Surgery 170 (2021) 1260–1267

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Scoping review of traumatic hemothorax: Evidence and knowledge gaps, from diagnosis to chest tube removal

Jeff Choi, MD, MSc[a,b,*], Joshua Villarreal, MD[a,b], Wyatt Andersen, MSHS[b,c], Jung Gi Min, BSc[b,c], Gavin Touponse, BSc[b,c], Connie Wong, MLIS, DVM[b], David A. Spain, MD[a,b], Joseph D. Forrester, MD, MSc[a,b]

[a] *Division of General Surgery, Department of Surgery, Stanford University, Stanford, CA*
[b] *Surgeons Writing About Trauma, Stanford University, Stanford, CA*
[c] *School of Medicine, Stanford University, Stanford, CA*

ARTICLE INFO

Article history:
Accepted 11 March 2021
Available online 19 April 2021

ABSTRACT

Background: Traumatic hemothorax is a common injury that invites diagnostic and management strategy debates. Evidence-based management has been associated with improved care efficiency. However, the literature abounds with long-debated, re-emerging, and new questions. We aimed to consolidate up-to-date evidence on traumatic hemothoraces, focusing on clinical conundra debated in literature.
Methods: We conducted a scoping review of 21 clinical conundra in traumatic hemothorax diagnosis and management according to PRISMA-ScR guidelines. Experimental and observational studies evaluating patients (aged ≥18 years) with traumatic hemothoraces were identified through database searches (PubMed, EMBASE, Web of Science, Cochrane Library; database inception to Sep, 26 2020) and bibliography reviews of selected articles. Three reviewers screened and selected articles using standardized forms.
Results: We screened 1,440 articles for eligibility, of which 71 met criteria for synthesis. The review comprises 6 sections: (1) Presumptive antibiotics before tube thoracostomy; (2) Initial diagnostic and intervention decisions; (3) Chest tubes; (4) Retained hemothoraces; (5) Delayed hemothoraces; and (6) Chest tube removal). The 21 conundra across these sections follow the format of a question, our recommendation based on interpretation of available evidence, and succinct rationale. Rationale sections detail knowledge gaps and opportunities for future research.
Conclusion: Even practices engrained into surgical dogma, such as obtaining chest x-rays after inserting or removing chest tubes and mandating operation for patients who develop chest tube output above a certain threshold, deserve re-evaluation. Some knowledge gaps require rigorous future investigation; sound clinical judgment can likely supplement others.

Introduction

Traumatic hemothorax is a common injury identified and managed during resuscitation. Massive hemothoraces compromising ventilation or circulation require immediate intervention, but other hemothoraces invite diagnostic and management strategy debates. The Eastern Society for the Surgery of Trauma (EAST) and the American Association for the Surgery of Trauma (AAST) have conducted multiple studies to update evidence for management of traumatic hemothoraces,[1–6] which have been associated with reduced interventions and improved care efficiency.[7,8]

Despite existing guidelines, traumatic hemothorax literature abounds with long-debated (eg, presumptive antibiotics before tube thoracostomy),[3,9,10] re-emerging (eg, delayed hemothoraces [dHTX])[11–14] and new (eg, chest tube thoracic irrigation to mitigate retained hemothoraces [rHTX])[15] questions. Scoping reviews are ideal tools to evaluate expansive bodies of evidence and identify knowledge gaps.[16,17] Scoping review of traumatic hemothoraces may help clinicians align practice with evidence and direct targeted research agenda. Even practices engrained into surgical dogma and widely taught by Advanced Trauma Life Support, such as obtaining

* Reprint requests: Jeff Choi, MD, 300 Pasteur Drive, H3591, Stanford, CA 94305.
E-mail address: jc2226@stanford.edu (J. Choi);
Twitter: @JeffChoi01

https://doi.org/10.1016/j.surg.2021.03.030

chest x-rays (CXR) after inserting or removing chest tubes and mandating operation for patients who develop chest tube output above a certain threshold, deserve re-evaluation.

We aimed to consolidate up-to-date evidence on traumatic hemothoraces, focusing on clinical conundra debated in literature. We selected studies systematically and present a succinct review highlighting 21 conundra. We hope conundrum-focused assessment of evidence and knowledge gaps can facilitate evidence-based practice adoption and guide future discoveries.

Methods

Study selection

We defined conundra as "challenging questions," from the perspective of a surgeon who may encounter hemothoraces in practice but is not an expert on hemothorax literature. We defined 21 conundra through peer discussion before literature review, according to subjective knowledge of ongoing debates and knowledge gaps in hemothorax literature (J.C., D.A.S., J.D.F.).

We conducted a scoping review of management of traumatic hemothoraces according to scoping review guidelines.[16–18] Supplementary Table S1 contains our Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist.[18] A research librarian (C.W.) designed and performed searches of 4 bibliographic databases: (1) PubMed, (2) EMBASE, (3) Web of Science, and (4) the Cochrane Library (Supplementary Table S2). Eligible studies included experimental and observational studies evaluating adult patients (aged ≥18 years) with traumatic hemothoraces and published in English (from database inception to September 26, 2020). We excluded animal and cadaver studies (we aimed to evaluate evidence from clinical practice), studies of children (aged <18 years), case studies, conference abstracts, and commentaries.

We uploaded selected studies to Covidence, a Cochrane-sanctioned web-based application that facilitates screening. Two reviewers (J.V. and W.A.) screened eligible studies and identified studies relevant for answering 21 conundra (Table I) using standardized forms. A third reviewer (J.C.) resolved disagreements. We reviewed bibliographies of selected studies to identify additional relevant studies.

Scoping review strategy

We report study design, population size, and effect sizes (eg, odds ratio [OR] with 95% confidence intervals [CI]) for significant findings. We did not doubly describe primary studies subsequently synthesized within meta-analysis. Some conundra (eg, necessity of graduated chest tube removal) could only be answered by studies comprising patients with concurrent pneumothoraces. In these cases, we specify proportion of patients with isolated hemothoraces and report hemothorax subgroup-specific results when available. All conundra follow the format of a question, recommendation (our interpretation of available evidence), and succinct rationale. When appropriate, rationale specifies knowledge gaps and opportunities for future research. This study did not meet criteria for review by Stanford University Institutional Review Board.

