Thoracic irrigation for traumatic hemothorax: A systematic review and meta-analysis

Nicole B. Lyons, MD, Brianna L. Collie, MD, Michael D. Cobler-Lichter, MD, Jessica M. Delamater, MD, Larisa Shagabayeva, MD, Luciana Tito-Bustillos, MD, Kenneth G. Proctor, PhD, Julie Y. Valenzuela, MD, FACS, Jonathan P. Meizoso, MD, MSPH, FACS, *and* **Nicholas Namias, MD, MBA, FACS**, *Miami, Florida*

BACKGROUND: Traumatic hemothoraces (HTXs) are common, and tube thoracostomy (TT) insertion is generally the initial management. However, a retained HTX can develop into a fibrothorax or empyema requiring secondary intervention. We hypothesized that irrigation of the thoracic cavity at the time of TT may prevent retained HTX.

METHODS: Pubmed, EMBASE, and Scopus were searched from inception to May 2024. Studies with adult trauma patients with traumatic HTX who received a TT and had patients who underwent thoracic irrigation were included. The primary outcome was failure rate, defined as retained HTX requiring a second intervention. Cumulative analysis was performed with χ^2 for dichotomous variables and unpaired *t* test for continuous variables. A fixed-effects model was applied for meta-analysis.

RESULTS: Six studies were included in the analysis; two retrospective and four prospective observational studies. These studies included 1,319 patients (513 irrigated TT, 837 nonirrigated TT). The mean age of patients was 45 years, 81% were male, mean Injury Severity Score was 21, and 42% had penetrating trauma. Failure rate was significantly lower in the irrigation group on cumulative analysis (10.7% vs. 18.2%, $p < 0.001$) and meta-analysis (effect size, 0.704; 95% confidence interval, 0.218–1.190; $I^2 = 0.4$; $p < 0.001$]. In addition, on meta-analysis, the irrigation group had a shorter TT duration and hospital and ICU length of stay (all $p < 0.05$). There were no differences in overall infectious complications, readmission, or mortality; however, all the models favored the irrigation group.

CONCLUSION: Patients who undergo simultaneous TT and thoracic irrigation have a lower rate of retained HTX and require fewer secondary interventions. Thoracic irrigation for traumatic HTX should be considered; however, randomized studies are needed prior to development of guidelines. (*J Trauma Acute Care Surg.* 2024;00: 00–00. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic Review/Meta-analysis; Level III.

KEY WORDS: Thoracic irrigation; traumatic hemothorax; chest tube; tube thoracostomy.

Traumatic hemothorax (HTX) occurs in more than 300,000 patients per year in the United States and is routinely treated with tube thoracostomy (TT).[1] In 5% to 30% of cases, a retained HTX, defined as residual blood remaining in the thorax, develops and can lead to complications such as fibrothorax or empyema.[1] In these cases, a secondary intervention, such as thrombolysis, video-assisted thoracoscopic surgery (VATS), or open thoracotomy, may be required to evacuate the retained HTX.[1,2] Complications and these subsequent interventions can lead to longer intensive care unit (ICU) and hospital length of stay (LOS) and increased cost.[2,3]

Various methods have been tested to try to reduce the rate of retained HTX and the associated complications, including early VATS and Yankauer suction evacuation of HTX before TT placement.[1,4] Recently, simultaneous TT insertion with thoracic cavity irrigation through the TT has been evaluated to reduce the rate of retained HTX and the need for secondary interventions. We performed a systematic review and meta-analysis to test the hypothesis that trauma patients treated with thoracic irrigation after TT placement will have a lower failure rate than those who did not receive it.

Submitted: June 20, 2024, Revised: August 12, 2024, Accepted: August 23, 2024, Published online: November 7, 2024.

From the Divisions of Trauma, Surgical Critical Care, and Burns, DeWitt Daughtry Family Department of Surgery, Ryder Trauma Center, University of Miami Miller School of Medicine, Miami, Florida.

This work was presented at the 7th World Trauma Congress, September 11–14, 2024, in Las Vegas, Nevada.

Systematic review registration number: CRD42024546996.

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: Nicole B. Lyons, MD, Division of Trauma, DeWitt Daughtry Family Department of Surgery, Ryder Trauma Center, University of Miami Miller School of Medicine, Ste T-215, 1800 NW 10th Ave, Miami, FL 33136; email: nblyons@med.miami.edu.

