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Featured Article

Management of simple and retained hemothorax: A practice management guideline from the Eastern Association for the Surgery of Trauma

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ABSTRACT

Background: Traumatic hemothorax poses diagnostic and therapeutic challenges both acutely and chronically. A working group of the Eastern Association for the Surgery of Trauma convened to formulate a practice management guideline for traumatic hemothorax.

Methods: We formulated four questions: whether tube thoracostomy vs observation be performed, should pigtail catheter versus thoracostomy tube be placed to drain hemothorax, should thrombolytic therapy be attempted versus immediate thoracoscopic assisted drainage (VATS) in retained hemothorax (rHTX), and should early VATS (≤4 days) versus late VATS (>4 days) be performed?

A systematic review was undertaken from articles identified in multiple databases.

Results: A total of 6391 articles were identified, 14 were selected for guideline construction. Most articles were retrospective with very low-quality evidence. We performed meta-analysis for some of the outcomes for three of the questions.

Conclusions: For traumatic hemothorax we conditionally recommend pigtail catheters, in hemodynamically stable patients. In patients with rHTX, we conditionally recommend VATS rather than attempting thrombolytic therapy and recommend that it should be performed early (≤4 days).

Introduction

The thorax is injured in approximately 30–40% of all trauma patients[1] resulting in approximately 300,000 cases of hemothorax in the United States each year.[2–6] These thoracic injuries contribute substantially to the morbidity and mortality of trauma patients, with 25% of trauma deaths related to injuries in the chest cavity.[7]

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Current Eastern Association for the Surgery of Trauma (EAST) guidelines recommend that all hemothorax be drained with tube thoracostomy.[8] However, this guideline does not address the threshold volume for which drainage is necessary, and the size of the catheter used for drainage, which has been challenged in recent years. Additionally, the timing of video-assisted thoracic surgery (VATS) and use of intrapleural thrombolytic therapy remains controversial.

Retained hemothorax (rHTX) occurs when there is hemothorax remaining after initial drainage via tube thoracostomy or pigtail catheter. However, the amount of blood remaining in the chest to be deemed rHTX is variable in the literature. The incidence of rHTX is reported to be between 5 and 30%,[9] leaving these patients at high-risk for developing empyema, and other complications. Therefore, guidance beyond the initial tube thoracostomy in patients with traumatic hemothorax is critical.

The purpose of this practice management guideline is to evaluate critical questions in the management of hemothorax beyond the initial tube thoracostomy. A systematic review was conducted to develop an evidence-based practice management guideline utilizing the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.

Objectives

We developed this guideline by assembling a working group which consisted of members of EAST with a plan to utilize the GRADE methodology.[10,11] We defined four population, intervention, comparison, and outcome (PICO) questions prior to literature search and systematic review as follows:

Question 1: In hemodynamically stable patients with a small traumatic hemothorax (less than 500 ml) should routine tube thoracostomy, vs observation, be performed?

Question 2: In hemodynamically stable patients with a traumatic hemothorax requiring drainage should pigtail catheter (14 Fr or smaller) vs. thoracostomy tube (20 Fr or larger) be placed?

Question 3: In hemodynamically stable patients with retained traumatic hemothorax, should intrapleural thrombolytic therapy (i.e. tPA) be attempted vs. immediate thoracoscopic assisted drainage (VATS)?

Question 4: In hemodynamically stable patients with retained traumatic hemothorax deemed to require drainage should early VATS (less than or equal to 4 days) vs. late VATS (greater than 4 days) be performed?

Outcome measures

The hemothorax working group identified pertinent outcomes for each PICO question. These were then rated from 1 to 9 by each member of the group independently. Outcomes with scores of 7–9 were deemed *critical*, 4–6 were *important*, and 1–3 were considered *least important*. Important and critical outcomes were utilized for data extraction. For PICO 1 and 2, the critical outcomes were need for any additional procedure, rHTX, and empyema. The need for any additional procedure for PICO 1 and 2 was defined as placement of additional pigtail catheters/tube thoracostomy and/or operative intervention such as VATS/thoracotomy. For PICO 3, the critical outcomes were need for additional pigtail catheter/tube thoracostomy, empyema, and need for additional operative procedure (repeat VATS/thoracotomy). For PICO 4, the critical outcomes were need for additional pigtail catheter/tube thoracostomy, conversion to open thoracotomy, empyema, and LOS – hospital. Table 1 summarizes the outcome ratings.

Identification of references

With the assistance of a professional librarian, a literature search and systematic review was performed on March 24, 2019. MEDLINE (via PubMed), EMBASE (via Elsevier), the Cochrane Library (via Wiley), and Web of Science (via Clarivate) were searched for English language citations. The search strategies can be found in the Appendix. All time periods were included but review articles, case reports, and animal studies were excluded. Non-randomized studies were included due to the fact that there are far too few randomized studies regarding hemothorax management in order to conduct a meta-analysis. The working group conducted a blinded title and abstract review followed by full text review with each article being reviewed by two working group members to determine inclusion or exclusion at each stage of review. Any discrepancies during review were resolved by a third reviewer. The PRISMA flow diagram for the systematic review is shown in Fig. 1.

Data extraction and methodology

Data extraction was performed from each study by two reviewers using standardized data collection sheets with any discrepancies being reviewed by third reviewer. This data was then entered into Review Manager (RevMan) software Version 5.3 (The Cochrane Collaboration, London, United Kingdom) and where possible, meta-analysis was performed using random-effect modeling to generate forest plots. For hospital and ICU LOS, differences in mean were calculated, while for the rest of the dichotomous data points, relative risk was calculated for the intervention versus the comparator groups. Heterogeneity was calculated and quantified with I^2. Low degree of heterogeneity had I^2 values less than 50% and those >75% were indicative of high heterogeneity.[12] Using GRADE methodology, each reviewer voted on quality of evidence (high, moderate, low or very low) for each PICO question, and evidence tables were created using GRADEpro GDT (Guideline Development Tool) software (McMaster University, 2014). To generate final recommendations for each PICO questions, all members of the committee voted, taking into consideration the quality of evidence, relationship of benefits and harms, patient values and preferences, and resource utilization.

RESULTS

Tube thoracostomy or observation for small traumatic hemothorax (PICO 1)

Qualitative analysis

There were two retrospective studies that compared tube thoracostomy to observation for management of small traumatic hemothorax but showed considerable heterogeneity from a methodological perspective.[13,14]

One study included patients older than 15 years of age with traumatic hemothorax and ISS $\geq$ 12. Those who died within 24 h, requiring an emergent thoracotomy or laparotomy were excluded. Presence and volume of hemothorax was confirmed using CT images. Volume of hemothorax was divided into <300 ml (considered small hemothorax), 300–499 ml, and $\geq$500 ml. Demographics between the tube thoracostomy and expectant management were similar without statistical differences. Outcomes included in-hospital mortality, hospital and ICU LOS, and empyema (defined as positive pleural fluid culture with a single SIRS criterion or diagnosis by the surgeon).[13]

The second study included patients 18 years or older with traumatic hemothorax. Patients without a chest CT or those who received tube thoracostomy prior to CT were excluded. CT images

Table 1
PICO 1–4 outcomes rating.