Methodologic limitations

We identified studies systematically and supplemented relevant studies through bibliography reviews, but our search likely did not capture all available evidence that 21 distinct systematic reviews would have consolidated. Our "recommendations" are subjective interpretations of available evidence. Absence of methodologic quality appraisal is a limitation of scoping reviews, but we detail objective rationale to facilitate others deriving their own interpretations.[17]

Results

A total of 1,440 studies underwent screening for eligibility; 71 studies, including 4 identified from bibliography review, were included in our evidence synthesis Figure I.

Presumptive antibiotics before tube thoracostomy

Should presumptive antibiotics be administered to decrease incidence of infectious complications?

Recommendation. Presumptive antibiotics are likely unnecessary; performing tube thoracostomy under sterile condition is likely more important.

Rationale. A meta-analysis of 11 randomized controlled trials (RCTs) (RCT; inclusive of all RCTs synthesized by Sanabria et al) concluded presumptive antibiotics decrease rates of empyema (OR [95% CI]: 0.3 [0.2–0.6]) and overall infections (OR [95% CI]: 0.2 [0.1–0.5]), but not pneumonia.[9,10] A third systematic review contested there is insufficient high-quality evidence to support presumptive antibiotic use.[3] Two subsequent prospective observational multi-center studies re-visited this question.[4,19] In the first study (20 trauma centers, $N = 238$ patients with rHTX), presumptive antibiotics was associated with lower odds of developing pneumonia (OR [95% CI]: 0.4 [0.2–0.8]).[4] In the second (23 trauma centers, $N = 1887$) study, there were no associations between presumptive antibiotics and odds of developing empyema or pneumonia.[19] Many patients undergoing tube thoracostomy develop pneumonia (hemothorax: up to 15%,[19] rHTX: up to 46%[4]), but a causal relationship between tube thoracostomy and pulmonary infection has not been established. Presumptive antibiotics are not given for similar procedures (eg, urinary catheter and central line insertion) and we suspect performing tube thoracostomy under sterile condition is likely more important than administration of antibiotics.

If presumptive antibiotics are administered before tube thoracostomy, is there an ideal antibiotic regimen, dosage, or duration?

Recommendation. If presumptive antibiotics are used, a single dose of cefazolin before tube thoracostomy is likely sufficient.

Rationale. Two meta-analyses supporting presumptive antibiotics synthesized variable antibiotic strategies (eg, Bosman et al: 8 antibiotics, 3 drug classes, 7 dosages, and 3 antibiotic durations).[9,10] Two prospective multi-center studies reported 12 and 14 different antibiotics; cefazolin was most common, but dosage and duration varied.[4,19] Of note, an RCT ($N = 188$, penetrating injury victims) reported similar pneumonia and empyema rates between patients receiving single-dose, presumptive intravenous ampicillin and those on additional oral prophylaxis as long as the chest tube was in place.[20] Lack of a placebo arm precluded ascertaining ampicillin's clinical utility. Given the unclear benefit of presumptive antibiotics and the importance of antibiotic stewardships, if presumptive antibiotics are desired, a single dose of cefazolin before tube thoracostomy is likely sufficient.

Table I
Clinical conundra in traumatic hemothorax diagnosis and management

Section	Conundrum
Presumptive antibiotics before tube thoracostomy	Should presumptive antibiotics be administered to decrease incidence of infectious complications?
	If presumptive antibiotics are administered before tube thoracostomy, is there an ideal antibiotic regimen, dosage, or duration?
	Does blunt or penetrating injury mechanism affect presumptive antibiotic efficacy for tube thoracostomy?
Initial diagnostic and intervention decisions	Among blunt injury victims, how should occult hemothoraces be managed?
	What is bedside ultrasound's role for diagnosing hemothoraces?
	What initial chest tube output mandates surgical intervention?
Chest tubes	Does chest tube size affect outcomes?
	Does chest tube insertion site or trajectory influence secondary intervention rates?
	Should confirmatory CXR follow tube thoracostomy?
	Does placing chest tubes on suction or water seal affect outcomes?
rHTX	What are the risk factors for rHTX?
	What is the optimal lytic therapy regimen for rHTX?
	What is the role of VATS compared to tube thoracostomy or lytic therapy for rHTX?
	When is the ideal time to perform VATS for rHTX?
dHTX	What is the incidence of dHTX among patients with blunt thoracic injuries?
	What is the etiology and presenting symptoms of dHTX?
Chest tube removal	Is a graduated chest tube removal (suction to water seal to clamp trial) necessary?
	Is it unsafe to remove chest tubes in patients on positive pressure ventilation?
	Should chest tubes be removed at end-inspiration or end-expiration?
	Is a confirmatory CXR required after chest tube removal?

CXR, chest x-ray; *dHTX*, delayed hemothoraces; *rHTX*, retained hemothoraces; *VATS*, video-assisted thoracoscopic surgery.

Does blunt or penetrating injury mechanism affect presumptive antibiotic efficacy for tube thoracostomy?

Recommendation. Presumptive antibiotics are likely unnecessary, regardless of injury mechanism.

Rationale. Few studies evaluating presumptive antibiotics for tube thoracostomy delineate injury mechanism. In a subgroup analysis, 1 meta-analysis reported presumptive antibiotic was associated with reduced odds of overall infection among penetrating (OR [95% CI]: 0.3 [0.1–0.6]) but not blunt injury patients.[10] A prospective multi-center study reported blunt injury to be an independent risk factor for developing pneumonia among patients with rHTX but did not delineate antibiotic efficacy based on injury mechanism.[4]

Initial diagnostic and intervention decisions

Among blunt injury victims, how should occult hemothoraces be managed?

Recommendation. A majority of occult hemothoraces can likely undergo expectant management.