DOI: 10.1097/TA.0000000000004479

PATIENTS AND METHODS

This study was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement, and the protocol was registered online with PROSPERO (CRD42024546996).[5,6] The Preferred Reporting Items for Systematic Reviews and Meta-Analysis checklist is included in the supplemental material (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/E61).

Search Strategy and Selection Criteria

PubMed, EMBASE, Scopus, and Cochrane review were searched from database inception to May 2024. A search strategy for each database was constructed using free-text terms related to TT for treatment of traumatic HTX using the following keywords: thoracic, thorax, chest, irrigation, wash out, and trauma. For example, this was the search used in PubMed:

(thoracic OR thorax OR chest) AND (irrigation OR "wash out") AND trauma. The reference lists of included articles were screened for other relevant studies.

Titles, abstracts, and full-text articles were screened for inclusion. One author screened all the articles. The inclusion criteria were defined a priori as follows: (1) randomized controlled trials or cohort studies (prospective and retrospective), (2) articles that included adult (18 years old or older) trauma patients who received a TT for treatment of a HTX or hemopneumothorax (HPTX) and included patients who underwent irrigation, and (3) articles that reported outcomes. Case reports and articles in a language other than English were excluded. If studies had overlapping patients, only the most recent study was included in cumulative analysis. Reviews were excluded, but the reference lists were screened for additional relevant studies.

Data Extraction and Quality Assessment

One author extracted the data. For each article, data including the number of patients, patient demographics, injury details, and clinical outcomes were extracted.

The Critical Appraisal Skills Program (CASP) checklists were used to assess the methodologic quality and risk of bias on the included articles.[7] The checklist for cohort studies includes 14 questions. Each question was eligible to receive up to 2 points for a possible 28 points total. One author evaluated the quality of the included studies using the appraisal tools and calculated a CASP score for each study. The studies were then categorized as high-, medium-, or low-quality based on their score of ≥18, 17 to 10, ≤9, respectively, and were devised *a priori* by the authors.

Statistical Analysis

The primary outcome was failure rate, defined as incompletely drained or retained HTX requiring a second intervention. Second interventions included insertion of a second TT, thrombolysis, VATS, and/or open thoracotomy. Secondary outcomes included TT duration, hospital and ICU LOS, infectious complications, readmission, mortality, and cost. Infectious complications were defined as pneumonia and empyema. Mean and SD were estimated for data reported as a median and interquartile range for cumulative data to be calculated and meta-analysis to be performed.[8] Cumulative analysis was performed with χ^2 test for dichotomous variables and unpaired *t* test for continuous variables. Heterogeneity among studies was quantified using Higgins I^2 statistics, with $I^2 > 75\%$ classified as high, 26% to 74% as moderate, and <25% as low heterogeneity. A fixed-effects model was applied for all meta-analyses. A fixed-

