even if a rHTX was encountered. Secondary outcome measures included development of empyema, LOS, and TT duration.

To determine the experimental cohort, a sample size calculation was performed utilizing a one-side sample z-test with an alpha of 0.05 and 80% power. Using historic and experimental data, a power analysis utilizing 10% and 20% secondary intervention rates for the irrigation and standard cohorts, respectively, was performed. Based on a 50% reduction in secondary interventions, 108 patients would be needed within the irrigation cohort. A propensity score analysis was planned with an anticipated 25% rate of thoracic irrigation. An *a priori* decision by the study PI limited the coordinating site's irrigated cohort to <50% to improve the representation of other institutions.

The data at each participating site were collected by a member of the site-specific study team and entered into a Research Electronic Data Capture (REDCap) database specifically created for this project. Data were transferred from participating sites to the coordinating site via REDCap. All data entered into REDCap and transferred between sites were deidentified. Variables extracted by each institution included the following: demographics, trauma-specific details (mechanism of injury [MOI], number of rib fractures, presence of bilateral injuries, chest Abbreviated Injury Scale [AIS]), TT specific details (TT size, initial and daily TT output, duration of TT), thoracic irrigation details (initial output, volume irrigated, fluid removed following irrigation), radiographic findings (before/after TT placement and until TT removal when available), hospital specific outcomes (intensive care unit [ICU]/hospital length of stay, discharge disposition), 30-day outcomes (outpatient clinic or ED visits, imaging, readmission), and occurrence/indication for secondary intervention. Each hemithorax was considered separately when bilateral HTX were present.

Univariate analysis was performed using Wilcoxon rank-sum test and χ^2 test with Rao & Scott's second-order correction for continuous and categorical variables, respectively. Propensity score methods were also used to adjust for potential selection bias in this comparative study. Propensity scores were estimated using a logistic regression model with age, sex, MOI, chest AIS, bilateral TT, and TT size as predictors. The predicted

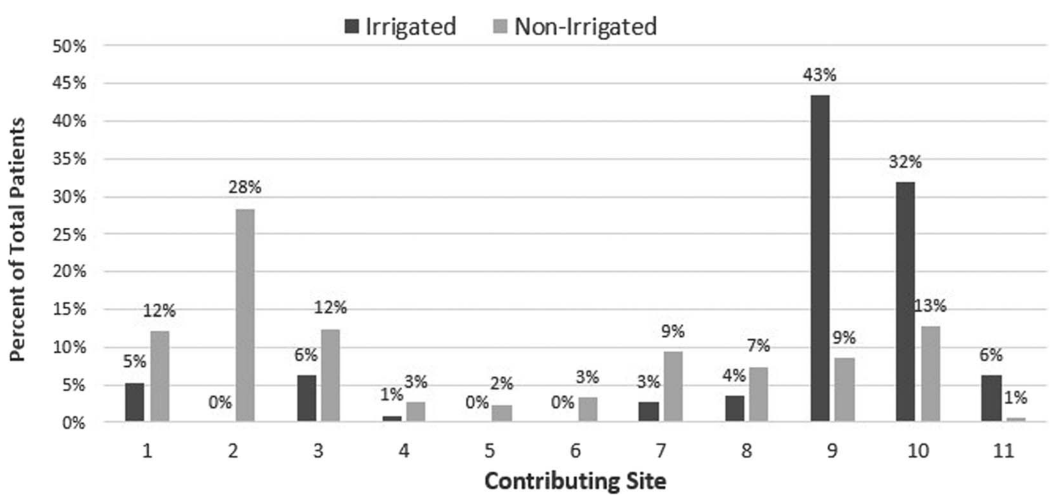

Figure 1. Distribution of patients from contributing sites.

probabilities were then used to obtain the weights as the inverse probability of treatment. Data were analyzed using a weighted logistic regression model for the categorical outcome (secondary intervention) and a weighted linear regression model for the log-transformed numeric outcomes (TT duration, ICU length of stay, hospital length of stay). Cluster-robust standard errors were used in the regression models to account for within-site correlation. This approach also adjusts for the within-subject correlation for bilateral hemothoraces, as those are nested within site. Analyses were performed using SAS 9.4 (SAS Institute, Cary, NC), using the Surveyfreq and Surveyreg procedures for the propensity-weighted regression models.