Rationale. Hemothoraces are increasingly diagnosed in the era of frequent computed tomography (CT) scans for injured patients. Occult hemothoraces are defined as hemothoraces visible on CT but not on CXR. A planned secondary analysis of 2 prospective studies ($N = 384$) reported that 80% of hemothoraces among blunt injury victims are occult.[21] Half of patients with occult hemothoraces underwent tube thoracostomy due to practice pattern rather than necessity. Two retrospective studies aimed to delineate occult hemothoraces that require tube thoracostomy but acknowledged they had characterized practice patterns (eg, decision to perform tube thoracostomy) rather than physiologic need for tube thoracostomy.[22,23] One reported all hemothoraces measuring >3 cm in pleural gutters (CT axial view) underwent tube thoracostomy,[22] whereas another reported no significant differences in chest tube output or duration between occult and non-occult hemothoraces.[23]

With tube thoracostomy complication rates approaching 20%,[24,25] there is emerging interest in selective expectant management of hemothoraces. One retrospective study ($N = 635$, 67% with hemothoraces <300 mL) reported no incidence of empyema after expectant hemothorax management.[26] A meta-analysis of 6 studies ($N = 1405$) reported that 77% of occult hemothoraces undergo successful expectant management.[27] A prospective study ($N = 67$) reported an 83% expectant management success rate, which was not affected by concurrent occult pneumothoraces.[28] Retrospective studies report risk factors of expectant management failure to be older age and larger hemothoraces (≥300 mL or >1.5 cm pleural gutter fluid thickness on axial view).[29,30] Patients who fail expectant management and undergo delayed tube thoracostomy may not necessarily experience higher mortality or morbidity compared to those undergoing early tube thoracostomy.[29]

Radiographically defining occult hemothoraces can be misleading: occult hemothoraces comprise variable volumes and risks for hemothorax progression. Futures studies should define hemothoraces that can undergo expectant management by incorporating physiologic, injury mechanism, anatomic, and patient considerations.

What is bedside ultrasound's role for diagnosing hemothoraces?

Recommendation. Ultrasound may be a valuable screening and prognostication tool for hemothoraces during primary surveys.

Rationale. A meta-analysis ($N = 449$) reported ultrasound has 60% sensitivity and 98% specificity for diagnosing hemothoraces;[31] a prospective study ($N = 142$) reported 13% sensitivity and 98% specificity.[32] However, CT—which also detects clinically insignificant occult hemothoraces—was the gold standard for assessing ultrasound sensitivity. Low sensitivity of ultrasound may represent a favorable failure to detect clinically insignificant hemothoraces. Pleural margins are routinely visualized during Focused Assessment with Sonography for Trauma; evaluating whether hemothorax volumes measured on ultrasound can predict expectant management failure should be studied. One retrospective study ($N = 84$) reported that using ultrasound was associated with fewer non-therapeutic (<500 mL total chest tube output) tube thoracostomies.[33]

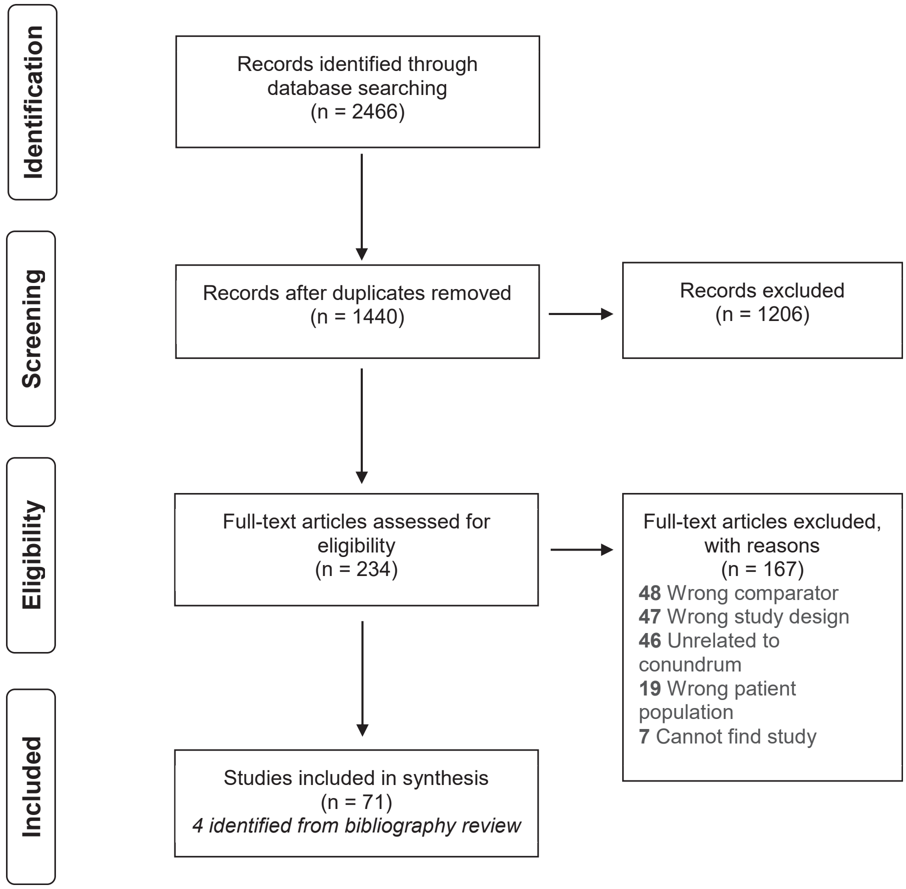

Fig. 1. PRISMA flow diagram of studies included in evidence synthesis. *PRISMA*, Preferred Reporting Items for Systematic reviews and Meta-Analyses extension.

What initial chest tube output mandates surgical intervention?

Recommendation. A singular threshold output should not guide the decision to operate.

Rationale. A multi-center retrospective case series of patients with hemothoraces who underwent urgent thoracotomy ($N = 157$) reported 3 times higher mortality among patients with 1,500 mL compared to 500 mL of chest tube output.[34] Although authors presented associations between mortality and chest tube output among patients who underwent urgent thoracotomy, the findings have been misinterpreted to become the basis for the recommendation to perform thoracotomy for initial chest tube output >1500 mL. This recommendation permeates trauma literature including Advanced Trauma Life Support guidelines. However, an inclusion criterion (undergoing urgent thoracotomy), by definition, cannot be a predicted outcome. Moreover, retrospective studies can only elucidate risk factors for the *decision to* operate rather than the *need to* operate. Study design challenges (ie, sufficiently measuring and controlling for important confounders, such as time from injury to tube thoracostomy) and ethical considerations preclude validating a single threshold output. Sound clinical judgment based on clinical trends, chest tube output trends, and injury pattern can inform the decision to operate.

Chest tubes

Does chest tube size affect outcomes?

Recommendation. Smaller chest tubes have similar outcomes as larger chest tubes.