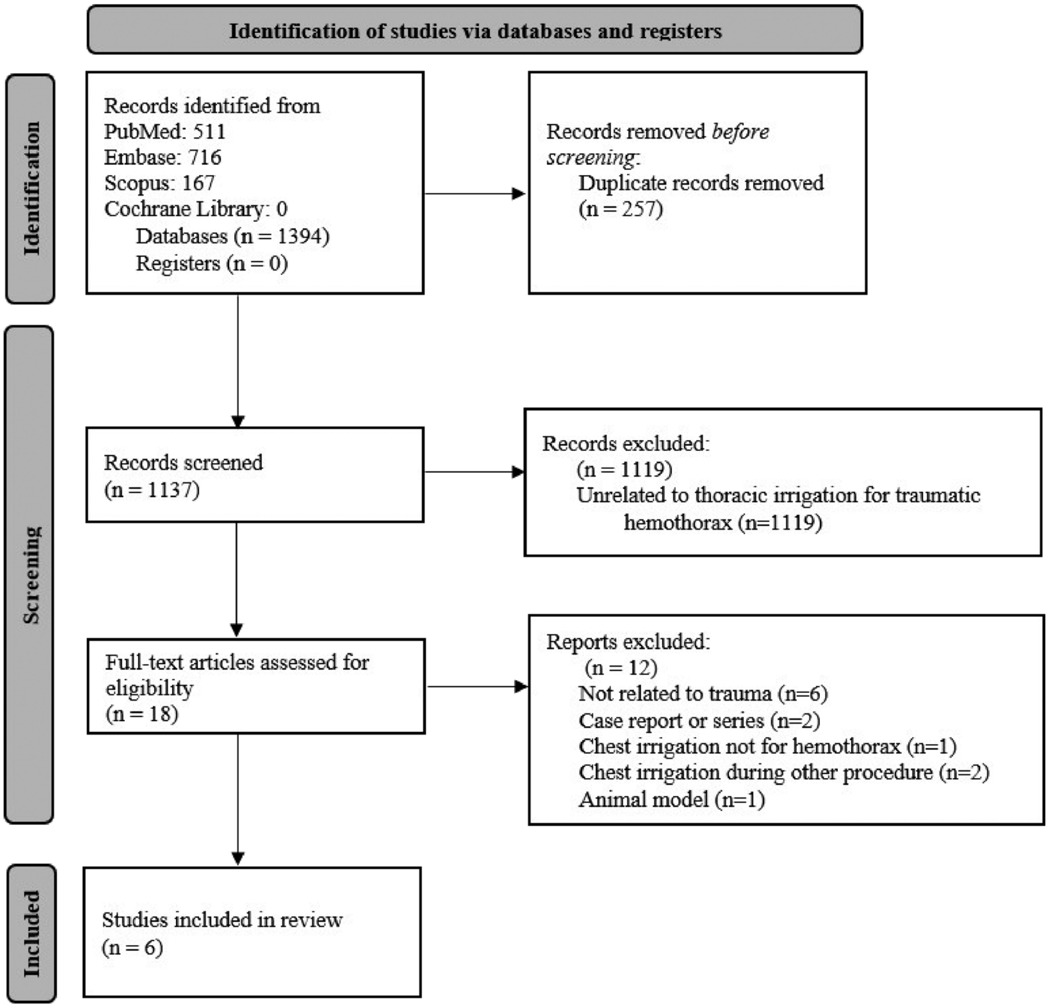

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis 2020 flow diagram.

effects model was chosen as our review included a small number of studies. In addition, this model is preferable when one study is much larger and presumed more trustworthy than the smaller studies, as the fixed-effects model gives it more weight than smaller studies.[9] Only studies reporting outcomes for both irrigated and nonirrigated patients were included in the meta-analysis. Two-sided p values <0.05 were considered statistically significant. Statistical analysis was performed with SPSS Statistics, version 28.0 (IBM Corp., Armonk, NY).

RESULTS

In total, 1,394 articles were identified from the initial search. After duplicates were removed, 1,137 articles remained. Of these, six were included in the review (Fig. 1).[10–15] No additional studies were identified by review of reference lists from included studies, and no previous review articles were found.

Quality Assessment and Description of Included Studies

The six studies underwent a full-text evaluation, and the risk of bias was assessed using the cohort study CASP checklist. The study and background information, as well as the methodology of the included studies, is in Table 1. Most studies were high-quality cohort studies; however, two were categorized as medium-quality. Although these two were both prospective, they each had a small sample size and did not have a control group.[13,15]

Of the six studies, two were retrospective and four were prospective, one of which was a multicenter trial that included 11 sites. They were all from the United States and were published in the last eight years. The studies included 1,319 patients (513 irrigated TT, 837 nonirrigated TT). Three studies gave periprocedural antibiotics when placing the tubes, one did not, and the other two did not mention antibiotics. The size of tubes placed ranged from 14 to 36 Fr. McLauchlan et al.[15] only included patients who received a pigtail catheter, whereas Crankshaw et al.[12] excluded all patients with a pigtail catheter. All but three patients had the TT placed in the first 24 hours of admission. The mean age was 45 years, 81% were male, mean Injury Severity Score was 21, and 42% had penetrating trauma. Only two studies mentioned whether the patients were hemodynamically stable at the time of TT placement and irrigation. Al Tannir et al.[10] included some hemodynamically unstable patients (11%), whereas McLauchlan et al.[15] excluded unstable patients. Several studies excluded patients who were emergently or urgently taken to the operating room.[10,11,13,14] The majority (71%) of irrigated patients had 1,000 mL of saline instilled; however, 22% received less than 1 L, and 8% had more than a liter. The patients who received irrigation were similar to those who did not. The control group had a slightly higher Injury Severity Score of 22 compared with 19 for the irrigation group, which is statistically but not necessarily clinically significant (Table 1).