Outcome	PICO 1 Mean Score	PICO 2 Mean Score	PICO 3 Mean Score	PICO 4 Mean Score
Need for any additional Procedure	8.2*	8.2*	7.9*	8.1*
RHTX	7.8*	8.0*	–	–
Empyema	7.5*	7.6*	7.9*	7.8*
Mortality	6.2	5.8	–	6.8
Duration of Chest tube/pigtail	5.9	6.3	6.4	–
LOS - hospital	5.8	5.7	6.2	7.0*
LOS - ICU	4.7	4.6	5.2	6.4
Need for additional pigtail/tube thoracostomy	–	–	8.2*	8.1*
Conversion to open thoracotomy	–	–	–	8.1*
Duration of Mechanical Ventilation	–	–	5.2	5.8

*Critical outcome

were used to measure size of hemothorax. Each hemothorax was categorized as small (<300 ml) or large (≥300 ml). There was a difference in the mean age and number of patients age >65 years (both higher) in the tube thoracostomy group ($p < 0.031$ and 0.018, respectively), however ISS were similar between the group without any statistical difference. Patients were divided into early tube thoracostomy or initial observation; those initially observed were further divided into failed observation/delayed tube thoracostomy and no tube thoracostomy subgroups. Comparison was performed between those who did not require tube thoracostomy undergoing successful observation and patients who required tube thoracostomy (early or delayed). Outcomes reported were 30-day hospital free days, discharge disposition, mortality, pneumothorax, need for tPA administration and empyema (defined as pleural fluid culture with bacterial growth).[14]

Quantitative analysis

There were 749 patients with hemothorax in the first study, 491 in the tube thoracostomy cohort, and 258 in the observation cohort. Logistic regression showed that tube thoracostomy had an adjusted increase in hospital LOS of 47.14% (25.57–69.71%, $p < 0.01$), an adjusted increase in ICU LOS of 32.11% (−6.16 to 85.98%, $p = 0.11$), and an adjusted OR for in-hospital mortality of 3.99 (0.87–18.29, $p = 0.08$), compared to observation. A subgroup analysis for small hemothorax (<300 ml) showed equivalent results. Empyema only occurred within the tube thoracostomy group (8% vs 0%, $p < 0.01$).[13]

The second study had a total of 340 patients, 131 were in the no tube thoracostomy group and 209 in the tube thoracostomy group. Comparison between the two groups showed that tube thoracostomy was associated with fewer hospital-free days (19 vs 26, $p < 0.001$), more frequent discharge to rehabilitation facility (49% vs 31%, $p = 0.001$), and more frequent administration of tPA (17% vs 0%, $p < 0.001$). There was a higher rate of empyema in the no tube thoracostomy group however this was not statistically significant (2% vs 0%, $p = 0.111$). There was no difference in mortality between the two groups. On multivariate analysis, age (OR per year older 1.03, 1.01–1.05, $p = 0.013$), ventilator-free days (OR per vent-free day 0.93, 0.98–0.97, $p = 0.003$), hemothorax size ≥300 ml (OR 8.51, 1.56–46.28, $p = 0.013$), and presence of concurrent pneumothorax (OR 4.6, 1.94–10.94, $p = 0.001$) were independent predictors of failed observation.[14]

Grading the evidence

Overall, the quality of evidence was very low for all outcomes mainly due to the heterogeneity of the patient population, imprecision, and significant indirectness associated with the two studies.

Recommendation

While the studies did examine the outcomes of treating small traumatic hemothorax with drainage vs observation, there was inconsistency in the definition of "small" hemothorax defined as < 300 mL[14] or 500 ml cutoffs.[13] Due to the lack of adequate quantitative evidence for the outcomes and inability to extract individual data, the group unanimously decided that a recommendation could not be made for or against routine drainage with tube thoracostomy of small (<500 ml) traumatic hemothorax. Future studies need to be performed with consistent definitions of "small" hemothorax using objective measurement using CT imaging. Until then, clinician judgment and effect on pulmonary function should be considered in the decision to drain small hemothorax.

Pigtail catheter or thoracostomy tube for drainage (PICO 2)

Qualitative analysis

There were two prospective observational studies[16,17] performed at the same institution which were similar from a methodologic standpoint, one randomized controlled trial,[18] and one retrospective study[19] that compared pigtail catheter (14Fr or less) to thoracostomy tube (20Fr or larger) for drainage of traumatic hemothorax.

The two prospective studies included trauma patients who required drainage of hemothorax or hemopneumothorax via 14 Fr pigtail catheter or tube thoracostomy over a period of 30 months[16] and 7 years.[17] In these studies, the pigtail group were older and had higher percentage of blunt trauma both of which were statistically significant ($P < 0.001$ and $P < 0.01$, respectively), however injury severity score (ISS) were similar. The randomized study included traumatic hemothorax patients but excluded "coagulated and infected hemothorax patients", however did not specify how they determined these prior to exclusion. Both groups in this study were similar in age and ISS without any statistical difference.[18] The retrospective study conducted by Rivera and colleagues, included trauma patients who required placement of pigtail catheter or tube thoracostomy for pneumothorax, hemothorax, empyema, or effusion over a period of 43 months. In this study, the small catheter group were older and had lower ISS scores compared to the tube thoracostomy group ($P < 0.05$ and < 0.01, respectively).[19] In the prospective studies, 14Fr pigtail catheters and 32-40Fr thoracostomy tubes were placed by trauma team.[16,17] In the randomized controlled trial, a central venous catheter (7 Fr) was placed using ultrasound guided technique compared to conventional chest tubes (approximately 2 cm external diameter).[18] In the retrospective study, 32-36Fr thoracostomy tubes were placed by trauma surgeons or house staff, whereas the 10-14Fr pigtail catheters were placed by interventional radiologist under image guidance.[19]

Two of the four studies categorized procedures into emergent and non-emergent.[17,19] Rivera and colleagues' study categorized all pigtail catheters and thoracostomy tubes placed in the intensive

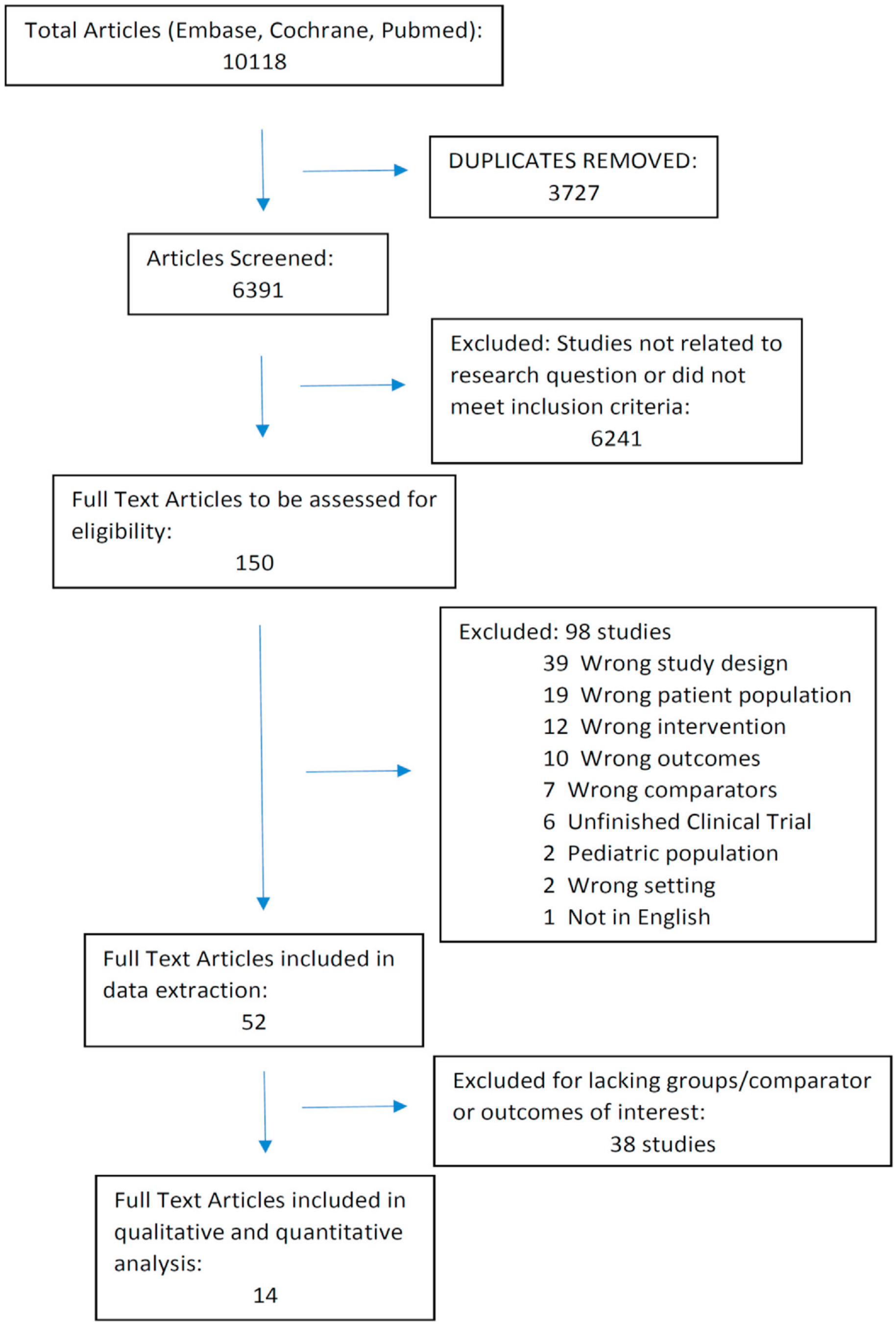


Fig. 1. PRISMA flow diagram.