Rationale. Studies most commonly categorize 28 Fr or 32 Fr chest tubes (range: 28 Fr–40 Fr) as large-bore, and 14 Fr chest tubes (range: 8 Fr–22 Fr) as small-bore. Studies to date (5 retrospective, 1 prospective cohort) report similar initial output volumes, drainage rates, and overall complication rates for patients undergoing small- and large-bore tube thoracostomies.[35–40] No study assessed tube-site-specific pain between small- and large-bore tubes. Selection bias (eg, older and more clinically stable patients received small-bore tubes) and variable time to tube thoracostomy confound associations between chest tube size and outcomes.

Does chest tube insertion site or trajectory influence secondary intervention rates?

Recommendation. As long as chest tubes are in the pleural space, insertion site and trajectory (apical versus caudal) likely do not influence secondary intervention rates.

Rationale. A retrospective study ($N = 297$) reported chest tube insertion site (80% inserted in fifth–seventh intercostal space) did not affect secondary intervention rates if tubes were in the pleural space.[41] Another retrospective study ($N = 88$) found no difference between secondary intervention or complications rates between tubes placed in the second–third intercostal space (midclavicular line) and fourth–fifth intercostal space (midaxillary line).[42] A retrospective study ($N = 458$) categorized tube trajectory as "ideal" (apical course) or "nonideal" (medial or caudal course); authors concluded tube trajectory does not influence secondary intervention rates.[43] Offsetting skin incision and pleurotomy (to facilitate tract closure after tube removal) and avoiding lower rib insertion (risk of intra-abdominal insertion) remain important considerations.

Should confirmatory CXR follow tube thoracostomy?

Recommendation. Beyond clinical examination, confirmatory CXR is unlikely to change management for appropriately functioning chest tubes.

Rationale. Confirmatory CXR is routinely obtained after tube thoracostomy confirm accurate position. However, for hemothoraces, intrapleural placement likely suffices, and CXR may not be reliable for detecting malpositioned tubes. A retrospective study ($N = 76$) reported that CXR detected only 21% of malpositioned (intraparenchymal or intrafissure) chest tubes seen on CT.[44] Another retrospective study ($N = 1042$; 75% penetrating injury victims) reported that 15% of patients had post-tube thoracostomy management "influenced by" confirmatory CXR.[45] However, excluding patients with persistent symptoms or tube dysfunction that would have prompted CXR (eg, non-draining tube), only 4% (kinked or too deep [subjectively too close to mediastinum]) underwent tube readjustment and 1% (too shallow or wrong side) underwent new tube thoracostomy. CXR is not required to detect tube depth or sidedness. Of note, both studies comprised patients with hemothoraces and pneumothoraces and did not delineate findings for patients with isolated hemothoraces. Among asymptomatic patients with chest tubes, confirmatory CXR after tube thoracostomy is likely unnecessary. Routine confirmatory CXR after tube thoracostomy for hemothoraces could be re-examined in select settings where financial or workflow costs of an additional CXR are prohibitive.

Does placing chest tubes on suction or water seal affect outcomes?

Recommendation. Placing chest tubes on suction may lower tube duration and hospital length of stay (LOS), but there is poor quality of evidence.

Rationale. A meta-analysis of 3 RCTs ($N = 270$) found that compared to water seal, chest tubes on suction (−20 cm H_2O in 2 RCTs, −5 to −20 cm H_2O in 1 RCT) resulted in decreased tube duration (mean difference [95% CI]: −3.4[−5.7 to −1.0] days), hospital LOS (mean difference [95% CI]: −3.9 [−6.0 to −1.8] days), and persistent air leak (OR [95% CI]: 0.3 [0.1–0.5]).[46] Pooled analysis did not find significant difference in secondary intervention rates. The authors reported overall very low Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) quality of evidence, except moderate quality of evidence for mitigating persistent air leaks. All 3 RCTs included patients with hemothoraces and pneumothoraces; hemothorax-specific evidence synthesis was not performed.

Retained hemothoraces (rHTX)

What are risk factors for developing rHTX?

Recommendation. Higher thoracic injury burden is likely associated with rHTX.

Rationale. Patients with rHTX are at risk of developing empyema (27% incidence according to a prospective multi-center study[$N = 328$]).[5] CXR may be unreliable for rHTX diagnosis; a prospective study recommended CT confirmation.[47] Observational evidence suggests rHTX risk factors include larger initial hemothorax volumes, higher ISS, bilateral injuries, mechanical ventilation.[48–50] A prospective study ($N = 154$) did not find an association between rHTX and chest tube trajectory or intrapleural length.[51] Mitigating rHTX and subsequent complications requires characterizing high-risk injury and management patterns: specific risk factors for rHTX require further study.

What is the optimal lytic therapy regimen for rHTX?

Recommendation. Tissue plasminogen activator is a safe, effective, and the most commonly-studied lytic therapy.

Rationale. A meta-analysis ($N = 162$; 1 RCT, 9 observational studies) reported 87% (95% CI: 81–92%) overall efficacy of lytic therapy (avoiding operative rHTX intervention).[52] Tissue plasminogen activator (tPA) efficacy was 83% (95% CI: 71–94%), and non-tPA (streptokinase, urokinase) efficacy was 85% (95% CI: 82–93%). Highly variable lytic therapy strategies (time from tube thoracostomy to lytic therapy, dose, interval, discontinuation criteria) precluded recommending an optimal strategy. Despite theoretical bleeding risk of fibrinolytic therapy in patients with recent intrathoracic trauma, only 1 patient experienced a bleeding complication (hematuria). Of note, a recent single-center retrospective study ($N = 14$) reported 42% tPA efficacy for rHTX; 1 patient experienced a bleeding complication.[53]

What is the role of video-assisted thoracoscopic surgery (VATS) compared to tube thoracostomy or lytic therapy for rHTX?

Recommendation. VATS has superior efficacy to second thoracostomy tube and similar efficacy as lytic therapy for rHTX.