Clinical Outcomes

All six studies reported the primary outcome of failure rate. The failure rate was significantly lower in the irrigation group than the control group (10.7% vs. 18.2%, p < 0.001). There were also fewer individual procedures of second TT, VATS, and open thoracotomy in the irrigation group. There was no difference between groups for the rate of thrombolysis (Table 2).

The irrigation group also had a significantly shorter hospital (10.4 vs. 13.5 days, p < 0.001) and ICU LOS (2.7 vs. 6.4 days, p < 0.001). The irrigation group also had a lower rate of infectious complications (9.7% vs. 15.6%, p = 0.012). There were no differences in TT duration, readmission rate, or mortality between the groups. Finally, only one study reported the mean cost of the hospital stay and found that cost was lower in patients who underwent irrigation ($223,729 vs. $312,481, p < 0.001) (Table 2).[12]

Meta-analysis

When comparing irrigation to no irrigation on meta-analysis, the irrigation group had a lower failure rate (effect size, 0.740; 95% confidence interval [CI], 0.384–1.097; I^2 = 0.40; p < 0.001), shorter TT duration (effect size, −0.144; 95% CI, −0.263 to −0.025; I^2 = 0.52; p = 0.018), shorter hospital LOS (effect size, −0.413; 95% CI, −0.536 to −0.290; I^2 = 0.97; p < 0.001), and shorter ICU LOS (effect size, −0.701; 95% CI, −0.827 to −0.575; I^2 = 0.98; p < 0.001). The I^2 on meta-analysis for hospital and ICU LOS showed that the included studies had high heterogeneity, so the results for these outcomes should be cautiously interpreted (Supplemental Digital Content, Supplementary Data 2, http://links.lww.com/TA/E62; Supplementary Data 3, http://links.lww.com/TA/E63; Supplementary Data 4, http://links.lww.com/TA/E64; and Supplementary Data 5, http://links.lww.com/TA/E65).

There were no significant differences between groups in the infectious complication rate (effect size, 0.448; 95% CI, −0.005 to 0.901; I^2 = 0; p = 0.053), readmission rate (effect size, −0.12; 95% CI, −0.975 to 0.952; I^2 = 0; p = 0.981), or mortality rate (effect size, 0.18; 95% CI, −0.494 to 0.851; I^2 = 0; p = 0.603); however, all the models favored the irrigation group (Supplemental Digital Content, Supplementary Data 6, http://links.lww.com/TA/E66; Supplementary Data 7, http://links.lww.com/TA/E67; and Supplementary Data 8, http://links.lww.com/TA/E68).

DISCUSSION

In this systematic review, patients who underwent thoracic irrigation at the time of TT placement for traumatic HTX demonstrated a lower failure rate, shorter TT duration, and shorter ICU and hospital LOS compared with those who did not undergo thoracic irrigation. These findings suggest that thoracic irrigation should be considered at the time of initial TT placement in patients with traumatic HTX.

Retained HTX is common, and thoracic irrigation serves as a promising intervention to decrease the rate of retained HTX leading to less secondary interventions.[1] Historically, larger chest tubes (≥36 Fr) were used for treatment, but recently, smaller (20-32 Fr) chest tubes and pigtail catheters (≤14 Fr) are increasingly used to evacuate HTX, and research has shown that these small-bore TT may be as effective as large bore TT.[1,16–18] This may be because a component of the HTX has already clotted and will not drain no matter what tube size is inserted. Thoracic irrigation may work to decrease the rate of retained HTX by breaking-up any clot that has form and dilute remaining blood allowing the HTX to more completely drain.[10]

Several subtleties in the management of traumatic HTX are debated in the literature and likely impact our findings. For