care unit or on regular nursing floor as non-emergent.[19] The second study categorized pigtail catheter or thoracostomy as emergent if placed in the trauma bay, and non-emergent if placed after the stay in trauma bay.[17] The other two studies did not categorize procedures as emergent or non-emergent.[16,18]

Outcomes included initial drain output, duration of pigtail catheter/thoracostomy tube, procedure-related complications, hospital LOS, ICU LOS, ventilator days, mortality and failure rate (defined in two studies as incompletely drained or rHTX that required a second intervention) and patients undergoing VATS.[16,17] Yi et al. focused-on drainage of volume, severe complications, duration of catheter/tube, medical cost, wound healing time, wound infection, analgesic treatment and success rate of first thoracic drainage.[18] The retrospective study outcomes focused on subsequent interventions such as second pigtail catheter/thoracostomy tube, video-assisted thoracoscopy/open thoracotomy, mechanical ventilation days, ICU LOS, and complications associated with non-emergent placement of tube thoracostomy versus small catheter (including rHTX, empyema, tube dislodgement/malposition).[19]

Quantitative analysis

We were able to perform quantitative analysis on two critical outcomes for PICO 2 which were reported in the selected studies (Fig. 2).[16–19] However, only one study reported the other critical outcome (empyema) and the important outcomes (duration of pigtail/tube thoracostomy, duration of mechanical ventilation, mortality, hospital and ICU LOS) so meta-analysis could not be performed, however all favored pigtail catheters in that study.

The risk for rHTX was reported in all four studies: the pigtail catheter group had 475 patients with a rate of 18.3% and the thoracostomy tube group had 716 patients with a rate of 22.3%; the relative risk (RR) was 0.87 with a 95% confidence interval (CI) of 0.56–1.36. The need for additional procedure (operative and/or 2nd tube thoracostomy/pigtail) was reported in three studies[16–18]: the pigtail catheter group had 439 patients with a rate of 3.9% and the thoracostomy tube group had 691 patients with a rate of 13%; the RR was 0.45 with a 95% CI of 0.21–0.99, favoring pigtail catheter. The rate of empyema was reported in one study, therefore meta-analysis could not be performed. The reported rate was 3.8% in the pigtail catheter group and 1.4% in the thoracostomy group, although this difference was not statistically significant.[19]

Grading the evidence

The quality of evidence was very low for the reported outcomes of rHTX and need for additional procedure due to risk of bias/publication, inconsistency, indirectness, and imprecision of the data.

Recommendation

After reviewing the quality of evidence, considering risk of harm versus benefit to patients, perceived value, and resource utilization, 10 out of 14 members (71%) of the PMG group ***conditionally recommended*** using pigtail catheter for drainage of traumatic hemothorax compared to thoracostomy tube to decrease rate of rHTX and need for additional procedure; four members (29%) of the group had no recommendation. A conditional recommendation was made for pigtail catheters instead of thoracostomy tubes was based on very low-quality evidence. It should be noted that there might be a duplication in data published in two of the studies[16,17] as they were from the same institution with a time period that partially overlapped. These studies likely also suffered from selection bias since the pigtail catheters were more commonly placed in older patients with blunt trauma, less severity of injury and in a delayed fashion. To decrease this selection bias, Rivera excluded emergently placed tube thoracostomy in the trauma bay, where the time required for the procedure could pose a threat to the patient's life, but the results of Rivera did not support a difference in outcomes. A conditional recommendation was made seeing that the meta-analysis found no statistical difference in the retained hemothorax between the pigtail catheter and tube thoracostomy and a decrease in need for additional operative/2nd pigtail/tube thoracostomy which was statistically significant. The decrease in need for additional for 2nd pigtail/tube thoracostomy or operative intervention could be explained by the fact that all 3 studies utilized ultrasound guided pigtail placement placing the pigtail in the specific location of the hemothorax versus the tube thoracostomy placed in a standard blinded fashion thus leading to improved resolution of the hemothorax. Another factor considered in the decision is the belief by many that clotted hemothorax would not successfully drain whether by pigtail or tube thoracostomy and a second procedure would need to be undertaken regardless of size of the tube. Taking into consideration this as well as patient preference to have a smaller catheter placed if given a choice especially with no difference in the rate for rHTX for pigtails compared to tube thoracostomy and a chance of decreased additional procedures, the working group felt conditional recommendation was appropriate. However, it is important to note, the group felt strongly that patient selection was key to this recommendation. This systemic review specifies that the conditional recommendation applies only to hemodynamically stable trauma patients with ultrasound guidance based off of staff comfort level with imaging. In unstable, emergent situations tube thoracostomy is still the preferred choice to drain hemothorax.

Intrapleural thrombolytic therapy or immediate VATS for rHTX (PICO 3)

Qualitative analysis

Three studies compared intrapleural thrombolytic therapy to VATS for management of rHTX following placement of tube thoracostomy.[9,20,21] These studies differed significantly from a methodologic standpoint; one was a retrospective study, the second was a prospective observational study, and the third was a randomized controlled trial (RCT).

All three studies included trauma patients with rHTX who required a thoracostomy tube for drainage. One study required a chest CT following placement of a thoracostomy tube for the diagnosis of rHTX,[20] whereas the other two utilized a plain chest radiograph, ultrasound, or chest CT for diagnosis.[9,21] Demographics were not compared between the two groups in the randomized controlled article.[21] DuBose et al. compared demographics of

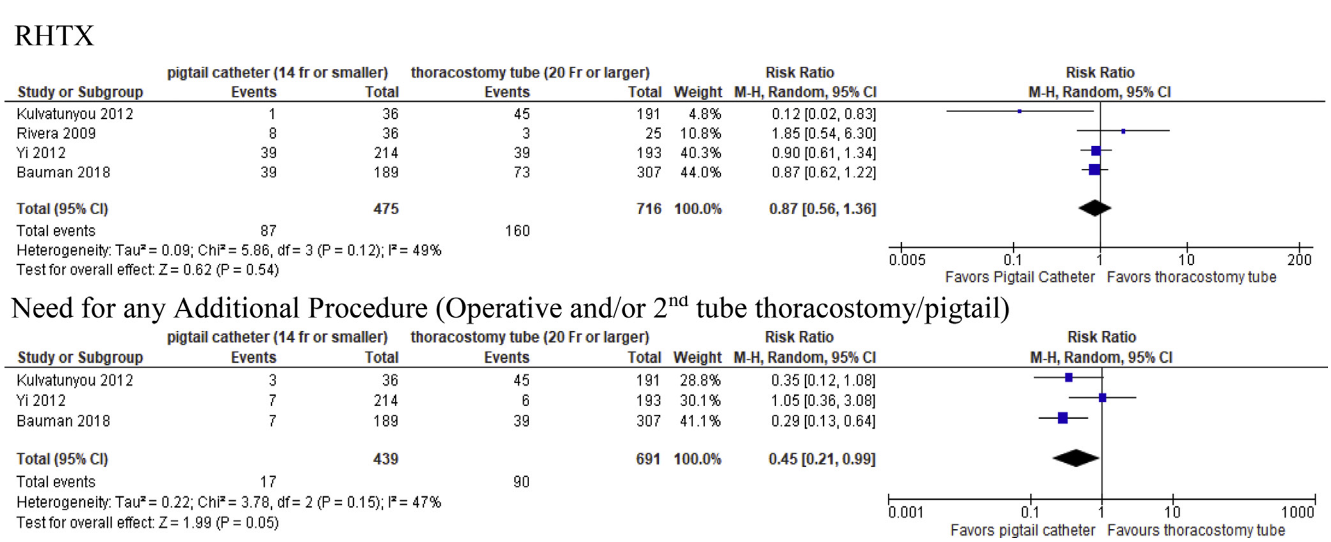


Fig. 2. Forest plots illustrating outcomes for PICO 2: pigtail catheter (14 Fr or smaller) versus thoracostomy tube (20 Fr or larger).