This study was approved by the institutional review board of the coordinating site (PRO00029527). All participating centers received approval through their respective Institutional Review Boards with a waiver of consent and HIPAA authorization. This study was conducted following the STROBE guidelines (Supplemental Table 1, http://links.lww.com/TA/D782).

RESULTS

Over the 5-year period, 11 sites contributed 493 hemithoraces (462 unique patients) that met inclusion criteria. One hundred twenty-three (25%) hemithoraces were irrigated at the time of TT placement and 370 (75%) non-irrigated chests were utilized as controls (Fig. 1). The breakdown of included and excluded patients can be found in the CONSORT diagram (Fig. 2). The characteristics and demographics of the subjects are shown in Table 1. The median age of the cohort was 40 (interquartile range [IQR], 29–60), 83% were male, and 42% suffered a penetrating injury. Median Injury Severity Score (ISS) was 18 (IQR, 13–29) and 32% of the group had an AIS chest score >3. Twenty-five patients (5.1%) died within 48 hours of arrival.

Eighty-nine percent of patients had a TT size of ≥28Fr and the median duration of the initial TT was 4 days (IQR, 3–6). The first day TT output median was 300 mL (IQR, 111–620), which was similar between groups. Initial TT output (only recorded in the irrigated group) median volume was 250 mL (IQR, 100–500). Fifty-one percent had an initial evacuated volume of ≥300 mL. Most patients were irrigated with 1,000 mL of saline but 24% of the group received <1000 mL of irrigation and 12% were irrigated with >1000 mL.

On univariate analysis, no significant differences between groups were found in any of the demographic or injury characteristics, aside from a statistical but clinically insignificant difference in ISS and ICU LOS (Table 1). Eleven empyemas were identified but no significant difference was seen between groups. A total of 57 (12%) secondary interventions were