Rationale. Two RCTs ($N = 39$ and $N = 60$) reported VATS is superior to a second tube thoracostomy for reducing chest tube duration and hospital LOS among patients with hemothoraces.[54,55] One RCT ($N = 48$) evaluating head-to-head efficacies of lytic therapy (streptokinase) and VATS for rHTX did not find significant difference in intervention failure (persistent rHTX requiring thoracotomy) or complication rates.[56] Comparative efficacy of lytic therapy compared to VATS deserve further study. Of note, a recent prospective study ($N = 296$) evaluated efficacy of thoracic irrigation (1 L sterile saline) during initial tube thoracostomy for mitigating rHTX risk.[15] Compared to conventional tube thoracostomy, tube thoracostomy with irrigation was associated with significantly lower odds (OR: 0.16) of requiring secondary intervention. Optimal rHTX management starts with prevention. Thoracic irrigation during initial tube thoracostomy deserves further evaluation.

When is the ideal time to perform VATS for rHTX?

Recommendation. VATS should be performed as soon as rHTX is diagnosed; a trial of lytic therapy may be attempted beforehand.

Rationale. Decision to perform VATS must balance time for non-operative rHTX management (eg, lytic therapy) versus intervening before advanced loculations prevent a minimally invasive option. Many studies, including EAST practice guidelines, recommend early VATS for rHTX.[2,57–61] However, the evidence base for this recommendation comprises retrospective studies (total $N = 504$) that variably and arbitrarily categorized "early" and "late" timing during *posteriori* analysis. To our knowledge, no study compared 2 *a priori*-determined VATS intervention time points, and only 1 study standardized the comparator group's rHTX management strategy.[56] Head-to-head comparisons of intervention time after standardized non-operative rTHX management is needed to understand what constitutes "early" VATS. Until further evidence is available, we believe VATS should be performed as soon as rHTX is diagnosed. If the patient or surgeon prefers, lytic therapy could be attempted before VATS.

Table II
Recommendations regarding conundra in traumatic hemothorax diagnosis and management

Conundrum	Recommendation
Should presumptive antibiotics be administered to decrease incidence of infectious complications?	Presumptive antibiotics are likely unnecessary; performing tube thoracostomy under sterile condition is likely more important.
If presumptive antibiotics are administered before tube thoracostomy, is there an ideal antibiotic regimen, dosage, or duration?	If presumptive antibiotics are used, a single dose of cefazolin prior to tube thoracostomy is likely sufficient.
Does blunt or penetrating injury mechanism affect presumptive antibiotic efficacy for tube thoracostomy?	Presumptive antibiotics are likely unnecessary, regardless of injury mechanism.
Among blunt injury victims, how should occult hemothoraces be managed?	A majority of occult hemothoraces can likely undergo expectant management.
What is bedside ultrasound's role for diagnosing hemothoraces?	Ultrasound may be a valuable screening and prognostication tool for hemothoraces during primary surveys.
What initial chest tube output mandates surgical intervention?	A singular threshold output should not guide the decision to operate.
Does chest tube size affect outcomes?	Smaller chest tubes have similar outcomes as larger chest tubes.
Does chest tube insertion site or trajectory influence secondary intervention rates?	As long as chest tubes are in the pleural space, insertion site and trajectory (apical versus caudal) likely do not influence secondary intervention rates.
Should confirmatory CXR follow tube thoracostomy?	Beyond clinical examination, confirmatory CXR is unlikely to change management for appropriately functioning chest tubes.
Does placing chest tubes on suction or water seal affect outcomes?	Placing chest tubes on suction may lower tube duration and hospital LOS, but there is poor quality of evidence.
What are risk factors for rHTX?	Higher thoracic injury burden is likely associated with rHTX.
What is the optimal lytic therapy regimen for rHTX?	Tissue plasminogen activator is a safe, effective, and the most commonly-studied lytic therapy.
What is the role of VATS compared to tube thoracostomy or lytic therapy for rHTX?	VATS has superior efficacy to second thoracostomy tube and similar efficacy as lytic therapy for rHTX.
When is the ideal time to perform VATS for rHTX?	VATS should be performed as soon as rHTX is diagnosed; a trial of lytic therapy may be attempted beforehand.
What is the incidence of dHTX among patients with blunt thoracic injuries?	A multi-center consortium suggests 12% dHTX incidence among patients with isolated thoracic injuries discharged from the ED. Patients appear to present with dHTX within 2 weeks of initial injury.
What is the etiology and presenting symptoms of dHTX?	Delayed disruption of intercostal arteries from rib fractures may lead to dHTX. Chest pain and dyspnea are common presenting symptoms.
Is a graduated chest tube removal (suction to water seal to clamp trial) necessary?	Graduated chest tube removal is likely unnecessary for isolated hemothoraces.
Is it unsafe to remove chest tubes in patients on positive pressure ventilation?	One experimental study did not find evidence suggesting chest tube removal before extubation is unsafe.
Should chest tubes be removed at end-inspiration or end-expiration?	Chest tube removal timing with respiratory cycle is likely unnecessary.
Is a confirmatory CXR required after chest tube removal?	A post-removal CXR is likely unnecessary.

CXR, chest x-ray; *ED*, emergency department; *dHTX*, delayed hemothoraces; *LOS*, length of stay; *rHTX*, retained hemothoraces; *VATS*, video-assisted thoracoscopic surgery.

Delayed hemothoraces (dHTX)

What is the incidence of dHTX among patients with blunt thoracic injuries?

Recommendation. A multi-center consortium suggests 12% dHTX incidence among patients with isolated thoracic injuries discharged from the emergency department (ED). Patients appear to present with dHTX within 2 weeks of initial injury.

Rationale. An early study reported 12 of 33 patients with blunt traumatic hemothoraces were diagnosed in a delayed fashion (18 hours to 6 days postinjury).[12]A subsequent single-center retrospective study ($N = 167$) reported 4% incidence of dHTX (diagnosed 22 hours to 16 days post injury; 86% within 4 days).[13] Among patients discharged from the ED after isolated thoracic injuries, 2 multi-center prospective cohort studies ($N = 450$ and $N = 482$) reported 12% dHTX incidence within 14 days.[11,14] In a planned subgroup analysis ($N = 32$), the same consortium of centers reported 12% incidence of dHTX within 14 days among patients discharged from the ED after isolated sternal fractures.[62] Delayed hemothorax incidence among admitted patients is unclear. Overall, there is not a consensus defining and limited evidence characterizing dHTX.

What is the etiology and presenting symptoms of dHTX?

Recommendation. Delayed disruption of intercostal arteries from rib fractures may lead to dHTX. Chest pain and dyspnea are common presenting symptoms.

