Thoracic irrigation prevents retained hemothorax: A prospective propensity scored analysis

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BACKGROUND: Thoracic trauma resulting in hemothorax (HTx) is typically managed with thoracostomy tube (TT) placement; however, up to 20% of patients develop retained HTx which may necessitate further intervention for definitive management. Although optimal management of retained HTx has been extensively researched, little is known about prevention of this complication. We hypothesized that thoracic irrigation at the time of TT placement would significantly decrease the rate of retained HTx necessitating secondary intervention.

METHODS: A prospective, comparative study of patients with traumatic HTx who underwent bedside TT placement was conducted. The control group consisted of patients who underwent standard TT placement, whereas the irrigation group underwent standard TT placement with immediate irrigation using 1 L of warmed sterile 0.9% saline. Patients who underwent emergency thoracotomy, those with TTs removed within 24 hours, or those who died within 30 days of discharge were excluded. The primary end point was secondary intervention defined by additional TT placement or operative management for retained HTx. A propensity-matched analysis was performed with scores estimated using a logistic regression model based on age, sex, mechanism of injury, Abbreviated Injury Scale chest score, and TT size.

RESULTS: In over a 30-month period, a total of 296 patients underwent TT placement for the management of traumatic HTx. Patients were predominantly male (79.6%) at a median age of 40 years and were evenly split between blunt (48.8%) and penetrating (51.2%) mechanisms. Sixty (20%) patients underwent thoracic irrigation at time of initial TT placement. The secondary intervention rate was significantly lower within the study group (5.6% vs. 21.8%; OR, 0.16; $p < 0.001$). No significant differences in TT duration, ventilator days, or length of stay were noted between the irrigation and control cohort.

CONCLUSION: Thoracic irrigation at the time of initial TT placement for traumatic HTx significantly reduced the need for secondary intervention for retained HTx. (*J Trauma Acute Care Surg.* 2017;83: 1136–1141. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic Study, Level III.

KEY WORDS: Irrigation; retained hemothorax; hemopneumothorax; thoracic trauma.

Thoracostomy tube (TT) placement is the most common procedure used for the treatment of traumatic pneumothorax (PTx), hemothorax (HTx), or hemopneumothorax (HPTx).[1] Although the majority of HTx is successfully managed with primary TT placement, retained HTx may occur in up to 20% of patients and can result in empyema and fibrothorax leading to significant morbidity and mortality.[2–8] The majority of research has focused on the optimal management of retained collections; however, little is known about the methods to prevent retained HTx in trauma patients.[5,9–17]

Despite efforts to improve primary management of traumatic HTx, rates of retained HTx have remained relatively unaffected.[1,13,18–21] A pilot study using thoracic irrigation performed at the time of TT placement resulted in fewer interventions for retained HTx.[22] Based on those promising results, we sought to determine the efficacy of initial thoracic cavity irrigation to prevent retained HTx requiring secondary intervention in a larger patient group. We hypothesized that thoracic cavity irrigation at the time of initial TT placement would decrease the rate of intervention for retained HTx by at least 50%.

METHODS

Study Design

Froedtert Memorial Lutheran Hospital is an American College of Surgeons' Committee on Trauma-verified Level I adult trauma center that serves the suburban and urban population of Milwaukee, Wisconsin. The Medical College of Wisconsin's Institutional Review Board reviewed and approved the design of this prospective comparative study, which consisted of a nonirrigation control arm and a thoracic irrigation experimental arm. Thoracic irrigation at the time of initial TT placement was done at the discretion of the attending trauma surgeon using the procedure described below. Patients were entered in a prospectively maintained thoracic trauma database. All patients 18 years or older presenting within 24 hours of blunt or penetrating injury resulting in traumatic HTx on imaging were enrolled. HTx was determined by the staff trauma surgeon at time of the initial resuscitation based on initial imaging. Exclusion criteria included