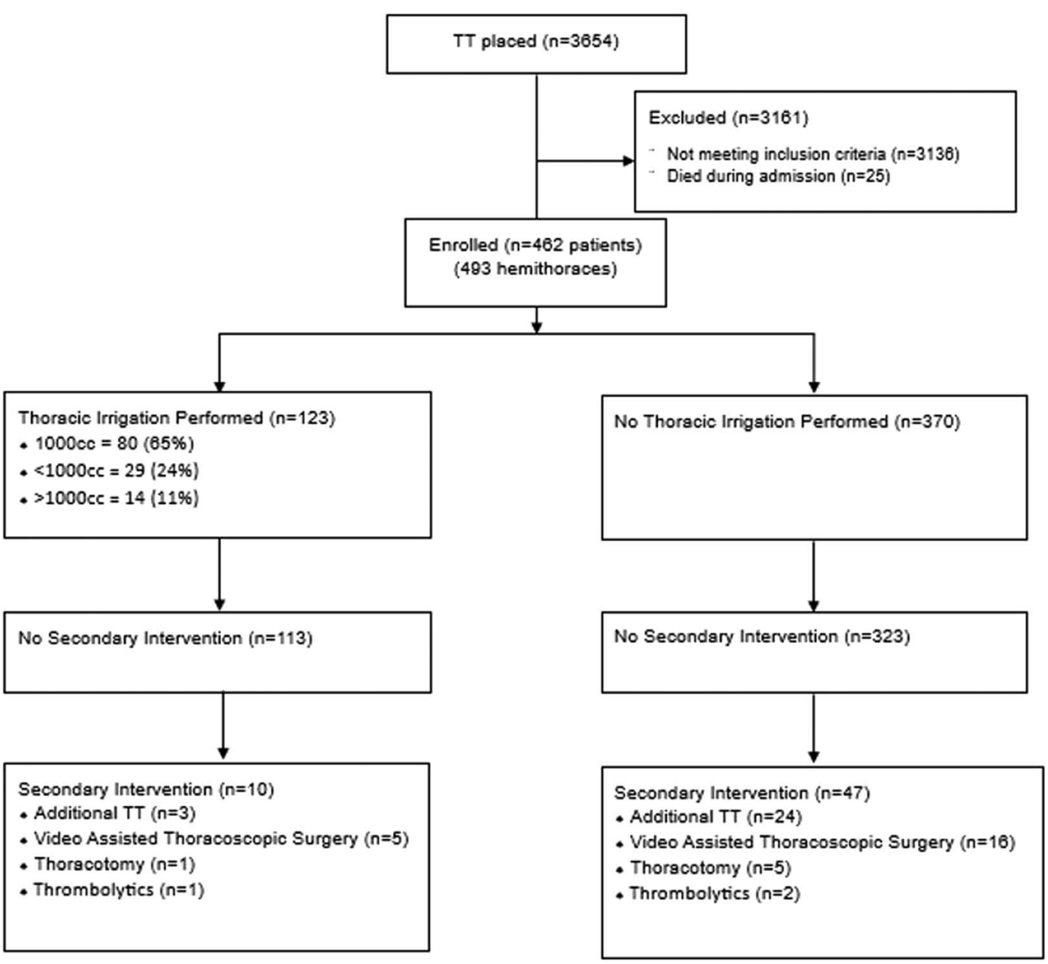

Figure 2. CONSORT diagram of included subjects.

TABLE 1. Demographics and Characteristics of Study Cohorts

Characteristics	Overall, N = 493 (462 Unique)	Irrigated, n = 123	Nonirrigated, n = 370	p
Age	40 (29, 60)	40 (30, 59)	38 (29, 59)	0.3
Sex, male	408 (83)	97 (79)	311 (84)	0.2
Race				0.2
White	306 (62)	76 (62)	230 (62)	
Black	121 (25)	41 (33)	80 (22)	
Other	35 (13)	6 (5)	60 (16)	
BMI	26.6 (23.5, 30.0)	26.5 (22.9, 29.4)	26.6 (23.6, 30.2)	0.4
Penetrating injury	207 (42)	55 (45)	152 (41)	0.7
ISS	18 (12, 29)	18 (10, 25)	18 (13, 29)	0.04
AIS chest score >3	144 (32)	40 (35)	104 (31)	0.4
TT size, Fr	28 (28, 28)	28 (28,28)	28 (28,28)	0.7
≥ 28Fr	425 (89)	113 (92)	312 (84)	0.3
Day 1 TT output, mL	300 (111, 600)	300 (142, 650)	270 (103, 600)	0.8
Initial TT d	4 (3, 6)	4 (3, 6)	4 (3, 6)	0.6
ICU LOS, d	3 (1, 7)	3 (0, 6)	3 (2, 8)	0.02
Total LOS, d	8 (5, 16)	7 (5, 14)	8 (5, 18)	0.3
Death	25 (5)	6 (5)	20 (5)	0.9
Empyema	11 (2.2)	4 (3.3)	7 (1.9)	0.4
Secondary intervention	**57 (12)**	**10 (8)**	**47 (13)**	**0.015**
2ndTT	27 (47)	3 (30)	24 (51)	0.15
Thrombolytics	3 (5)	1 (10)	2 (4)	0.44
VATS/Thoracotomy	27 (47)	6 (60)	21 (45)	0.29
Multiple	9	3	6	—

Data displayed either median (Q1, Q3) or n (%).
BMI, body mass index.

performed. A statistically significant difference in secondary interventions between the irrigated and nonirrigated groups was noted (8% vs. 13%, $p = 0.01$, respectively). The most common secondary interventions were additional TT (47%) and VATS (37%) (Table 1). Only six thoracotomies were performed, one in the irrigated group. Although 22 of 25 additional TTs were placed in the nonirrigated group, this difference did not meet statistical significance.