TABLE 1. Study and Patient Characteristics

Author	Al Tannir et al.[10]	Carver et al.[11]	Crankshaw et al.[12]	Kugler et al.[13]	Kugler et al.[14]	McLauchlan et al.[15]	Overall	*p*
Year	2024	2024	2022	2016	2017	2024	2016–2024	—
Years of enrollment	2017–2021	2018–2023	2019–2020	—	30 mo	2021–2023	—	—
Country	USA	USA	USA	USA	USA	USA	USA	—
Study design	Retrospective	Multicenter, prospective	Retrospective	Prospective	Prospective	Prospective	—	—
Patients, n	370	462	198	20	260	9	1,319	—
Irrigation (TT)	225	123	82	20	54	9	513	—
Control (TT)	145	370	116	0	206	0	837	—
Tube sizes	14 Fr 13% 24–28 Fr 70% 32–36 Fr 17%	<28 Fr 14% ≥28 Fr 86%	Pigtails excluded	36 Fr	32 or 36 Fr	14 Fr	—	—
Preprocedural antibiotics	Yes	—	Yes	—	No	Yes	—	—
Time of TT placement	<24 hours	<24 hours	—	<24 hours	<24 hours	<24 hours: 6 >24 hours: 3	—	—
Age, average, y						—		0.773
Irrigation	39*	40*	38	35*	33*		45	
Control	44*	38*	40	—	42*		45	
Male, n (%)						—		0.241
Irrigation	177 (79)	97 (79)	70 (85)	13 (65)	43 (80)		400 (79)	
Control	113 (78)	311 (84)	98 (85)	—	164 (80)		686 (82)	
ISS, average						—		**<0.001**
Irrigation	17*	18*	22	13*	13*		19	
Control	18*	18*	24	—	13*		22	
Chest AIS, average		—	—			—		1.000
Irrigation	3*			3*	3*		3	
Control	3*			—	3*		3	
Chest AIS, n (%)	—			—	—	—	—	—
1		—	6 (3)					
2		—	24 (12)					
3–5		144 (32)	168 (85)					
Penetrating, n (%)								0.827
Irrigation	93 (41)	55 (45)	48 (59)	11 (55)	29 (54)	1 (11)	217 (42)	
Control	44 (30)	152 (41)	49 (42)	—	104 (51)	—	349 (42)	
Hypotensive (SBP <90 mm Hg), n (%)		—	—	—	—		—	—
Irrigation	25 (11)					0 (0)		
Control	15 (10)					—		
Initial drainage, mL		—			—	—		0.225
Irrigation	200*		447	200*			348	
Control	200*		355	—			316	
24-h Drainage, mL	—					—		0.616
Irrigation		300*		290*	294*		548	
Control		270*		—	374*		587	
Irrigation volume, n (%)								—
<1,000 mL	24 (10)	29 (24)	47 (57)	1 (5)	6 (11)	3 (33)	110 (22)	
1,000 mL	187 (85)	80 (65)	21 (26)	19 (95)	47 (87)	6 (67)	360 (71)	
>1,000 mL	10 (5)	14 (11)	14 (17)	0 (0)	1 (2)	0 (0)	39 (7.7)	
CASP score (category)	27 (high)	24 (high)	26 (high)	17 (medium)	26 (high)	11 (medium)	—	—

*Median; all other numbers are the mean; *p* values in bold are statistically significant.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; SBP, systolic blood pressure.

example, the choice of when to perform a secondary procedure, as well as which one to perform, is left to the judgment of the attending surgeon. There is no agreement about when and what secondary intervention should be performed for a retained HTX.[1] The Eastern Association for the Surgery of Trauma (EAST) recommends early VATS (≤4 days), as this decreases the rate of empyema, hospital and ICU LOS, and mortality compared with late VATS (>4 days).[1] They also recommend VATS over thrombolytic therapy to decrease the rate of additional operative intervention and hospital LOS.[1] In our meta-analysis,