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those younger than 18 years, TT placement greater than 24 hours after initial trauma, need for immediate thoracic operative intervention, operative placement of the TT, TT removal within 24 hours of placement, or death within 30 days. The primary outcome of the study was needed for secondary intervention, defined as performance of additional TT placement, video-assisted thoracoscopic surgery, or thoracotomy for the management of retained HTx. Patients were followed up for 30 days after discharge for all thoracic complications including pneumonia, empyema, recurrent PTx, and need for additional thoracic intervention. Imaging after discharge was obtained only when clinically indicated.[23]

Sample Size

To power the experimental cohort, a sample size calculation was performed using a two-sample z test with an alpha of 0.05% and 80% power. Based on prior institutional experience and the current literature, we anticipated a secondary intervention rate within the control and experimental cohorts of 20% and 7%, respectively.[22] Using these estimates, we determined 60 thoracic irrigation patients would be required to meet statistical significance. The study was stopped after successful, consecutive enrollment of 60 patients within the irrigation cohort. The control cohort was comprised of individuals enrolled within our prospective thoracic trauma database who met the stated inclusion criteria.

Institutional TT Practice

HTx is managed in our institution by placing a 32 or 36 French TT at the bedside using standard aseptic technique with the goal of a posterior and apical intrathoracic position.[24] Patients underwent irrigation at time of placement at the discretion of the attending trauma surgeon and/or senior trauma resident. Patients who were hemodynamically unstable or required immediate operative thoracic intervention were historically excluded from irrigation. Figure 1 outlines the institutional thoracic irrigation protocol. In brief, initial suction evacuation of the thoracic cavity was performed by applying suction to the TT until minimal return was noted. Five hundred milliliters of warm sterile 0.9% saline was then poured into the chest tube followed by immediate evacuation of the fluid. An additional 500 mL was then instilled and evacuated. The TT was connected to a standard pleural drainage system, and placed to −20 cm H_20 suction in all patients. All patients underwent immediate postprocedure imaging to confirm intrathoracic position of the TT. Routine periprocedural antibiotics are not part of our institutional practice pattern. In accordance with institutional practice, routine imaging was not obtained throughout their hospital stay. Indications for repeat imaging include physician discretion, persistent air leak, high TT outputs, subjective shortness of breath, increasing oxygen requirements, inability to wean oxygen, and signs of infection. The decision for additional intervention after TT placement was made by the rounding trauma staff based on the patient's clinical status rather than routine radiographic imaging. All new and/or complex patients, often patients in whom operative intervention is being considered, were discussed at daily morning conference.

Statistical Analysis

All patients who underwent thoracic irrigation were analyzed using an intent-to-treat model. 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,