Rationale. An early study found 92% (11 of 12 patients) of dHTX occurred in patients with multiple or displaced rib fractures.[12] A majority of patients were diagnosed after reporting sudden onset pleuritic chest pain and dyspnea. The authors hypothesized rib fractures may disrupt intercostal arteries in a delayed fashion after improved analgesia facilitates greater respiratory movement. Another retrospective single-center study ($N = 167$) similarly reported that all patients with dHTX had multiple rib fractures (5 out of 7 patients had displaced rib fractures).[13] Among patients presenting with dHTX after discharge from the ED, 54% presented with chest pain and 25% with dyspnea.[11] Another study suggested rib fracture location (lower, middle, or upper ribs) confers variable odds of dHTX; however, uncertainty of estimates precluded deriving meaningful assocation.[14] Granular assessments of higher-risk injury patterns require further study. The role of selective serial monitoring for dHTX requires better understanding of the incidence and clinical significance of dHTX.

Chest tube removal

Is a graduated chest tube removal (suction to water seal to clamp trial) necessary?

Recommendation. Graduated chest tube removal is likely unnecessary for isolated hemothoraces.

Rationale. Water seal and clamp trials have largely been evaluated in patients with traumatic pneumothoraces, not hemothoraces. An RCT ($N = 205$; unclear proportion with hemothorax) found that water seal resulted in lower pneumothorax recurrence compared to suction removal but postulated that patients undergoing suction removal had insufficient time for primary pneumothorax resolution.[63]Another RCT ($N = 80$) reported no difference in pneumothorax recurrence between water seal and suction removal but shorter tube duration with suction removal.[64] An RCT ($N = 180$; 16% with hemopneumothorax) did not find significant difference in pneumothorax recurrence among patients who did and did not undergo clamp trials.[65] A retrospective study ($N = 499$; 28% with hemothoraces) reported clamp trials were associated with lower 30-day odds of repeat pleural drainage (OR [95% CI]: 0.4 [0.2–0.8]).[66] However, our analysis of primary data did not find significant association between clamp trial and repeat pleural drainage performed for *hemothorax*. Another retrospective study ($N = 254$; 50% with hemo or hemo-pneumothorax) did not find an association between clamp trials and need for repeat pleural drainage.[67] Graduated tube removal largely aims to detect occult pneumothoraces. Chest tubes for hemothoraces are frequently removed after trending output over longer periods; several additional hours of clamp trial is likely unnecessary for isolated hemothoraces.

Is it unsafe to remove chest tubes in patients on positive pressure ventilation?
Recommendation. One experimental study did not find evidence suggesting chest tube removal before extubation is unsafe.

Rationale. An RCT ($N = 92$; 69% for hemo or hemopneumothorax) of injured patients with chest tubes on positive pressure ventilation reported that late (at time of extubation) or early (5–7 days after insertion) chest tube removal did affect complication rates.[68]

Should chest tubes be removed at end-inspiration or end-expiration?
Recommendation. Chest tube removal timing with respiratory cycle is likely unnecessary.

Rationale. An RCT ($N = 102$; 24% with hemothorax, 15% on mechanical ventilation) comparing tube removal at end-inhalation with end-exhalation did not find significant difference in pneumothorax recurrence rates.[69] Of note, a retrospective study ($N = 234$; 41% with hemo or hemopneumothorax) did not find an association between being on positive pressure ventilation and pneumothorax recurrence or repeat pleural drainage rates after chest tube removal.[70] We did not find evidence suggesting that chest tube removal while on positive pressure ventilation is unsafe.

Is a confirmatory CXR required after chest tube removal?
Recommendation. A postremoval CXR is likely unnecessary.

Rationale. Three retrospective studies ($N = 73$, $N = 488$, and $N = 116$) suggested postremoval CXR offers no additional advantage over clinical observation for repeat pleural drainage.[71–73]A cost-effectiveness analysis (modeled on a healthy patient with hemopneumothorax with <200 mL serous output/24 hours and tolerating water seal) reported clinical observation is cost-effective compared to postremoval CXR.[74]

In conclusion, Table II summarizes our synthesis of up-to-date evidence and knowledge gaps for diagnosing and managing traumatic hemothoraces.

Funding/Support

There was no funding specifically for this scoping review.

Conflict of interest/Disclosure

All authors declare no financial or personal conflicts of interest.

Acknowledgments

Dr. Choi would like to thank the Neil and Claudia Doerhoff Fund for support of his scholarly activities.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.surg.2021.03.030.

References

1. Luchette FA, Barrie PS, Oswanski MF, et al. Practice management guidelines for prophylactic antibiotic use in tube thoracostomy for traumatic hemopneumothorax: the EAST Practice Management Guidelines Work Group. Eastern Association for Trauma. *J Trauma*. 2000;48:753–757.
2. Mowery NT, Gunter OL, Collier BR, et al. Practice management guidelines for management of hemothorax and occult pneumothorax. *J Trauma*. 2011;70:510–518.
3. Moore FO, Duane TM, Hu CKC, et al. Presumptive antibiotic use in tube thoracostomy for traumatic hemopneumothorax: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73:S341–S344.
4. Bradley M, Okoye O, DuBose J, et al. Risk factors for post-traumatic pneumonia in patients with retained haemothorax: results of a prospective, observational AAST study. *Injury*. 2013;44:1159–1164.
5. DuBose J, Inaba K, Okoye O, 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. DuBose J, Inaba K, Demetriades D, et al. Management of post-traumatic retained hemothorax: a prospective, observational, multicenter AAST study. *J Trauma Acute Care Surg*. 2012;72:11–22.
7. Dennis BM, Gondek SP, Guyer RA, Hamblin SE, Gunter OL, Guillamondegui OD. Use of an evidence-based algorithm for patients with traumatic hemothorax reduces need for additional interventions. *J Trauma Acute Care Surg*. 2017;82:728–732.
8. Adrales G, Huynh T, Broering B, et al. A thoracostomy tube guideline improves management efficiency in trauma patients. *J Trauma Acute Care Surg*. 2002;52:210–216.
9. Sanabria A, Valdivieso E, Gomez G, Echeverry G. Prophylactic antibiotics in chest trauma: a meta-analysis of high-quality studies. *World J Surg*. 2006;30:1843–1847.
10. Bosman A, Jong MB de, Debeij J, Broek PJ van den, Schipper IB. Systematic review and meta-analysis of antibiotic prophylaxis to prevent infections from chest drains in blunt and penetrating thoracic injuries. *BJS*. 2012;99:506–513.
11. Émond M, Sirois M-J, Guimont C, et al. Functional impact of a minor thoracic injury: an investigation of age, delayed hemothorax, and rib fracture effects. *Ann Surg*. 2015;262:1115–1122.
12. Simon BJ, Chu Q, Emhoff TA, Fiallo VM, Lee KF. Delayed hemothorax after blunt thoracic trauma: an uncommon entity with significant morbidity. *J Trauma*. 1998;45(4):673–676.
13. Sharma OP, Hagler S, Oswanski MF. Prevalence of delayed hemothorax in blunt thoracic trauma. *Am Surg*. 2005;71:481–486.
14. Plourde M, Émond M, Lavoie A, et al. Cohort Study on the prevalence and risk factors for delayed pulmonary complications in adults following minor blunt thoracic trauma. *CJEM*. 2014;16:136–143.
15. 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.
16. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol*. 2018;18:143.
17. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc*. 2015;13(3):141–146.
18. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation, The EQUATOR Network. Available at: https://www.equator-network.org/reporting-guidelines/prisma-scr/. Accessed February 5, 2021.
19. Cook A, Hu C, Ward J, et al. 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.