successful observation group, who were older ($P < 0.027$), had higher rates of blunt injury ($P < 0.004$), and had higher ISS ($P < 0.001$) compared to intervention group but did not directly compare the thrombolytics versus VATS group.[20] In the retrospective study, only demographics compared was the age of the thrombolytic group (average age 39.8) versus the VATS group (average age of 41.1) but it is unclear if this was statistically significant.[9] The definition of rHTX also differed between studies; DuBose and colleagues defined it as a heterogenous fluid collection on chest CT with Hounsfield units of 35–70 and evidence of pleural thickening,[20] whereas Kumar and colleagues defined it as any pleural collection on a plain radiograph, US, or chest CT after 48 h of thoracostomy tube placement.[21] The definition of rHTX was not stated in the third study.[9]

There were significant differences in management of patients among the three studies. In Oguzkaya and colleagues' retrospective study, streptokinase was administered between the 3rd and 7th days after placement of thoracostomy tube and was repeated 3 to 7 times.[9] Patients in the prospective RCT received streptokinase instillations twice daily for 3 days.[21] Open thoracotomy was the treatment of choice in both studies for patients who failed after streptokinase instillations. The management of patients, choice of interventions, and timing of subsequent interventions in the third prospective, multicenter, observational study was left up to the individual participation center.[20]

Outcomes evaluated in these studies included need for thoracotomy following failure of intrapleural thrombolytic therapy or VATS, hospital LOS, ICU LOS, complications, and mortality.[9,20,21]

Quantitative analysis

Three critical outcomes for PICO 3 were reported in the various selected studies,[9,20,21] however, only the risk for additional operative intervention was reported in all three studies (Fig. 3). There were 63 patients in the intrapleural thrombolytic therapy group with a rate of 27.0% and 162 patients in the VATS groups with a rate of 17.3% that required additional operative intervention; the RR was 2.44 with a 95% CI of 0.66–9.04. Meta-analysis could not be performed for risk of empyema and need for additional procedure, as they were only reported in one study. The rates for both empyema (9.7% vs 2.9%, $p = 0.1$) and additional procedure (29.0% vs 5.9%, $p < 0.02$) were higher in the intrapleural thrombolytic therapy group in this study.[9] Only one important outcome, hospital LOS, was reported in two of the selected studies: there were 48 patients in thrombolytic therapy group and 52 patients in the immediate VATS group; mean difference for hospital LOS was 3.8 days, favoring VATS.[9,21]

Grading the evidence

The quality of evidence was very low for the reported outcomes of additional operative intervention and hospital LOS due to risk of bias/publication, inconsistency, and imprecision of the data.

Recommendation

After reviewing the quality of evidence, considering risk of harm versus benefit to patients, perceived value, and resource utilization of the two treatment options, 12 out of 14 members (86%) of the PMG group ***conditionally recommended*** performing VATS over intrapleural thrombolytic therapy for rHTX to decrease rate of additional operative intervention and hospital LOS. One member (7%) voted against this recommendation, while another member (7%) voted for no recommendation. The rationale for the recommendation is based on factors such as patient preference and resource utilization along with the very low quality of evidence. Hendriksen et al. recently performed a meta-analysis and systematic review of lytic therapy for retained hemothorax which showed average hospital LOS of 14.88 days however this was not compared to VATS.[22] Our meta-analysis which included three studies did not find any difference in the need for additional operative interventions.[9,20,21] However, the second meta-analysis demonstrated a decreased hospital LOS with a mean difference of 3.8 days which was statistically significant with the more aggressive approach of VATS rather than utilizing thrombolytic therapy.[9,21] By utilizing VATS as the next line of treatment for retained hemothorax there is an opportunity to significantly decrease LOS which would ultimately benefit the patient and hospitals. Patient preference and resource utilization is a significant factor in the conditional recommendation seeing that a decrease in hospital LOS is something the patients would ultimately prefer and benefits hospitals by not having prolonged hospitalization freeing up patient beds. However, the working group does acknowledge there may be situations that thrombolytics may be the preferred choice of treatment such as elderly patient with significant co-morbidities or a critically ill patient unable to undergo surgical intervention. Clinical judgement must still be utilized by the surgeon in this regard.

Timing of VATS for rHTX: early VATS (≤4 days) versus late VATS (>4 days) (PICO 4)

Qualitative analysis

Seven studies evaluated VATS for evacuation of rHTX and its impact on outcomes; five of them were retrospective, and two were prospective and observational in nature.[1,23–28]

All studies included trauma patients with chest injuries who required placement of a thoracostomy tube. Two studies only included patients with chest AIS score of 3 or higher.[23,26] Three studies focused on patients with blunt injuries,[26–28] and one evaluated a patient population with combined blunt thoracic and head trauma.[28] The size of thoracostomy tube placed initially in patient with blunt trauma was 32Fr in one study,[28] and 36Fr in another study.[27] Two of the papers did not compare the demographics between the two groups.[23,24] While Ahmed et al. discussed age (similar between the two groups) and mechanism (higher rate of penetrating trauma) between the two groups but did not do a statistical analysis.[25] The rest of the four articles the demographics did not show any statistical difference between the two groups.[1,26–28]

The definition of rHTX varied between studies but was largely based on the presence of pleural effusion and inability to visualize the costophrenic angle on imaging at 48 h after placement of thoracostomy tube. Plain chest radiograph was sufficient for the diagnosis of rHTX in one study,[25] while this was supplemented by a chest CT if necessary in another study.[1] Four studies relied on chest CT for the diagnosis of rHTX.[24,26–28]

Preliminary review of the literature (prior to forming PICO questions) revealed a wide variety of cut offs in days for defining a VATS early or late. These cutoffs ranged from 2 to 7 days, with most centering around day 4. Therefore, this cutoff was deemed appropriate by our EAST working group to allow the greatest number of literature to be included into the guideline. In addition, it represents an early enough time point in the course of disease, by which a minimally invasive intervention (VATS) is likely to be clinically beneficial, without increasing the risk of conversion to open thoracotomy with its associated morbidity. Timing of VATS was categorized into groups in four studies.[1,25,27,28] Two studies defined early VATS as within 2 days,[1,25] one study defined it as within 4 days or less after thoracostomy tube placement.[28] Another study categorized it into three groups, 2–3 days, 4–6 days, and after 6 days.[27] There was significant variation between studies in terms of technical aspects of the operation, including number and location of