TABLE 2. Outcomes

Author	Al Tannir et al.[10]	Carver et al.[11]	Crankshaw et al.[12]	Kugler et al.[13]	Kugler et al.[14]	McLauchlan et al.[15]	Overall	*p*
Patients, n	370	462	198	20	260	9	1,319	—
Irrigation (TT)	225	123	82	20	54	9	513	
Control (TT)	145	370	116	0	206	0	837	
Failure rate, n (%)								**<0.001**
Irrigation (n = 513)	25 (11)	10 (8.1)	15 (18)	1 (5)	3 (5.6)	1 (11)	55 (10.7)	
Control (n = 837)	36 (25)	47 (13)	24 (21)	—	45 (22)	—	152 (18.2)	
Second TT	15 (4.1)							**0.011**
Irrigation (n = 288)	—	3 (2.4)	5 (6.1)	0 (0)	0 (0)	0 (0)	5 (1.7)	
Control (n = 692)	—	24 (6.5)	5 (4.3)	—	8 (3.9)	—	37 (5.3)	
Thrombolysis					—			0.157
Irrigation (n = 459)	9 (4.0)	1 (0.8)	2 (2.4)	0 (0)		1 (11)	13 (2.8)	
Control (n = 631)	8 (5.5)	2 (0.5)	0 (0)	—		—	10 (1.6)	
VATS								**0.013**
Irrigation (n = 513)	14 (6.2)	5 (4.1)	8 (10)	1 (5)	3 (5.6)	0 (0)	31 (6.0)	
Control (n = 837)	28 (19)	16 (4.3)	9 (7.8)	—	30 (15)	—	83 (9.9)	
Open thoracotomy	—							**0.033**
Irrigation (n = 288)		1 (0.8)	3 (3.7)	0 (0)	0 (0)	0 (0)	4 (1.4)	
Control (n = 692)		5 (1.4)	16 (13.8)	—	7 (3.4)	—	28 (4.0)	
TT duration, average (d)								0.530
Irrigation	4 [3–7]	4 [3–6]	3.7 (0.5)	5 [4–6]	6 [4–7]	4 [5–9]	5.1	
Control	6 [3–9]	4 [3–6]	3.8 (0.6)	—	6 [4–8]	—	5.2	
Hospital LOS, average (d)								**<0.001**
Irrigation	7 [5–13]	7 [5–14]	11.5 (1.4)	7 [5–7]	7 [5–12]	6 [5–9]	10.4	
Control	9 [5–16]	8 [5–18]	15.6 (2.3)	—	8 [4–13]	—	13.5	
ICU LOS, average (d)						—		**<0.001**
Irrigation	2 [0–5]	3 [0–6]	5 (1.5)	0.5 [0–2]	1 [0–2]		2.7	
Control	3[0–8]	3 [2–8]	9 (1.4)	—	1 [0–4]		6.4	
Infectious complication, n (%)		—		—				**0.012**
Irrigation (n = 370)	14 (6.2)		14 (17)		6 (11)	2 (22)	36 (9.7)	
Control (n = 467)	19 (13.1)		21 (18)		33 (16)	—	73 (15.6)	
Pneumonia		—		—				**0.017**
Irrigation (n = 370)	8 (3.6)		13 (16)		5 (9.3)	2 (22)	28 (7.6)	
Control (n = 467)	10 (6.9)		20 (17)		29 (14)	—	59 (12.6)	
Empyema				—				0.828
Irrigation (n = 493)	6 (2.7)	4 (3.3)	1 (1.2)		1 (1.9)	0 (0)	12 (2.4)	
Control (n = 837)	9 (6.2)	7 (1.9)	2 (1.7)		4 (1.9)	—	22 (2.6)	
Readmission, n (%)		—	—			—		0.298
Irrigation (n = 299)	9 (4.0)			2 (10)	1 (1.9)		12 (4.0)	
Control (n = 351)	6 (4.1)			—	3 (1.5)		9 (2.6)	
Mortality, n (%)				—	—			0.600
Irrigation (n = 439)	9 (4.0)	6 (4.9)	0 (0)			0 (0)	15 (3.4)	
Control (n = 631)	7 (4.8)	20 (5.4)	1 (0.9)			—	28 (4.4)	
Cost, mean	—	—		—	—	—		**<0.001**
Irrigation			$223,729				$223,729	
Control			$312,481				$312,481	

Averages are listed as median [interquartile range] or mean (SD); *p* values in bold are statistically significant.

the irrigation group required fewer secondary interventions, including the individual interventions of second TT, VATS, and thoracotomy, than the nonirrigation group. These interventions are associated with increased hospital cost and hospital LOS, so it makes sense that the irrigation group, which required less secondary interventions, also had a lower hospital and ICU LOS as well as decreased costs.[2]

Another current debate regarding TT is whether antibiotics should be given before the procedure.[19] Three of the included studies gave them, one did not, and two did not mention preprocedural antibiotics. Several studies have found that antibiotic prophylaxis decreases the rate of infectious complications including empyema, and EAST conditionally recommends antibiotic prophylaxis before TT insertion for this reason.[20,21]

However, other studies, including an American Association for the Surgery of Trauma multicenter study, found no difference in pneumonia or empyema rates between groups receiving antibiotic prophylaxis or not.[22,23] Future studies should report whether preprocedural antibiotics were used, including the regimen, dosage, and duration.