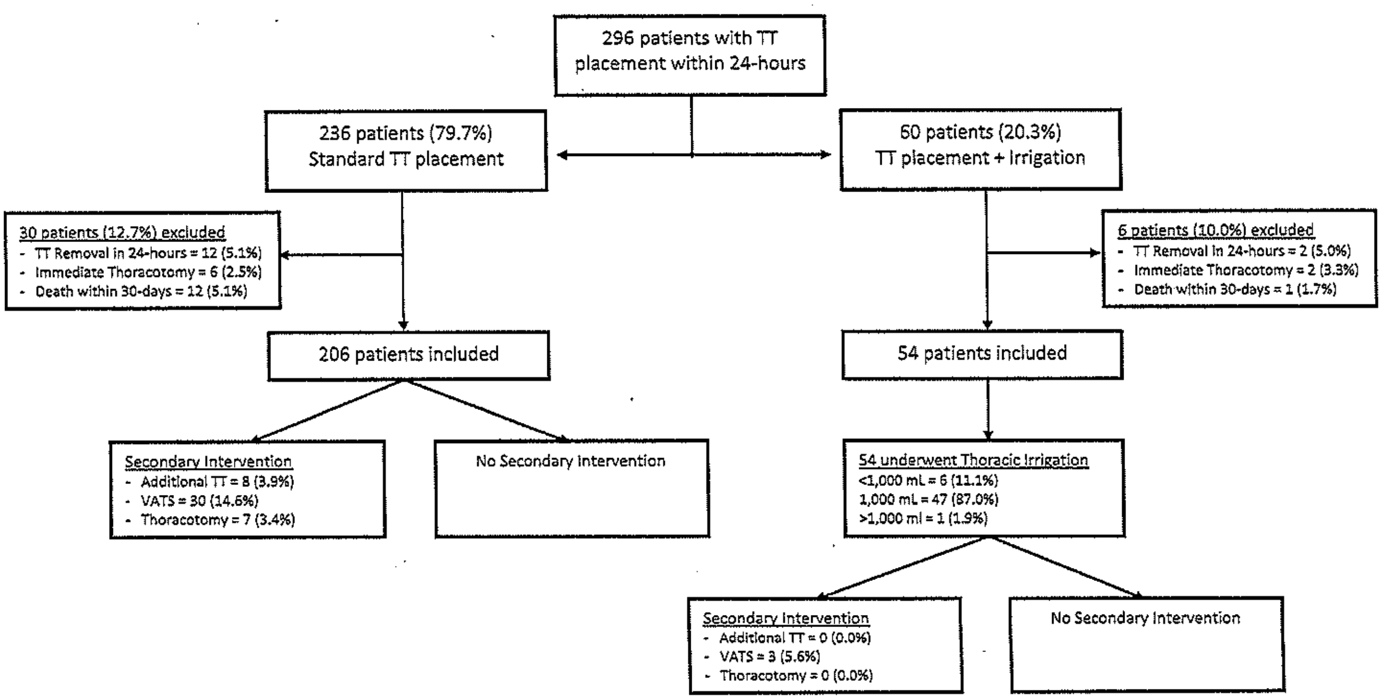

Figure 1. An overview of the necessary supplies required to conduct the thoracic irrigation procedure. An overview of the steps necessary to conduct the procedure in an attempt to help standardize the approach to irrigation of the thoracic cavity.

ventilator days, intensive care unit length of stay, hospital length of stay). Propensity score methods were used to adjust for potential selection bias in this comparative study. Propensity scores were estimated using a logistic regression model with age, sex, mechanism of injury, Abbreviated Injury Scale (AIS) chest, and TT size as predictors. The predicted probabilities were then used to obtain the weights as the inverse probability of treatment. Corresponding estimates (odds ratio and mean differences) and p values are reported.

RESULTS

A total of 296 patients underwent TT placement for the initial management of traumatic HTx or HPTx during 30 months. Sixty (20%) patients underwent thoracic irrigation at time of initial TT placement with the remaining 236 patients comprising the control cohort. Thirty-six (12.2%) patients were excluded from data analysis (Fig. 2) with TT removal within 24 hours and death within 30 days being the most common reasons. Patients were predominantly men (79.6%) and had a median age of 40 years. Patients were almost evenly split between blunt (48.8%) and penetrating (51.2%) mechanisms. Intervention and control cohort characteristics are summarized in Table 1. Table 2 outlines the outcome variables of each cohort. The majority (85%) of patients within the irrigation cohort received a 1,000-mL irrigation with six (11.1%) patients receiving less than 1,000 mL. Median initial TT output in the thoracic irrigation group was 200 mL. The faculty placing the TT and the rounding faculty were different in 74.1% of the irrigation cohort and 62.6% of the control cohort. All patients in the irrigation cohort who underwent secondary intervention had a different placement and rounding faculty, whereas 82.2% of control cohort patients had different rounding and initial placement faculty.

Table 3 provides an overview of the propensity score parameter analysis and demonstrates no significant differences. The propensity scored weighted logistic regression analysis is detailed in Table 4 and shows that secondary intervention rates were significantly lower within the irrigation group (5.6% vs. 21.8%; OR, 0.16; $p < 0.001$). Secondary outcomes are outlined in Table 4 and demonstrate no significant differences between the irrigation and control cohorts.