Analysis of the subset of patients that required a secondary intervention is shown in Table 2. Aside from race and AIS chest score >3, no other significant differences were identified in the demographic or injury characteristics. Not surprisingly, patients undergoing a secondary intervention had significantly longer hospital LOS (15 vs. 8 days, $p = 0.01$).

The propensity score analysis is shown in Table 3. The odds ratio for secondary intervention was 0.56 (95% confidence

TABLE 2. Demographics and Outcomes in Secondary Intervention Cohort

Characteristics	No Intervention, n = 436	Secondary Intervention, n = 57	p
Age	40 (29, 60)	38 (31, 58)	0.9
Sex, male	362 (83)	46 (81)	0.7
Race			0.08
White	279 (64)	27 (47)	
Black	106 (24)	15 (26)	
Other	48 (12)	13 (25)	
Penetrating injury	184 (42)	23 (40)	0.8
ISS	18 (11, 27)	19 (13, 33)	0.3
AIS chest score >3	119 (30)	25 (48)	0.03
TT size, Fr	28 (28, 28)	28 (28, 28)	0.8
≥ 28	367 (87)	57 (100)	0.3
Day 1 TT output, mL	300 (101, 615)	305 (140, 900)	0.2
TT duration, d	4 (3, 6)	4 (3, 5)	0.4
ICU LOS, d	3 (0, 6)	5 (2, 13)	0.07
Total LOS, d	8 (5, 16)	15 (7, 34)	0.01

Data displayed either median (Q1, Q3) or n (%).

TABLE 3. Propensity Scores Parameter Estimates

Variables	OR (95% CI)	*p*
Age	1.0 (0.99–1.02)	0.53
Sex	1.45 (0.83–2.46)	0.17
MOI	0.79 (0.49–1.28)	0.32
AIS chest score	0.78 (0.5–1.22)	0.28
Bilateral TT	1.69 (0.81–3.34)	0.15
TT size (continuous)	1.01 (0.96–1.07)	0.72
Secondary intervention OR estimate		
Irrigated vs. nonirrigated	0.56 (0.35–0.85)	0.005

interval, 0.34–0.85 $p = 0.005$) when irrigation was performed. Weighted linear regression identified an association with fewer ICU days in patients undergoing irrigation (log-scale estimate −0.23, fold-change 0.76, $p = 0.03$) but no significant association with TT duration or hospital LOS was found.

DISCUSSION

Several years ago, a method was developed to irrigate the thoracic cavity with warmed normal saline to decrease the rate of complications related to a rHTX. What started as a pilot study, became a 60-patient prospective, observational study, and ultimately a WTA multi-center study of over 450 patients. This study has demonstrated that thoracic irrigation decreases the odds of requiring a secondary intervention rate for rHTX by 44%.

A recent EAST multicenter study highlighted the ongoing challenges associated with management of traumatic HTX.[1] Prakash et al. demonstrated a 28.7% rate of rHTX among 17 centers. They found that AIS chest, penetrating mechanism, and amount of blood on initial CT scan to all be significantly associated with rHTX. Those with a rHTX had longer ICU and hospital LOS, more ventilator days, and higher pneumonia rates. Finally, they found that 67% of patients with a rHTX underwent another intervention.[1] These outcomes emphasize the importance of prevention when managing patients with a HTX.

Hemothorax management continues to evolve, and several important studies have been published recently. Observation may be appropriate for some people with a HTX, especially if the HTX is small (<300 mL), but quantification of HTX size is not universally performed.[18,19] Interestingly, even when a < 300 mL HTX was managed with a chest tube, a rHTX occurred in 23% of patients.[1] In this current study, there were 57 irrigated patients that had recorded initial output of <300 mL but only six of them (10.5%) required a secondary intervention, suggesting that there may be a benefit to irrigation even when a small HTX is encountered.