20. Demetriades D, Breckon V, Breckon C, et al. Antibiotic prophylaxis in penetrating injuries of the chest. *Ann R Coll Surg Engl*. 1991;73:348–351.
21. Rodriguez RM, Canseco K, Baumann BM, et al. Pneumothorax and hemothorax in the era of frequent chest computed tomography for the evaluation of adult patients with blunt trauma. *Ann Emerg Med*. 2019;73:58–65.
22. Malekpour M, Widom K, Dove J, et al. Management of computed tomography scan detected hemothorax in blunt chest trauma: what computed tomography scan measurements say? *World J Radiol*. 2018;10:184–189.
23. Patel BH, Lew CO, Dall T, Anderson CL, Rodriguez R, Langdorf MI. Chest tube output, duration, and length of stay are similar for pneumothorax and hemothorax seen only on computed tomography vs. chest radiograph. *Eur J Trauma Emerg Surg*. https://doi.org/10.1007/s00068-019-01198-y. Online ahead of print.
24. Hernandez MC, El Khatib M, Prokop L, Zielinski MD, Aho JM. Complications in tube thoracostomy: systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2018;85:410–416.
25. Etoch SW, Bar-Natan MF, Miller FB, Richardson JD. Tube thoracostomy: factors related to complications. *Arch Surg*. 1995;130:521–526.
26. Wells BJ, Roberts DJ, Grondin S, et al. To drain or not to drain? predictors of tube thoracostomy insertion and outcomes associated with drainage of traumatic hemothoraces. *Injury*. 2015;46:1743–1748.
27. Gilbert RW, Fontebasso AM, Park L, Tran A, Lampron J. The management of occult hemothorax in adults with thoracic trauma: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2020;89:1225–1232.
28. Mahmood I, Abdelrahman H, Al-Hassani A, Nabir S, Sebastian M, Maull K. Clinical management of occult hemothorax: a prospective study of 81 patients. *Am J Surg*. 2011;201:766–769.
29. Demetri L, Aguilar MMM, Bohnen JD, et al. Is observation for traumatic hemothorax safe? *J Trauma Acute Care Surg*. 2018;84:454–458.
30. Sriprasit P, Akaraborworn O, Kiranantawat N, Sungsiri J, Kongkamol C. Predictors of pleural decompression in blunt traumatic occult hemothorax: A retrospective study. *Arch Trauma Res*. 2018;7:150–154.
31. Staub LJ, Biscaro RRM, Kaszubowski E, Maurici R. Chest ultrasonography for the emergency diagnosis of traumatic pneumothorax and haemothorax: a systematic review and meta-analysis. *Injury*. 2018;49:457–466.
32. Abboud PAC, Kendall J. Emergency department ultrasound for hemothorax after blunt traumatic injury. *J Emerg Med*. 2003;25:181–184.
33. Chung MH, Hsiao CY, Nian NS, et al. The benefit of ultrasound in deciding between tube thoracostomy and observative management in hemothorax resulting from blunt chest trauma. *World J Surg*. 2018;42:2054–2060.
34. Karmy-Jones R, Jurkovich GJ, Nathens AB, et al. Timing of urgent thoracotomy for hemorrhage after trauma: a multicenter study. *Arch Surg*. 2001;136:513–517.
35. Bauman ZM, Kulvatunyou N, Joseph B, 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.
36. Kulvatunyou N, Joseph B, Friese RS, et al. 14 French pigtail catheters placed by surgeons to drain blood on trauma patients: Is 14-Fr too small? *J Trauma Acute Care Surg*. 2012;73:1423–1427.
37. Orlando A, Cordero J, Carrick MM, et al. Comparing complications of small-bore chest tubes to large-bore chest tubes in the setting of delayed hemothorax: a retrospective multicenter cohort study. *Scand J Trauma Resusc Emerg Med*. 2020;28:56.
38. Rivera L, O'Reilly EB, Sise MJ, et al. Small catheter tube thoracostomy: effective in managing chest trauma in stable patients. *J Trauma*. 2009;66:393–399.
39. Tanizaki S, Maeda S, Sera M, et al. Small tube thoracostomy (20–22 Fr) in emergent management of chest trauma. *Injury*. 2017;48:1884–1887.
40. Terada T, Nishimura T, Uchida K, Hagawa N, Esaki M, Mizobata Y. How emergency physicians choose chest tube size for traumatic pneumothorax or hemothorax: a comparison between 28Fr and smaller tube. *Nagoya J Med Sci*. 2020;82:59–68.
41. Benns MV, Egger ME, Harbrecht BG, et al. Does chest tube location matter? an analysis of chest tube position and the need for secondary interventions. *J and Acute Care Surg*. 2015;78:386–390.
42. Maybauer MO, Geisser W, Wolff H, Maybauer DM. Incidence and outcome of tube thoracostomy positioning in trauma patients. *Prehosp Emerg Care*. 2012;16:237–241.
43. Kugler NW, Carver TW, Knechtges P, Milia D, Goodman L, Paul JS. Thoracostomy tube function not trajectory dictates reintervention. *J Surg Res*. 2016;206:380–385.
44. Lim K-E, Tai S-C, Chan C-Y, et al. Diagnosis of malpositioned chest tubes after emergency tube thoracostomy. *Clin Imaging*. 2005;29:401–405.
45. Kong VY, Oosthuizen GV, Clarke DL. What is the yield of routine chest radiography following tube thoracostomy for trauma? *Injury*. 2015;46:45–48.
46. Feenstra TM, Dickhoff C, Deunk J. Systematic review and meta-analysis of tube thoracostomy following traumatic chest injury; suction versus water seal. *Eur J Trauma Emerg Surg*. 2018;44:819–827.