There is a question of the volume that should be used when performing thoracic irrigation. The included studies generally used 1,000 mL of normal saline as Kugler et al.[13] used in their pilot study. However, some of the included studies had patients that received different amounts. Carver et al.[11] found that a volume of irrigation <1,000 mL compared with 1,000 mL did not correlate with outcomes. Moreover, 57% of patients in Crankshaw et al.[12] received <1,000 mL of irrigation, and they did not find a difference in failure rate between the groups. In addition, there is a risk of arrhythmia with thoracic irrigation, so limiting the amount of fluid instilled to the minimum necessary amount is preferred. For now, the data would conditionally recommend that 1,000 mL of normal saline should be used for thoracic irrigation. Future studies should investigate whether instillation of larger amounts of fluid, for example, until the effluent is clear, results in improved outcomes compared with 1,000 mL.

The included studies had a wide variety of TT sizes. Some studies included patients who received pigtail catheters, whereas Crankshaw et al.[12] excluded them. Recent evidence has shown that there is no difference in outcomes between smaller chest tubes (28–32 Fr) and larger chest tubes (>36 Fr).[18] Moreover, in hemodynamically stable patients, EAST conditionally recommends pigtail catheters over chest tubes for the drainage of traumatic HTX, as they have a lower rate of retained HTX and less need for additional procedures.[1] The included studies did not have many patients who received irrigation through a pigtail catheter. McLauchlan et al.[15] only included patients who received a pigtail catheter and irrigation; however, their sample only included nine patients. Since placement of a pigtail catheter with concurrent thoracic irrigation is a relatively new technique for the treatment of traumatic HTX, there is an opportunity to conduct a 2×2 factorial randomized controlled trial to provide evidence for an interaction between the two treatments.

There are several limitations to this systematic review and the included studies. First, it is possible that we did not identify all the relevant studies. None of the included studies are randomized trials, making them prone to selection bias. Randomized trials addressing this topic are still needed. The primary outcome of failure rate was defined as incompletely drained or retained HTX requiring a second intervention. There is neither a consensus definition of a retained HTX nor a consensus imaging modality to diagnose it.[1] There is also no cutoff of when a retained HTX can be diagnosed. The included studies could have used different definitions and diagnostic criteria. The included studies did not report all the outcomes of interest; for example, only four of the six studies reported overall infectious complications. Future studies should include all relevant outcomes with clear definitions and diagnostic criteria. Some of the included studies reported median values, so we had to use estimated mean values for cumulative analysis and meta-analysis. The included studies were heterogenous in terms of patient management, including the size of TT placed, whether prophylactic antibiotics were given with TT placement, technique used for irrigation, and diagnosis of retained HTX.[20] Moreover, there is no consensus on what subsequent procedure to perform and when to perform it. The choice of secondary intervention and when it was performed can impact outcomes, which may have contributed to differences between the groups in terms of LOS. In addition, the I^2 on meta-analysis for hospital and ICU LOS showed the included studies had high heterogeneity. Finally, two of the six studies did not have a control group, so including their outcomes could have skewed the cumulative analysis. These studies were not included in meta-analysis to limit this skewness.

CONCLUSION

Patients receiving thoracic irrigation had a 41% reduction in the risk of requiring a secondary intervention for retained HTX as well as a shorter hospital LOS, ICU LOS, and TT duration. Thoracic irrigation for traumatic HTX should be considered at the time of TT placement; however, randomized studies are still needed prior to development of guidelines.

AUTHORSHIP

N.B.L., B.L.C., L.T.B., J.Y.V., J.P.M., and N.N. contributed to the study conception and design. N.B.L., B.L.C., M.D.C.-L., J.M.D., and L.S. contributed to the acquisition of data. N.B.L., B.L.C., K.G.P., J.Y.V., J.P.M., and N.N. contributed to the analysis and interpretation of data. N.B.L., K.G.P., J.P.M., and N.N. contributed to the drafting of the manuscript. All authors contributed to the critical revision of the manuscript and provided final approval of the version to be published.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms for all authors have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E69).