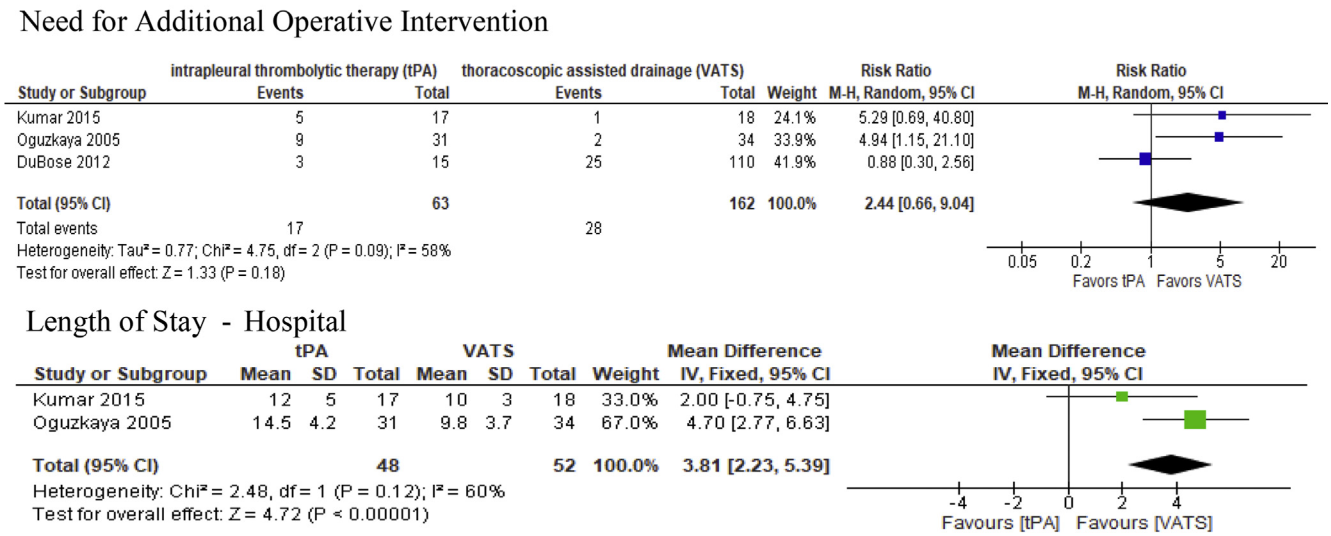


Fig. 3. Forest plots illustrating outcomes for PICO 3: intrapleural thrombolytic therapy (tPA) versus thoracoscopic assisted drainage (VATS).

ports, choice of thoracoscope, instruments used to evacuate the clot, number of thoracostomy tubes placed at the end of procedure for drainage, and type of surgeon performing the procedure. The procedure was clearly stated to be performed by thoracic surgeons in one study,[27] while another study employed a group consisting of general and trauma surgeons.[26]

Outcomes evaluated in these studies included timing of VATS, conversion to thoracotomy, need for additional procedures, post-operative complications, hospital LOS, ICU LOS, ventilator days, and in-patient mortality.[1,23–28]

Quantitative analysis

All four critical outcomes for PICO 4 were reported in the selected studies (Fig. 4).[1,23–28] The risk for conversion to thoracotomy was reported in six studies: the early VATS group had 159 patients with a rate of 4.4% and the late VATS group had 112 patients with a rate of 22.3%; the RR was 0.23 with a 95% CI of 0.10–0.52. The risk of empyema was reported in five studies: the early VATS group had 162 patients with a rate of 8.0% and the late VATS group had 176 patients with a rate of 30.1%; the RR was 0.30 with a 95% CI of 0.16–0.55. The risk for additional procedure was reported in three studies: the early VATS group had 83 patients with a rate of 4.8% and the late VATS group had 122 patients with a rate of 13.1%; the RR was 0.42 with a 95% CI of 0.08–2.18. The hospital LOS was reported in six studies: the early VATS group had 191 patients and the late VATS group had 200 patients; the mean difference for hospital LOS was 11.1 days, favoring early VATS.

All three important outcomes for PICO 4 were also reported in the selected studies (Fig. 5).[1,23–28] The ICU LOS was reported in three studies: the early VATS group had 100 patients and the late VATS group had 131 patients; the mean difference for ICU LOS was 5.5 days [-7.0,-4.0], favoring early VATS. The number of days on the ventilator was reported in 2 studies: the early VATS had 73 patients and the late VATS had 124 patients; the mean difference for ventilator days was 7.9 days, favoring early VATS. The risk for inpatient mortality was reported in five studies: the early VATS group had 140 patients with a rate of 0.7% and the late VATS group had 160 patients with a rate of 3.8%; the RR was 0.33 with a 95% CI of 0.07–1.58.

Grading the evidence

The quality of evidence was very low for all the critical and important outcomes due to risk of bias/publication, inconsistency, indirectness, and imprecision of the data.

Recommendation

After reviewing the quality of evidence, considering risk of harm versus benefit to the patients, perceived value, and resource utilization of the two treatment options, 10 out of 14 members (71%) of the PMG group ***recommends*** performing early VATS (≤4 days) compared to late VATS (>4 days) for drainage of rHTX, to decrease rate of conversion to thoracotomy, risk of empyema, need for additional procedure, hospital LOS, ICU LOS, number of days on the ventilator, and in-patient mortality; 4 out of 14 members (29%) voted to conditionally recommend early VATS. The recommendation was made despite the very low quality of evidence due to the fact that the meta-analysis clearly showed decrease in conversion to open thoracotomy, length of hospital and ICU stay, duration of mechanical ventilation, and empyema all which were statistically significant favoring performing VATS ≤4 days. When taking patient preference/value into account, patients would prefer early VATS especially since this decreases rate of conversion to open thoracotomy thus resulting in less pain and LOS in ICU and hospital overall while simultaneously decreasing complication rates such as empyema which is higher if VATS was performed later than 4 days. The hospital benefits with regards to resource utilization by decreasing patient's LOS in the hospital and ICU as well as duration of mechanical ventilation while mortality and need for additional procedures show no difference between the group whether VATS is done early or not. Ultimately the patient and the hospital would benefit from early VATS.

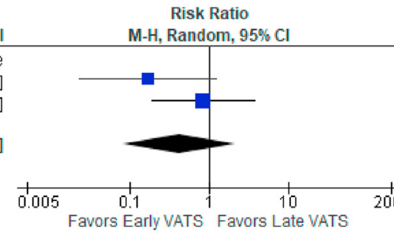
Utilizing the guideline in practice

Utilizing GRADE methodology, the working group members were able to generate recommendations on all PICO questions except for one. Unfortunately, due to the lack of evidence we were unable to make a recommendation for whether or not to drain small (<500 ml) traumatic hemothorax. At this time clinical judgement by the treating surgeon will have to be the deciding factor whether or not to drain the hemothorax. If the decision is made by the surgeon to drain the hemothorax, we conditionally recommend the use of 14 French pigtail catheters to initially drain hemothorax in most situations as opposed to any larger size tube

Need for Additional pigtail catheter/tube thoracostomy

Study or Subgroup	Early VATS (<=4 days) Events	Total	Late VATS (>4 days) Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Abolhoda 1997	0	11	0	5		Not estimable
Lin 2014	1	43	13	93	42.1%	0.17 [0.02, 1.23]
Morrison 2009	3	29	3	24	57.9%	0.83 [0.18, 3.73]
Total (95% CI)		**83**		**122**	**100.0%**	**0.42 [0.08, 2.18]**
Total events	4		16			

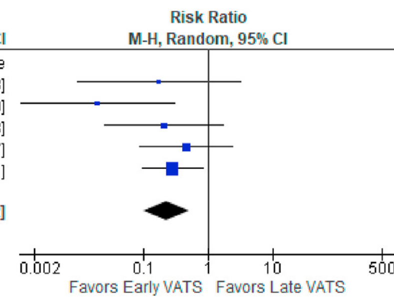
Heterogeneity: Tau² = 0.62; Chi² = 1.76, df = 1 (P = 0.18); I² = 43%
Test for overall effect: Z = 1.03 (P = 0.30)