TABLE 1. Patient and Trauma Demographics

	Irrigated	Nonirrigated
Total patients	n = 54	n = 206
Age, y	33 (26–52)	42 (28–54)
Male, n (%)	43 (79.6%)	164 (79.6%)
ISS	13 (9–21)	13 (9–22)
AIS-chest	3 (3–3)	3 (3–3)
Blunt trauma, n (%)		
Total	25 (46.3%)	102 (49.5%)
Motor vehicle collision	12 (22.2%)	46 (22.3%)
Fall	7 (13.0%)	25 (12.1%)
Motor pedestrian collision	2 (3.7%)	6 (2.9%)
Motorcycle collision	1 (1.9%)	18 (8.7%)
Assault	1 (1.9%)	5 (2.4%)
Other	2 (3.7%)	3 (1.5%)
Penetrating trauma, n (%)		
Total	29 (53.7%)	104 (50.5%)
Gunshot wound	21 (38.9%)	64 (31.1%)
Stab wound	8 (14.8%)	40 (19.4%)
TT indication, n (%)		
HTx	34 (63.0%)	109 (52.9%)
HPTx	20 (37.0%)	97 (47.1%)

An overview of the patient demographics along with the trauma characteristics. This table provides a comparison between those patients who underwent irrigation compared with those who did not.

All numbers are median (interquartile range) unless otherwise stated.

ISS, Injury Severity Score.

DISCUSSION

This study confirms the results of our pilot data that thoracic irrigation significantly reduces the secondary intervention rate for retained HTx. The current study demonstrated a 75% reduction in the secondary intervention rate. The addition

Necessary Supplies:

Standard Thoracostomy Tube Tray
32 or 36-French Thoracostomy Tube (TT)
1000mL of sterile WARM normal saline
Sterile Suction Setup with Associated Wall Suction
60mL sterile Toomey syringe (plunger removed)

Procedure Outline:

1.Patients are placed in a standard supine position
2.A 32 or 36-French TT is placed utilizing standard aseptic technique
3.Sterile suction catheter is inserted within the TT Suction maintained till no return of effluent. Operative Intervention pursued in the setting of initial output >1500mL.
4.Sterile 60 mL Toomey syringe is connected to the TT5.500mL of warm sterile saline is instilled via pour technique. Saline is poured by the assistant into the open end of the 60mL syringe. Syringe should be held above the level of the chest to ensure proper instillation.
6.Sterile suction is reinserted within the TT for complete evacuation of the thoracic cavity.
7.Steps 3-5 are repeated for a total of 1,000mL of irrigation.
8.TTis connected to a standard Atrium and placed to -20mmHg suction for the first 24 hours.

Figure 2. An overview of patient enrollment and the results of the study. This consort flow diagram provides critical details to the results of the study in an illustrative fashion such that readers will be able to understand the study flow.

TABLE 2. Results Overview

	Irrigation Cohort	Control Cohort
Irrigation volume, n (%)		N/A
<1,000 mL	6 (11.1%)	
1,000 mL	47 (87.0%)	
>1,0000 mL	1 (1.9%)	
TT output, mL		
First 24 h	294 (200–593)	374 (196–750)
Total	1124 (470–1,675)	1015 (447–1,917)
Reintervention, n (%)		
Total	3 (5.6%)	45 (21.8%)
Additional TT	0	8 (3.9%)
Video-assisted thoracoscopic surgery	3 (5.6%)	30 (14.6%)
Thoracotomy	0	7 (3.4%)
Infectious complications		
Pneumonia	5 (9.3%)	29 (14.1%)
Empyema	1 (1.9%)	4 (1.9%)
TT duration, d	6 (4,7)	6 (4,8)
Post-pull chest X-ray, n (%)	44 (73.3%)	178 (75.4%)
Post-pull PTx	11 (25.0%)	23 (12.9%)
Length of stay, d	7 (5–12)	8 (4.13)
ICU length of stay, d	1 (0–2)	1 (0–4)
30-d Readmission, %		
Thoracic related,	1.9	1.5
30-d Clinic follow-up, %	87.9	84.7