REFERENCES

1. 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.
2. DuBose J, Inaba K, Okoye O, Demetriades D, Scalea T, O'Connor J, et al, AAST Retained Hemothorax Study Group. 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.
3. 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.
4. 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.
5. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Available at: https://www.prisma-statement.org//. Accessed June 11, 2024.
6. Lyons N, Namias N. Thoracic Irrigation for Traumatic Hemothorax. PROSPERO 2024 CRD42024546996 Available at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024546996. Accessed June 11, 2024.
7. CASP Critical Appraisal Checklists. Critical Appraisal Skills Programme. Available at: https://casp-uk.net/casp-tools-checklists/. Accessed May 15, 2024.
8. McGrath S, Zhao X, Steele R, Thombs BD, Benedetti A, DEPRESsion Screening Data (DEPRESSD) Collaboration. Estimating the sample mean and standard deviation from commonly reported quantiles in meta-analysis. *Stat Methods Med Res*. 2020;29:2520–2537.
9. Tufanaru C, Munn Z, Stephenson M, Aromataris E. Fixed or random effects meta-analysis? Common methodological issues in systematic reviews of effectiveness. *Int J Evid Based Healthc*. 2015;13(3):196–207.
10. Al Tannir AH, Biesboer EA, Golestani S, Tentis M, Maring M, Gellings J, et al. Thoracic cavity irrigation prevents retained hemothorax and decreases

surgical intervention in trauma patients. *J Trauma Acute Care Surg*. 2024; 97(1):90–95.
11. Carver TW, Berndtson AE, McNickle AG, Boyle KA, Haan JM, Campion EM, et al. Thoracic irrigation for prevention of secondary intervention after thoracostomy tube drainage for hemothorax: a Western Trauma Association multi-center study. *J Trauma Acute Care Surg*. 2024.
12. 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.
13. Kugler NW, Carver TW, Paul JS. Thoracic irrigation prevents retained hemothorax: a pilot study. *J Surg Res*. 2016;202:443–448.
14. 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.
15. McLauchlan N, Ali A, Beyer CA, Brinson MM, Joergensen SM, Yelon J, et al. Percutaneous thoracostomy with thoracic lavage for traumatic hemothorax: a performance improvement initiative. *Trauma Surg Acute Care Open*. 2024;9(1):e001298.
16. Kulvatunyou N, Bauman ZM, Zein Edine SB, de Moya M, Krause C, Mukherjee K, et al. The small (14 Fr) percutaneous catheter (P-CAT) versus large (28-32 Fr) open chest tube for traumatic hemothorax: a multicenter randomized clinical trial. *J Trauma Acute Care Surg*. 2021;91:809–813.
17. Bauman ZM, Kulvatunyou N, Joseph B, Jain A, Friese RS, Gries L, et al. A prospective study of 7-year experience using percutaneous 14-French pigtail catheters for traumatic hemothorax/hemopneumothorax at a level-1 trauma center: size still does not matter. *World J Surg*. 2018;42:107–113.
18. Inaba K, Lustenberger T, Recinos G, Georgiou C, Velmahos GC, Brown C, 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(2):422–427.
19. Choi J, Villarreal J, Andersen W, Min JG, 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.
20. Freeman JJ, Asfaw SH, Vatsaas CJ, Yorkgitis BK, Haines KL, Burns JB, et al. Antibiotic prophylaxis for tube thoracostomy placement in trauma: a practice management guideline from the Eastern Association for the Surgery of Trauma. *Trauma Surg Acute Care Open*. 2022;7:e000886.
21. Bosman A, de Jong MB, Debeij J, van den Broek PJ, Schipper IB. Systematic review and meta-analysis of antibiotic prophylaxis to prevent infections from chest drains in blunt and penetrating thoracic injuries. *Br J Surg*. 2012;99:506–513.
22. Cook A, Hu C, Ward J, Schultz S, Moore Iii FO, Funk G, et al, AAST Antibiotics in Tube Thoracostomy Study Group. Presumptive antibiotics in tube thoracostomy for traumatic hemopneumothorax: a prospective, multicenter American Association for the Surgery of Trauma study. *Trauma Surg Acute Care Open*. 2019;4:e000356.
23. Maxwell RA, Campbell DJ, Fabian TC, Croce MA, Luchette FA, Kerwin AJ, et al. Use of presumptive antibiotics following tube thoracostomy for traumatic hemopneumothorax in the prevention of empyema and pneumonia–a multi-center trial. *J Trauma*. 2004;57:742–748; discussion 748-9.