Conversion to Thoracotomy

Study or Subgroup	Early VATS (<=4 days) Events	Total	Late VATS (>4 days) Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Huang 2018	0	30	0	31		Not estimable
Vassiliu 2001	0	13	2	11	7.6%	0.17 [0.01, 3.23]
Ahmed 2010	0	27	7	7	8.7%	0.02 [0.00, 0.30]
Morrison 2009	1	29	4	24	14.2%	0.21 [0.02, 1.73]
Abolhoda 1997	2	11	2	5	22.6%	0.45 [0.09, 2.37]
Smith 2011	4	49	10	34	46.9%	0.28 [0.09, 0.81]
Total (95% CI)		**159**		**112**	**100.0%**	**0.23 [0.10, 0.52]**
Total events	7		25			

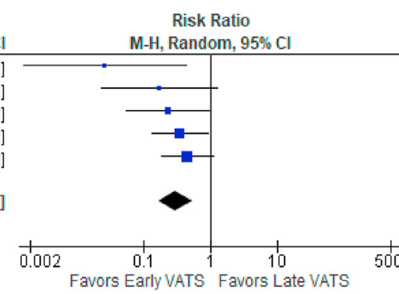
Heterogeneity: Tau² = 0.08; Chi² = 4.34, df = 4 (P = 0.36); I² = 8%
Test for overall effect: Z = 3.51 (P = 0.0004)



Empyema

Study or Subgroup	Early VATS (<=4 days) Events	Total	Late VATS (>4 days) Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Ahmed 2010	0	27	5	7	4.6%	0.03 [0.00, 0.42]
Vassiliu 2001	1	13	5	11	8.8%	0.17 [0.02, 1.24]
Huang 2018	2	30	9	31	16.2%	0.23 [0.05, 0.98]
Smith 2011	5	49	10	34	32.4%	0.35 [0.13, 0.92]
Lin 2014	5	43	24	93	37.9%	0.45 [0.18, 1.10]
Total (95% CI)		**162**		**176**	**100.0%**	**0.30 [0.16, 0.55]**
Total events	13		53			

Heterogeneity: Tau² = 0.04; Chi² = 4.36, df = 4 (P = 0.36); I² = 8%
Test for overall effect: Z = 3.92 (P < 0.0001)



Length of Stay - Hospital

Study or Subgroup	Early VATS (<4 days) Mean	SD	Total	Late VATS (>4 days) Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Ahmed 2010	4.3	0	27	9.4	0	7		Not estimable
Huang 2018	20.6	9.1	30	35.1	24.2	31	2.5%	-14.50 [-23.62, -5.38]
Lin 2014	16.2	9.6	43	27.8	17.6	93	9.7%	-11.60 [-16.19, -7.01]
Morrison 2009	10.8	0.8	29	30.5	5.8	24	37.3%	-19.70 [-22.04, -17.36]
Smith 2011	11	6	49	16	8	34	20.3%	-5.00 [-8.17, -1.83]
Vassiliu 2001	8	2	13	12	4	11	30.2%	-4.00 [-6.60, -1.40]
Total (95% CI)			**191**			**200**	**100.0%**	**-11.06 [-12.49, -9.63]**

Heterogeneity: Chi² = 95.35, df = 4 (P < 0.00001); I² = 96%
Test for overall effect: Z = 15.17 (P < 0.00001)

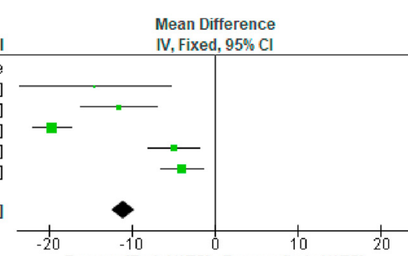


Fig. 4. Forest plots illustrating critical outcomes for PICO 4: early VATS (less than or equal to 4 days) vs late VATS (greater than 4 days).

thoracostomy. This is based on the fact that the pigtail catheter is non-inferior to the tube thoracostomy with regards to retained hemothorax rates, no difference in need for additional procedures when comparing pigtail vs. tube thoracostomy, and the patient preference of wanting a smaller caliber tube if given a choice. However, it should be stressed that this recommendation is for non-emergent drainage of hemothorax in a hemodynamically stable patients utilizing ultrasound based on experience of the staff.

There will be exceptions to this recommendation where clinical judgement will need to be used. In patients that subsequently develop rHTX after the initial drainage procedure is performed, we conditionally recommend utilization of VATS rather than any thrombolytic therapy in order to treat rHTX to help decrease length of stay in hospital. However, there will be cases where operative approach cannot be utilized such as a critically ill patient or elderly patient with significant comorbidities who are unable to undergo

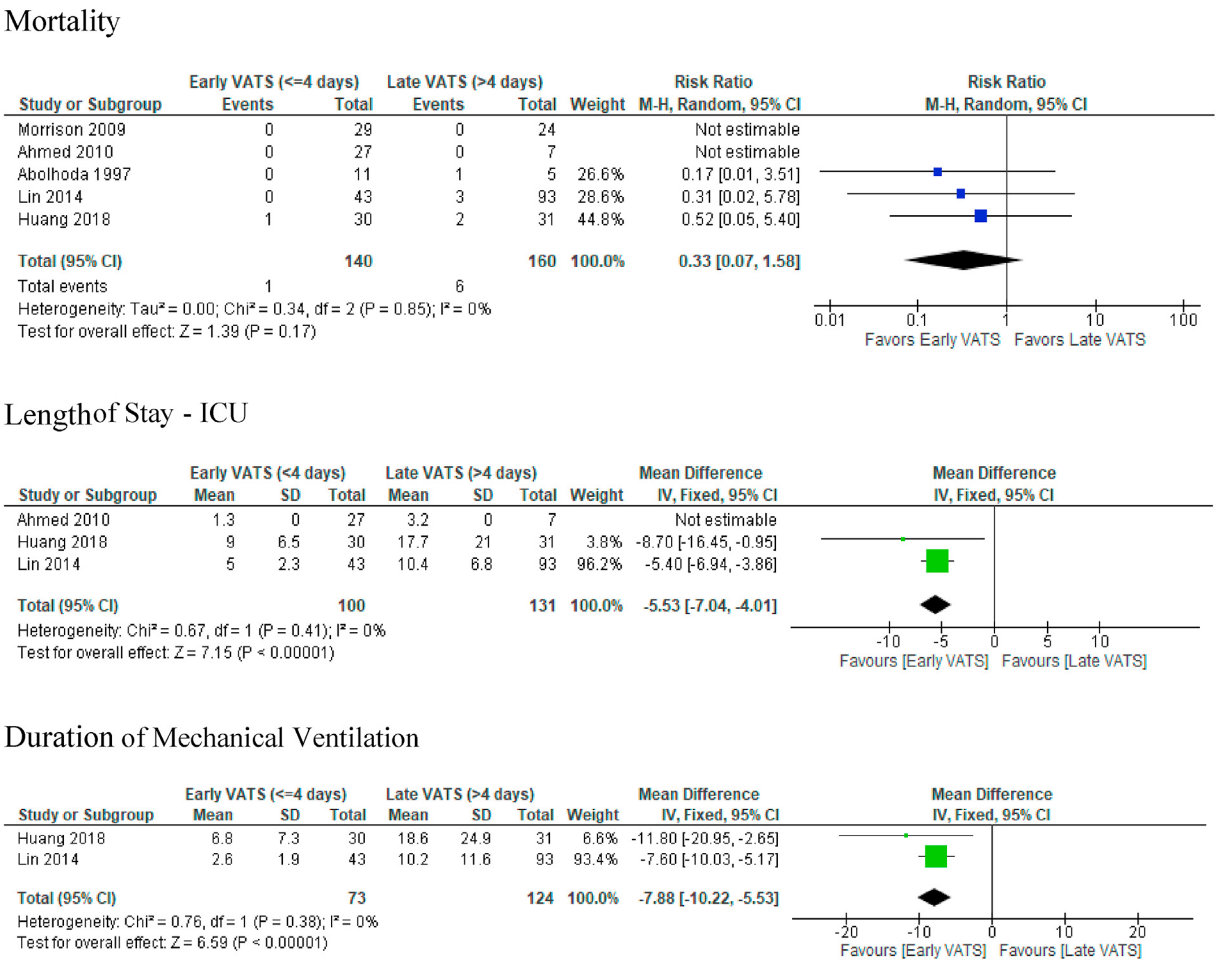


Fig. 5. Forest plots illustrating important outcomes for PICO 4: early VATS (less than or equal to 4 days) versus late VATS (greater than 4 days).

surgical intervention in which case thrombolytic therapy may need to be utilized. Once the surgeon has made the decision to utilize VATS as the next line of treatment for rHTX, the committee recommends early VATS ($\leq$4 days) rather than waiting > 4 days in order to decrease length of stay in hospital and ICU, need for additional procedures, risk of empyema, and conversion to open thoracotomy. Table 2 summarizes the recommendations of the committee with regards to management of rHTX.