An overview of the results for both the irrigated and nonirrigated cohorts.
All numbers are median (interquartile range) unless otherwise stated.
ICU, intensive care unit.

of evacuation and irrigation to standard bedside TT placement added less than 5 minutes to the procedure time. Residents and staff reported comfort with the procedure after performing a single case.

Several concepts have been explored to decrease retained HTx rates. "Ideal" intrathoracic positioning of a TT intuitively improves the efficacy of drainage; however, recent studies found no significant difference in the rate of retained HTx based off intrathoracic positions.[1,25] Thus, it would appear that techniques aiming to improve intrathoracic position provide no clinical benefit in the prevention of retained HTx.

Traumatic HTx consists of both a solid and a liquid component but the clotted portion is considered to be the major

TABLE 3. Propensity Score Parameters Analysis

	Odds Ratio	p
Age	0.99 (0.97–1.01)	NS
Sex (female vs. male)	0.93 (0.42–2.07)	NS
MOI (penetrating vs. nonpenetrating)	0.96 (0.46–1.99)	NS
AIS-chest		
<3 vs. > 3	0.94 (0.12–7.49)	NS
3 vs. > 3	3.50 (0.78–15.71)	NS
TT size (<36 vs. 36)	1.92 (0.52–7.07)	NS

An overview of the propensity scored parameters which were used in conducting the overall propensity score matched analysis.
MOI, mechanism of injury.

TABLE 4. Propensity Score Outcomes Analysis

Categorical Outcomes	Odds Ratio	p
Secondary intervention (irrigated vs. nonirrigated)	0.16 (0.08–0.31)	<0.001
Linear regression for numeric outcomes	Estimate	p
TT duration	+0.03	NS
Length of stay	+0.04	NS
ICU length of stay	−0.01	NS
Ventilator days	−0.02	NS

An overview of the propensity score matched final analysis for the primary study outcome of secondary intervention along with secondary outcome measures.

contributor to development of a retained HTX. Thus, it would seem logical that intrathoracic positioning would not affect secondary intervention rates. A pilot study using a sterile Yankauer suction catheter to remove early clot showed a 45% reduction (10% vs. 18.2%) in secondary interventions.[20] Savage and colleagues[26] evaluated 99 consecutive patients treated with suction evacuation (SEPS) before TT placement for the management of traumatic HTx and/or PTx. Although they demonstrated a significant reduction in recurrent PTx, they failed to demonstrate any significant reduction in retained HTx or the rate of secondary intervention which led them to question the role of SEPS in the prevention of retained HTx.[26]

We hypothesize that irrigation works through 2 mechanisms. First, irrigation leads to a mechanical disruption of the formed clot into smaller pieces that can be evacuated through the TT. Second, irrigation results in a dilution of intrathoracic blood. Respiration during irrigation results in distribution of the saline throughout the pleural space which maximizes the effect of both mechanisms, the diluting effect and mechanical benefits. The combination of these seems to effectively remove the majority of blood within the thoracic cavity.

The universal availability of sterile 0.9% saline, including in resource poor settings, makes it an ideal choice for an irrigant. Although sterile water is also nearly universally available, there exists theoretical concern for electrolyte derangements after hypotonic irrigation as seen in some gynecology and urology literature.[27,28] Although previous work highlights the benefits of tissue plasminogen activator and streptokinase in the management of retained HTx there are no studies that evaluate its utility or safety in the acute setting.[29–31] Additionally, given the recent trauma the potential for significant bleeding complications limits its use in the acute setting.