Only a handful of recent publications have focused on strategies to reduce the rHTX rate, including two that explored directly inserting a Yankauer into the chest cavity to more effectively drain the HTX. While YATS was found to be promising in a small pilot study,[14] Savage and colleagues found no benefit when compared with a historical cohort.[15] While YATS was used sporadically within the current study, utilizations rates were not obtained. Only one other institution has published regarding thoracic irrigation for the prevention of rHTX.[20] This group did not find a decreased rate of secondary intervention; however, they did note a decrease in LOS. One of the clearest distinctions to account for the conflicting thoracic irrigation findings is that Crankshaw's group used <1000 mL of NS in almost 60% of their patients. In the current multicenter study, only 24% of patients were irrigated with <1,000 mL and volume of irrigation did not appear to correlate with outcome.

A wide variety of TT sizes were used, sometimes within individual institutions. Size of TT placed for HTX drainage has evolved significantly in the past 15 years, with a shift away from the dogmatic placement of size 36 to 40 Fr TT placement in response to Inaba et al.'s paper in 2012.[21] Ongoing studies on the use of 14 Fr pigtail catheters have further challenged the size consideration in management of traumatic HTX.[22,23] While there is some data to suggest that TT size has no relation to development of rHTX, there is no clinical data regarding the impact of thoracic irrigation through a small-bore TT.[24] Size of TT was not associated with a difference in need for secondary intervention but, only 10 irrigated patients had a TT <28 Fr (and only three 14-Fr tubes), making it difficult to infer the impact of thoracic irrigation on rHTX rates when a small-bore TT is used.

In the current study, the most common secondary intervention was placement of an additional TT and VATS. Only three irrigated patients underwent second TT placement. One may argue that placing an additional TT does not provide an advantage,[25] but placement of an additional TT was successful 79% of the time in the current study. That said, the management of a rHTX was not the focus of this study and prior research has shown that operative management results in significantly better treatment outcome.[8,11,12]

There are several limitations to this study that must be addressed, most importantly the lack of randomization. The time-sensitive nature of trauma care often precludes informed consent, and this study would not have been feasible if we had tried to obtain consent and randomize. While propensity scoring is a well-described technique to help overcome the limitations associated with a nonrandomized trial, the potential for selection bias still exists. In addition, the fact that the intervention group was not blinded to study staff allows for additional treatment biases and other confounders. Patients undergoing an operative chest intervention within 6 hours were excluded because these patients were felt to represent a group of patients with ongoing bleeding or a diaphragm injury. The decision to perform operative intervention for a rHTX is usually not made without at least several hours of observation but the decision to exclude this group could have underestimated the rate of secondary intervention. There are several institutional differences that could not be controlled for, including why a TT was placed, whether irrigation was performed, technique used for irrigation, or which secondary intervention was done. Another limitation is that initial TT output was not quantified in the non-irrigated patients. We did collect day 1 TT output, but this was not standardized into 24-hour periods, which could lead to an overestimation or underestimation of the total 24-hour volume. Volumetric analysis was not performed when CT scans were available. Similarly, there was no attempt to quantify volume of rHTX that led to a secondary intervention. When an additional TT or surgical intervention was performed, each institution's PI was contacted to confirm the indication for the intervention. If there was ambiguity regarding the indication, the default of the study PI was to not count that as a secondary intervention, which was almost always to the benefit of the non-irrigated cohort. This decision could have led to an underestimation of the effectiveness of irrigation.

CONCLUSION

In this WTA multicenter study, thoracic irrigation resulted in a 44% reduction in the odds of requiring a secondary intervention for rHTX and was also associated with a decrease in length in ICU stay. This study has confirmed the findings of a previous single-center study and provides evidence that we can improve the care of patients being treated for a HTX. Further studies may help identify the patient population most likely to benefit from thoracic irrigation, but the efficacy of the procedure may justify adoption.

AUTHORSHIP

The author confirm contribution to the article as follows: T.W.C., M.A. dM., N.W.K., K.S.B. designed this study. All authors participated in data collection and interpretation of results. Statistical analysis was done by R. D.C. A.S., T.W.C. prepared the article, which all remaining authors critically reviewed.