Author contribution

NP designed the study. All authors except SC contributed to PICO development and data extraction however all authors reviewed and edited manuscript. SC performed the literature search. Abstract review performed by NP, LD, HL, DC, AM, DF, SK, and GK. Full text review performed by NP, LD, AM, NB, DF and SK. Manuscript was written by NP, LD, HL, DC and EK.

Declaration of competing interest

None of the authors have any conflict of interest or funding to disclose.

Table 2
Summary of Recommendations for PICO questions.

PICO	QUESTION	RECOMMENDATION
1	In hemodynamically stable patients with a small traumatic hemothorax (less than 500 ml) should routine tube thoracostomy vs. observation be performed to decrease need for additional procedure, rHTX and empyema?	**No Recommendation**
2	In hemodynamically stable patients with a traumatic hemothorax requiring drainage should pigtail catheter (14 Fr or smaller) vs. thoracostomy tube (20 Fr or larger) be placed to decrease need for additional procedure, rHTX and empyema?	**Conditionally Recommend pigtail catheter**
3	In hemodynamically stable patients with retained traumatic hemothorax, should intrapleural thrombolytic therapy (i.e. tPA) be attempted vs. immediate thoracoscopic assisted drainage (VATS) in order to decrease need for additional operative or non-operative procedure and empyema?	**Conditionally Recommend VATS**
4	In hemodynamically stable patients with retained traumatic hemothorax deemed to require drainage should early VATS (less than or equal to 4 days) vs. Late VATS (greater than 4 days) be performed in order to decrease need for additional procedure, conversion to open thoracotomy, empyema, and length of hospital stay?	**Recommend Early VATS**

Appendix. Search Strategies

Database: MEDLINE (via legacy PubMed)

Search date: 3/24/2019.

Search #	Search Strategy	Results
#1	“Hemothorax"[Mesh] OR “hemopneumothorax"[Mesh] OR hemothorax[tiab] OR haemothorax[tiab] OR hematothorax[tiab] OR haematothorax[tiab] OR hemothoraces[tiab] OR haemothoraces[tiab] OR hematothoraces[tiab] OR haematothoraces[tiab] OR HTX[tiab] OR hemopneumothorax[tiab] OR haemopneumothorax[tiab] OR hemopneumothoraces[tiab] OR haemopneumothoraces[tiab] OR hematopneumothorax[tiab] OR haematopneumothorax[tiab] OR hematopneumothoraces[tiab] OR haematopneumothoraces[tiab] OR intrathoracic[tiab] OR extrathoracic[tiab]	21,652
#2	“Wounds and Injuries"[Mesh] OR “Accidental Falls"[Mesh] OR “Accidents, Traffic"[Mesh] OR “Contusions"[Mesh] OR “Crush Injuries"[Mesh] OR “Rib Fractures"[Mesh] OR “Lacerations"[Mesh] OR “Hematoma"[Mesh] OR “Rupture"[Mesh] OR “Wounds, Penetrating"[Mesh] OR “Wounds, Gunshot"[Mesh] OR “Burns"[Mesh] OR trauma[tiab] OR traumatic[tiab] OR polytrauma[tiab] OR injury[tiab] OR injuries[tiab] OR injured[tiab] OR injure[tiab] OR injuring[tiab] OR blunt[tiab] OR crush[tiab] OR crushed[tiab] OR penetrate[tiab] OR penetrates[tiab] OR penetrating[tiab] OR penetrated [tiab] OR penetration[tiab] OR non-penetrating[tiab] OR fracture[tiab] OR fractures[tiab] OR fractured[tiab] OR lacerate[tiab] OR lacerates[tiab] OR lacerated[tiab] OR laceration[tiab] OR lacerations[tiab] OR perforation[tiab] OR perforations[tiab] OR perforate[tiab] OR perforates[tiab] OR perforated [tiab] OR rupture[tiab] OR ruptures[tiab] OR ruptured[tiab] OR falls[tiab] OR falling[tiab] OR abrasion[tiab] OR abrasions[tiab] OR contusion[tiab] OR contusions[tiab] OR wound[tiab] OR wounds[tiab] OR wounded[tiab] OR wounding[tiab] OR “motor vehicle collision"[tiab] OR “motor vehicle collisions"[tiab] OR “motor vehicle accident"[tiab] OR “motor vehicle accidents"[tiab] OR “motor vehicle crash"[tiab] OR “car accident"[tiab] OR “car accidents"[tiab] OR “car crash"[tiab] OR “vehicular accident"[tiab] OR “vehicular accidents"[tiab] OR “vehicular collision"[tiab] OR “vehicular collisions"[tiab] OR “vehicular crash"[tiab] OR “traffic accident"[tiab] OR “traffic accidents"[tiab] OR MVC[tiab] OR “traffic crash"[tiab] OR “automobile crash"[tiab] OR “automobile collision"[tiab] OR “automobile collisions"[tiab] OR “automobile accident"[tiab] OR Hematoma[tiab] OR hematomas[tiab] OR hematoma[tiab] OR haematomas[tiab] OR gunshot[tiab] OR “gunshot"[tiab] OR firearm[tiab] OR firearms[tiab] OR stab[tiab] OR stabbed[tiab] OR burn[tiab] OR burns[tiab] OR burned[tiab] OR Hemorrhage[tiab] OR hemorrhages[tiab] OR hemorrhaged[tiab] OR hemorrhaging[tiab] OR hemorrhage [tiab] OR haemorrhages[tiab] OR haemorrhaged[tiab] OR hemorrhaging[tiab] OR bleeding[tiab] OR bleed[tiab] OR bleeds[tiab] OR bled[tiab]	2,250,422
#3	#1 AND #2	6374
#4	#3 NOT (animals[mh] NOT humans[mh])	6060
#5	#4 NOT (Editorial[pt] OR Letter[pt] OR Case Reports[pt] OR Comment[pt])	3648
#6	#5 AND English[lang]	2794

Database: EMBASE (via Elsevier)

Search date: 3/24/2019.