Studies demonstrate variable rates of retained HTx, partly because of a lack of unified definition and method of diagnosis. Retained HTx rates in our institution range between 20% and 25%, which is consistent with the reported rates in the literature of 16% to 25%.[1,11,13,19–21,25] The risk factors associated with retained HTx remains debated. Helling et al.[6] noted increased rates of retained HTx in penetrating injuries compared to blunt; however, others have not found significant differences based off mechanism.[1,25] High initial HTx volume, elevated AIS-chest score, and Injury Severity Score are also inconsistently associated with increased rates of retained HTx.[1,25,26] Studies show that no relationship between secondary intervention and expertise of individuals performing TT placement, presence of an attending, or size of TT placed.[1,26,32] Because of such controversy surrounding risk factors for development of retained HTx, a propensity analysis was conducted on all gathered factors resulting in no significant differences.

Similar to previous direct suction evacuation safety data and the results of the thoracic irrigation pilot study, no significant safety concerns with irrigation of the thoracic cavity were noted.[20,22,26] A single patient who underwent thoracic irrigation required intubation after completion of the thoracic irrigation intervention. On review, this intubation appeared to be due to the injuries sustained and was not related to the irrigation. No other complications or safety concerns were noted in relation to thoracic irrigation. In theory, thoracic irrigation could be arrhythmogenic; however, no individuals in this study experienced any procedural-related arrhythmias.

Secondary outcomes for the study failed to demonstrate any significant differences in TT duration, ventilator days, and either intensive care unit or hospital length of stay. The lack of any significant differences is likely the result of several factors. First, the study was not appropriately powered for such outcomes and thus the potential for a type two error exists. Second, most patients within this cohort had extrathoracic injuries which make it difficult to demonstrate a link between thoracic irrigation and a reduction in length of stay.

This study has several limitations, most notably the lack of randomization, which created a selection bias. The decision to perform thoracic irrigation was at the discretion of the attending trauma surgeon and resulted in an unequal distribution among the faculty who performed thoracic irrigation. Also, patient factors, such as hemodynamics, presence of multiple injuries, and perceived volume of HTx, potentially affected which patients underwent irrigation. Of note, the decisions regarding management of the TT and the need to perform secondary intervention were usually made by a faculty that was not involved with the initial TT placement and counters some of the selection bias. A quarter of the patients in the irrigation cohort had the placement faculty involved with their subsequent care at some point during the hospital stay. Of note, none of those patients underwent secondary intervention, suggesting bias in this patient group. Performing a blinded randomized trial was not feasible because of the need for consent in emergent patients. To best address the lack of randomization in our study design, utilization of a propensity score matched analysis guided by identifiable risk factors as discussed above was incorporated. Although this does not eliminate bias, the propensity score match design does allow for isolation of the benefits of thoracic irrigation. To definitively determine if there is a benefit in this technique a true blinded randomized study is necessary.

Despite these limitations, we found that thoracic irrigation at the time of initial TT placement within 24 hours of a traumatic HTx results in a significant reduction in the rate of retained HTx as defined by the need for secondary intervention. To our knowledge, this is the only appropriately powered prospective study to investigate the effectiveness of thoracic irrigation at the time of initial TT placement and provides a solid foundation for a randomized control study.

AUTHORSHIP

N.W.K., T.W.C., and J.S.P. participated in the conception and design. N.W.K., T.W.C., D.M., and J.S.P. participated in analysis and interpretation. N.W.K. participated in data collection. N.W.K. participated in writing the article. N.W.K., T.W.C., D.M., and J.S.P. participated in the critical revision of the article. N.W.K., D.M., T.W.C., and J.S.P. participated in the statistical analysis. N.W.K., T.W.C., D.M., and J.S.P. participated in the final approval.

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DISCLOSURE

None of the authors have any financial and personal relationships with other people or organizations that could potentially and inappropriately influence their work and conclusions.

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