ACKNOWLEDGMENTS

We wish to thank the staff that contributed their time and effort to this study, especially the following site coordinators: Medical College of Wisconsin—Margo Mantz-Wichman; Scripps Mercy Hospital—Alexandra Rooney, Andrea Krzyzaniak; Mission Hospital—Andie Slivinski; Scripps Memorial Hospital—Matthew Castelo; Regions Hospital Health Partners—David Bachman; Methodist Health Systems—Heather Grossman Verner, Cynthia Villalta, DO; Ascension via Christi Hospital Saint Francis—Kelly Lightwine; Denver Health—Sara Gardon

DISCLOSURE

Conflict of Interest: The authors report no conflicts of interest as related to this study. All Journal of Trauma and Acute Care Surgery Disclosure forms have been supplied, are up to date, and are provided as supplemental digital content (http://links.lww.com/TA/D783).
Financial Disclosure: WB: Alexion, Inc for payments to institution, honoraria from UpToDate, multiple vendors for food/beverages, direct payment for medicolegal reviews. J.M.B.: multiple vendors for food/beverages. T.C.: Innovital, Inc for payments to institution, Cytovale, Inc for direct payments as medical monitor, Integra, Inc for food/beverages. J.P.: Intuitive, Inc for travel reimbursement. M.D.: Boston Scientific, Inc for direct payments as a consultant, direct payment for medicolegal reviews. A.M.: KLS Martin for honoraria for lectures, multiple vendors for food/beverages. M.J.S.: Main Line Health, Inc for honoraria for lecture, Harvard Medical School for honoraria for lecture, direct payments for medicolegal reviews. The remaining authors report no financial disclosures.