47. Velmahos GC, Demetriades D, Chan L, et al. Predicting the need for thoracoscopic evaluation of residual traumatic hemothorax: chest radiograph is insufficient. *J Trauma*. 1999;46:65–69.
48. Prakash PS, Moore SA, Rezende-Neto JB, 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.
49. Scott MF, Khodaverdian RA, Shaheen JL, Ney AL, Nygaard RM. Predictors of retained hemothorax after trauma and impact on patient outcomes. *Eur J Trauma Emerg Surg*. 2017;43:179–184.
50. Villegas MI, Hennessey RA, Morales CH, Londono E. Risk factors associated with the development of post-traumatic retained hemothorax. *Eur J Trauma Emerg Surg*. 2011;37:583–589.
51. Kumar S, Agarwal N, Rattan A, Rathi V. Does intrapleural length and position of the intercostal drain affect the frequency of residual hemothorax? a prospective study from north India. *J Emerg Trauma Shock*. 2014;7:274–279.
52. Hendriksen BS, Kuroki MT, Armen SB, Reed MF, Taylor MD, Hollenbeak CS. Lytic therapy for retained traumatic hemothorax: a systematic review and meta-analysis. *Chest*. 2019;155:805–815.
53. Narsule CK, Sarkar B, Kasotakis G, et al. Efficacy of intrapleural thrombolysis for treatment of traumatic retained hemothorax: a single-center experience. *J Am Coll Surg*. 2017;225:e177.
54. 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.
55. Cobanoglu U, Sayir F, Mergan D. Should videothorascopic surgery be the first choice in isolated traumatic hemothorax? A prospective randomized controlled study. *Ulu Travma Acil Cerrahi Derg*. 2011;17:117–122.
56. Kumar S, Rathi V, Rattan A, Chaudhary S, Agarwal N. VATS versus intrapleural streptokinase: a prospective, randomized, controlled clinical trial for optimum treatment of post-traumatic residual hemothorax. *Injury*. 2015;46:1749–1752.
57. Uribe CHM, Lanau MIV, Sanchez RDP. Best timing for thoracoscopic evacuation of retained post-traumatic hemothorax. *Surg Endosc*. 2008;22:91–95.
58. Lin HL, Huang WY, Yang C, et al. How early should VATS be performed for retained haemothorax in blunt chest trauma? *Injury*. 2014;45:1359–1364.
59. Ahmad T, Ahmed SW, Soomro NH, Sheikh KA. Thoracoscopic Evacuation of Retained Post-traumatic Hemothorax. *J Coll Physicians Surg Pak*. 2013;23:234–236.
60. Ambrogi MC, Lucchi M, Dini P, Mussi A, Angeletti CA. Videothoracoscopy for evaluation and treatment of hemothorax. *J Cardiovascular Surg (Torino)*. 2002;43:109–112.
61. Ahmed N, Chung R. Role of early thoracoscopy for management of penetrating wounds of the chest. *Am Surg*. 2010;76:1236–1239.
62. Racine S, Émond M, Audette-Côté J-S, et al. Delayed complications and functional outcome of isolated sternal fracture after emergency department discharge: a prospective, multicentre cohort study. *CJEM*. 2016;18:349–357.
63. Martino K, Merrit S, Boyakye K, et al. Prospective randomized trial of thoracostomy removal algorithms. *J Trauma*. 1999;46:369–373.
64. Davis JW, Mackersie RC, Hoyt DB, Garcia J. Randomized study of algorithms for discontinuing tube thoracostomy drainage. *J Am Coll Surg*. 1994;179:553–557.
65. Rasheed MA, Majeed FA, Shah SZA, Naz A. Role of clamping tube thoracostomy prior to removal in non-cardiac thoracic trauma. *J Ayub Med Coll Abbottabad*. 2016;28:476–479.
66. Becker JC, Zakaluzny SA, Keller BA, Galante JM, Utter GH. Clamping trials prior to thoracostomy tube removal and the need for subsequent invasive pleural drainage. *Am J Surg*. 2020;220:476–481.
67. Funk GA, Petrey LB, Foreman ML. Clamping thoracostomy tubes: a heretical notion? *Proc (Bayl Univ Med Cent)*. 2009;22:215–217.
68. Abbasi HR, Farrokhnia F, Sefidbakht S, Paydar S, Bolandparvaz S. Chest tube removal time in trauma patients on positive ventilation pressure: a randomized clinical trial. *Bull Emerg Trauma*. 2013;1:17–21.
69. Bell RL, Ovadia P, Abdullah F, Spector S, Rabinovici R. Chest tube removal: end-inspiration or end-expiration? *J Trauma*. 2001;50:674–677.
70. Tawil I, Gonda JM, King RD, Marinaro JL, Crandall CS. Impact of Positive Pressure Ventilation on Thoracostomy Tube Removal. *J Trauma*. 2010;68:818–821.
71. Palesty JA, McKelvey AA, Dudrick SJ. The efficacy of x-rays after chest tube removal. *Am J Surg*. 2000;179:13–15.
72. Goodman MD, Huber NL, Johannigman JA, Pritts TA. Omission of routine chest x-ray after chest tube removal is safe in selected trauma patients. *Am J Surg*. 2010;199:199–203.
73. Farzan R, Shojaee R, Haghdoost A, Mobayen M. Comparison of chest X-ray and clinical findings in trauma patients after chest tube removal. *J Clin Diagnos Res*. 2018;12:PC19–PC21.
74. Beattie G, Cohan CM, Chomsky-Higgins K, Tang A, Senekjian L, Victorino GP. Is a chest radiograph after thoracostomy tube removal necessary? a cost-effective analysis. *Injury*. 2020;51:2493–2499.