Search #	Search Strategy	Results
#1	‘hematothorax’/exp OR ‘hematopneumothorax’/exp OR hemothorax:ab,ti OR haemothorax:ab,ti OR hematothorax:ab,ti OR haematothorax:ab,ti OR hemothoraces:ab,ti OR haemothoraces:ab,ti OR hematothoraces:ab,ti OR haematothoraces:ab,ti OR HTX:ab,ti OR hemopneumothorax:ab,ti OR haemopneumothorax:ab,ti OR hemopneumothoraces:ab,ti OR haemopneumothoraces:ab,ti OR hematopneumothorax:ab,ti OR haematopneumothorax:ab,ti OR hematopneumothoraces:ab,ti OR haematopneumothoraces:ab,ti OR intrathoracic:ab,ti OR extrathoracic:ab,ti	36,038
#2	‘injury’/exp OR ‘falling’/exp OR ′traffic accident’/exp OR ‘contusion’/exp OR ′crush trauma’/exp OR ′rib fracture’/exp OR ′penetrating trauma’/exp OR ‘laceration’/exp OR ‘rupture’/exp OR ‘hematoma’/exp OR ′gunshot injury’/exp OR ‘burn’/exp OR trauma:ab,ti OR traumatic:ab,ti OR polytrauma:ab,ti OR injury:ab,ti OR injuries:ab,ti OR injured:ab,ti OR injure:ab,ti OR injuring:ab,ti OR blunt:ab,ti OR crush:ab,ti OR crushed:ab,ti OR penetrate:ab,ti OR penetrates:ab,ti OR penetrating:ab,ti OR penetrated:ab,ti OR penetration:ab,ti OR non-penetrating:ab,ti OR fracture:ab,ti OR fractures:ab,ti OR fractured:ab,ti OR lacerate:ab,ti OR lacerates:ab,ti OR lacerated:ab,ti OR laceration:ab,ti OR lacerations:ab,ti OR perforation:ab,ti OR perforations:ab,ti OR perforate:ab,ti OR perforates:ab,ti OR perforated:ab,ti OR rupture:ab,ti OR ruptures:ab,ti OR ruptured:ab,ti OR falls:ab,ti OR falling:ab,ti OR abrasion:ab,ti OR abrasions:ab,ti OR contusion:ab,ti OR contusions:ab,ti OR wound:ab,ti OR wounds:ab,ti OR wounded:ab,ti OR wounding:ab,ti OR ′motor vehicle collision’:ab,ti OR ′motor vehicle collisions’:ab,ti OR ′motor vehicle accident’:ab,ti OR ′motor vehicle accidents’:ab,ti OR ′motor vehicle crash’:ab,ti OR ′car accident’:ab,ti OR ′car accidents’:ab,ti OR ′car crash’:ab,ti OR ′vehicular accident’:ab,ti OR ′vehicular accidents’:ab,ti OR ′vehicular collision’:ab,ti OR ′vehicular collisions’:ab,ti OR ′vehicular crash’:ab,ti OR ′traffic accident’:ab,ti OR ′traffic accidents’:ab,ti OR MVC:ab,ti OR ′traffic crash’:ab,ti OR ′automobile crash’:ab,ti OR ′automobile collision’:ab,ti OR ′automobile collisions’:ab,ti OR ′automobile accident’:ab,ti OR Hematoma:ab,ti OR hematomas:ab,ti OR hematoma:ab,ti OR haematomas:ab,ti OR gunshot:ab,ti OR ‘gunshot’:ab,ti OR firearm:ab,ti OR firearms:ab,ti OR stab:ab,ti OR stabbed:ab,ti OR burn:ab,ti OR burns:ab,ti OR burned:ab,ti OR Hemorrhage:ab,ti OR hemorrhages:ab,ti OR hemorrhaged:ab,ti OR hemorrhaging:ab,ti OR hemorrhage:ab,ti OR haemorrhages:ab,ti OR haemorrhaged:ab,ti OR hemorrhaging:ab,ti OR bleeding:ab,ti OR bleed:ab,ti OR bleeds:ab,ti OR bled:ab,ti	3,585,805
#3	#1 AND #2	12,056
#4	#3 AND [humans]/lim	9637
#5	#4 NOT (‘case report’/exp OR ′case study’/exp OR ‘editorial’/exp OR ‘letter’/exp OR ‘note’/exp OR [conference abstract]/lim)	4532
#6	#5 AND [english]/lim	3737

Database: Cochrane Central Register of Controlled Trials (via Wiley)

Search date: 3/24/2019.

Search #	Search Strategy	Results
#1	[mh "Hemothorax"] OR [mh "hemopneumothorax"] OR hemothorax OR haemothorax OR hematothorax OR haematothorax OR hemothoraces OR haemothoraces OR hematothoraces OR haematothoraces OR HTX OR hemopneumothorax OR haemopneumothorax OR hemopneumothoraces OR haemopneumothoraces OR hematopneumothorax OR haematopneumothorax OR hematopneumothoraces OR haematopneumothoraces OR intrathoracic OR extrathoracic	978
#2	[mh "Wounds and Injuries"] OR [mh "Accidental Falls"] OR [mh "Accidents, Traffic"] OR [mh "Contusions"] OR [mh "Crush Injuries"] OR [mh "Rib Fractures"] OR [mh "Lacerations"] OR [mh "Hematoma"] OR [mh "Rupture"] OR [mh "Wounds, Penetrating"] OR [mh "Wounds, Gunshot"] OR [mh "Burns"] OR trauma OR traumatic OR polytrauma OR injury OR injuries OR injured OR injure OR injuring OR blunt OR crush OR crushed OR penetrate OR penetrates OR penetrating OR penetrated OR penetration OR non-penetrating OR fracture OR fractures OR fractured OR lacerate OR lacerates OR lacerated OR laceration OR lacerations OR perforation OR perforations OR perforate OR perforates OR perforated OR rupture OR ruptures OR ruptured OR falls OR falling OR abrasion OR abrasions OR contusion OR contusions OR wound OR wounds OR wounded OR wounding OR "motor vehicle collision" OR "motor vehicle collisions" OR "motor vehicle accident" OR "motor vehicle accidents" OR "motor vehicle crash" OR "car accident" OR "car accidents" OR "car crash" OR "vehicular accident" OR "vehicular accidents" OR "vehicular collision" OR "vehicular collisions" OR "vehicular crash" OR "traffic accident" OR "traffic accidents" OR MVC OR "traffic crash" OR "automobile crash" OR "automobile collision" OR "automobile collisions" OR "automobile accident" OR Hematoma OR hematomas OR hematoma OR haematomas OR gunshot OR "gunshot" OR firearm OR firearms OR stab OR stabbed OR burn OR burns OR burned OR Hemorrhage OR hemorrhages OR hemorrhaged OR hemorrhaging OR hemorrhage OR haemorrhages OR haemorrhaged OR hemorrhaging OR bleeding OR bleed OR bleeds OR bled	152,254
#3	#1 AND #2	288
#4	#3 AND limit to Trials	221

Database: Web of Science (via Clarivate)

Search date: 3/24/2019.

Search #	Search Strategy	Results
#1	TS=(hemothorax OR haemothorax OR hematothorax OR haematothorax OR hemothoraces OR haemothoraces OR hematothoraces OR haematothoraces OR HTX OR hemopneumothorax OR haemopneumothorax OR hemopneumothoraces OR haemopneumothoraces OR hematopneumothorax OR haematopneumothorax OR hematopneumothoraces OR haematopneumothoraces OR intrathoracic OR extrathoracic)	15,684
#2	TS=(trauma OR traumatic OR polytrauma OR injury OR injuries OR injured OR injure OR injuring OR blunt OR crush OR crushed OR penetrate OR penetrates OR penetrating OR penetrated OR penetration OR non-penetrating OR fracture OR fractures OR fractured OR lacerate OR lacerates OR lacerated OR laceration OR lacerations OR perforation OR perforations OR perforate OR perforates OR perforated OR rupture OR ruptures OR ruptured OR falls OR falling OR abrasion OR abrasions OR contusion OR contusions OR wound OR wounds OR wounded OR wounding OR "motor vehicle collision" OR "motor vehicle collisions" OR "motor vehicle accident" OR "motor vehicle accidents" OR "motor vehicle crash" OR "car accident" OR "car accidents" OR "car crash" OR "vehicular accident" OR "vehicular accidents" OR "vehicular collision" OR "vehicular collisions" OR "vehicular crash" OR "traffic accident" OR "traffic accidents" OR MVC OR "traffic crash" OR "automobile crash" OR "automobile collision" OR "automobile collisions" OR "automobile accident" OR Hematoma OR hematomas OR hematoma OR haematomas OR gunshot OR "gunshot" OR firearm OR firearms OR stab OR stabbed OR burn OR burns OR burned OR Hemorrhage OR hemorrhages OR hemorrhaged OR hemorrhaging OR hemorrhage OR haemorrhages OR haemorrhaged OR hemorrhaging OR bleeding OR bleed OR bleeds OR bled)	3,200,128
#3	#1 AND #2	4032
#4	(#3) AND DOCUMENT TYPES: (Article OR Review)	3688
#5	(#4) AND LANGUAGE: (English)	3366

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