REFERENCES

1. Prakash PS, Moore SA, Rezende-Neto JB, Trpcic S, Dunn JA, Smoot B, et al. Predictors of retained hemothorax in trauma: results of an Eastern Association for the Surgery of Trauma multi-institutional trial. *J Trauma Acute Care Surg*. 2020;89:679–685.
2. Patel NJ, Dultz L, Ladhani HA, Cullinane DC, Klein E, McNickle AG, et al. Management of simple and retained hemothorax: a practice management guideline from the Eastern Association for the Surgery of Trauma. *Am J Surg*. 2021;221:873–884.
3. Coselli JS, Mattox KL, Beall AC. Reevaluation of early evacuation of clotted hemothorax. *Am J Surg*. 1984;148:786–790.
4. Helling TS, Gyles NR 3rd, Eisenstein CL, Soracco CA. Complications following blunt and penetrating injuries in 216 victims of chest trauma requiring tube thoracostomy. *J Trauma*. 1989;29:1367–1370.
5. DuBose J, Inaba K, Okoye O, Demetriades D, Scalea T, O'Connor J, et al. Development of posttraumatic empyema in patients with retained hemothorax: results of a prospective, observational AAST study. *J Trauma Acute Care Surg*. 2012;73:752–757.
6. Griffith GL, Todd EP, McMillin RD, Zeok JV, Dillon ML, Utley JR, et al. Acute traumatic hemothorax. *Ann Thorac Surg*. 1978;26:204–207.
7. Choi J, Villarreal J, Andersen W, Gi Min J, Touponse G, Wong C, et al. Scoping review of traumatic hemothorax: evidence and knowledge gaps, from diagnosis to chest tube removal. *Surgery*. 2021;170:1260–1267.
8. DuBose J, Inaba K, Demetriades D, Scalea TM, O'Connor J, Menaker J, et al. Management of post-traumatic retained hemothorax: a prospective, observational, multicenter AAST study. *J Trauma Acute Care Surg*. 2012;72:11–22 discussion 22-4; quiz 316.
9. Heniford BT, Carrillo EH, Spain DA, Sosa JL, Fulton RL, Richardson JD. The role of thoracoscopy in the management of retained thoracic collections after trauma. *Ann Thorac Surg*. 1997;63:940–943.
10. Meyer DM, Jessen ME, Wait MA, Estrera AS. Early evacuation of traumatic retained hemothoraces using thoracoscopy: a prospective, randomized trial. *Ann Thorac Surg*. 1997;64:1396–1400; discussion 1400-1.
11. Ziapour B, Mostafidi E, Sadeghi-Bazargani H, Kabir A, Okereke I. Timing to perform VATS for traumatic-retained hemothorax (a systematic review and meta-analysis). *Eur J Trauma Emerg Surg*. 2020;46:337–346.
12. Zambetti BR, Lewis RH Jr., Chintalapani SR, Desai N, Valaulikar GS, Magnotti LJ. Optimal time to thoracoscopy for trauma patients with retained hemothorax. *Surgery*. 2022;172:1265–1269.
13. Smith JW, Franklin GA, Harbrecht BG, Richardson JD. Early VATS for blunt chest trauma: a management technique underutilized by acute care surgeons. *J Trauma*. 2011;71:102–105; discussion 105-7.
14. Ramanathan R, Wolfe LG, Duane TM. Initial suction evacuation of traumatic hemothoraces: a novel approach to decreasing chest tube duration and complications. *Am Surg*. 2012;78:883–887.
15. Savage SA, Cibulas GA 2nd, Ward TA, Davis CA, Croce MA, Zarzaur BL. Suction evacuation of hemothorax: a prospective study. *J Trauma Acute Care Surg*. 2016;81:58–62.
16. Kugler NW, Carver TW, Paul JS. Thoracic irrigation prevents retained hemothorax: a pilot study. *J Surg Res*. 2016;202:443–448.
17. Kugler NW, Carver TW, Milia D, Paul JS. Thoracic irrigation prevents retained hemothorax: a prospective propensity scored analysis. *J Trauma Acute Care Surg*. 2017;83:1136–1141.
18. Demetri L, Martinez Aguilar MM, Bohnen JD, Whitesell R, Yeh DD, King D, et al. Is observation for traumatic hemothorax safe? *J Trauma Acute Care Surg*. 2018;84:454–458.
19. Beyer CA, Byrne JP, Moore SA, McLauchlan NR, Rezende-Neto JB, Schroeppel TJ, et al. Predictors of initial management failure in traumatic hemothorax: a prospective multicenter cohort analysis. *Surgery*. 2023;174:1063–1070.
20. Crankshaw L, McNickle AG, Batra K, Kuhls DA, Chestovich PJ, Fraser DR. The volume of thoracic irrigation is associated with length of stay in patients with traumatic hemothorax. *J Surg Res*. 2022;279:62–71.
21. Inaba K, Lustenberger T, Recinos G, Georgiou C, Velmahos G, Brown CVR, et al. Does size matter? A prospective analysis of 28–32 versus 36–40 French chest tube size in trauma. *J Trauma Acute Care Surg*. 2012;72:422–427.
22. Bauman ZM, Kulvatunyou N, Joseph B, Gries L, Tang AL, Rhee P, et al. Randomized clinical trial of 14-French (14F) pigtail catheters versus 28-32F chest tubes in the management of patients with traumatic hemothorax and hemopneumothorax. *World J Surg*. 2021;45:880–886.
23. Beeton G, Ngatuvai M, Breeding T, Andrade R, Zagales R, Khan A, et al. Outcomes of pigtail catheter placement versus chest tube placement in adult thoracic trauma patients: a systematic review and meta-analysis. *Am Surg*. 2023;89:2743–2754.
24. McLauchlan NR, Igra NM, Fisher LT, Byrne JP, Beyer CA, Geng Z, et al. Open versus percutaneous tube thoracostomy with and without thoracic lavage for traumatic hemothorax: a novel randomized controlled simulation trial. *Trauma Surg Acute Care Open*. 2023;8:e001050.
25. Broderick SR. Hemothorax: etiology, diagnosis, and management. *Thorac Surg Clin*. 2013;23:89–96, vi-vii.