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Outcomes of Pigtail Catheter Placement versus Chest Tube Placement in Adult Thoracic Trauma Patients: A Systematic Review and Meta-Analysis

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Abstract

Introduction: A debate currently exists regarding the efficacy of pigtail catheters vs chest tubes in the management of thoracic trauma. This meta-analysis aims to compare the outcomes of pigtail catheters vs chest tubes in adult trauma patients with thoracic injuries.

Methods: This systematic review and meta-analysis were conducted using PRISMA guidelines and registered with PROSPERO. PubMed, Google Scholar, Embase, Ebsco, and ProQuest electronic databases were queried for studies comparing the use of pigtail catheters vs chest tubes in adult trauma patients from database inception to August 15th, 2022. The primary outcome was the failure rate of drainage tubes, defined as requiring a second tube placement or VATS, unresolved pneumothorax, hemothorax, or hemopneumothorax requiring additional intervention. Secondary outcomes were initial drainage output, ICU-LOS, and ventilator days.

Results: A total of 7 studies satisfied eligibility criteria and were assessed in the meta-analysis. The pigtail group had higher initial output volumes vs the chest tube group, with a mean difference of 114.7 mL [95% CI (70.6 mL, 158.8 mL)]. Patients in the chest tube group also had a higher risk of requiring VATS vs the pigtail group, with a relative risk of 2.77 [95% CI (1.50, 5.11)].

Conclusions: In trauma patients, pigtail catheters rather than chest tubes are associated with higher initial output volume, reduced risk of VATS, and shorter tube duration. Considering the similar rates of failure, ventilator days, and ICU length-of-stay, pigtail catheters should be considered in the management of traumatic thoracic injuries.

Study Type: Systematic Review and meta-analysis.

Keywords
pigtail catheter, chest tube, thoracic trauma, trauma outcomes

Introduction

Trauma-related injuries are the most common cause of mortality in the first four decades of life, of which traumatic thoracic injuries account for approximately 25%.[1,2] Traumatic thoracic injuries, including pneumothorax, hemothorax, and hemopneumothorax, necessitate rapid intervention, often with chest tube insertion.[3] The size of the chest tube being placed is a clinical decision that is left to the discretion of the provider and is often based on the results of a chest x-ray or focused assessment with sonography in a trauma (FAST)

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exam. However, there remains a significant debate regarding the insertion of large-bore chest tubes compared to smaller-bore pigtail catheters.[3]

Recent studies have suggested that smaller-diameter pigtail catheters may offer improved patient outcomes, including reduced complication rates and pain severity.[4,5] A study by Hussein et al found that chest tubes and pigtail catheters had comparable success rates in the management of spontaneous pneumothorax. Additionally, they found significantly increased complication rates in the chest tube group when compared to the pigtail group, and those receiving a chest tube reported significantly higher pain scores.[6] Similarly, a study conducted by Dull et al in 2002 discovered that pigtail catheter insertion in the management of pneumothoraces resulted in decreased daily patient narcotic use.[7] Despite these favorable outcomes associated with pigtail catheters, existing studies have demonstrated their use primarily in hemodynamically stable patients suffering blunt injuries, with minimal data surrounding their utility in patients who are hemodynamically unstable or suffering penetrating thoracic trauma.[4,8,9] Although these studies detail improved patient experiences when using pigtail catheters over a traditional chest tube, the 10th edition of the ATLS guidelines continues to suggest the use of larger 28-32 Fr chest tubes as a treatment for major thoracic injuries such as hemothoraces.[10] As such, further research comparing trauma-related patient outcomes is necessary to elucidate the benefits and risks of pigtail catheter utilization compared to chest tubes in the management of thoracic trauma.

This systematic review and meta-analysis offer insight into the relationship between thoracic trauma and type of pleural drainage tube through a comparison of pigtail catheters and large-bore chest tubes in relation to their effect on relevant outcomes. This study aimed to compare outcomes, including failure rate, initial drainage output, ICU length-of-stay (ICU-LOS), hospital length-of-stay (H-LOS), ventilator days, and tube duration in adult trauma patients with blunt and/or penetrating thoracic injuries who received either a pigtail catheter (≤14Fr) or chest tube (>16Fr). We hypothesize that the use of pigtail catheters in the management of thoracic trauma will demonstrate improved outcomes in adult trauma patients when compared to chest tubes. With this study, we aim to investigate current literature to provide evidence-based recommendations and direction for future investigations.

Methods

Population, Intervention, Comparator, and Outcomes (PICO)

A total of five population, intervention, comparison, and outcome (PICO) questions were defined before our literature search:

PICO 1: Are pigtail catheters (≤14Fr) associated with a difference in failure rates, among adult patients with traumatic pneumothorax, hemothorax, or hemopneumothorax when compared to chest tubes (>16 Fr)?

PICO 2: Are pigtail catheters (≤14Fr) associated with a difference in initial drainage output (within 30 minutes of insertion) among adult patients with traumatic pneumothorax, hemothorax, or hemopneumothorax when compared to chest tubes (>16 Fr)?

PICO 3: Are pigtail catheters (≤14Fr) associated with a difference in ICU-LOS or H-LOS among adult patients with traumatic pneumothorax, hemothorax, or hemopneumothorax when compared to chest tubes (>16 Fr)?

PICO 4: Are pigtail catheters (≤14Fr) associated with a difference in ventilator days among adult patients with traumatic pneumothorax, hemothorax, or hemopneumothorax when compared to chest tubes (>16 Fr)?

PICO 5: Are pigtail catheters (≤14Fr) associated with a difference in tube duration among adult patients with traumatic pneumothorax, hemothorax, or hemopneumothorax when compared to chest tubes (>16 Fr)?

Data Sources and Search Strategy. The systematic review and meta-analysis were performed according to the PRISMA guidelines of 2020. A search of all studies assessing the use of pigtail catheters vs chest tubes in patients who experienced a trauma-related pneumothorax, hemothorax, pleural effusion, or hemopneumothorax on PubMed, Google Scholar, Embase, Ebsco, and ProQuest was conducted from database inception to August 15th, 2022. All studies published from the database's inception to August 15th 2022 were included. This study has been registered with PROSPERO with an ID number 343780. The following search keywords were included: "Chest Tube" AND "Pigtail" OR "Thoracostomy Tube" AND "Pigtail" OR "Trauma" AND "Thoracostomy" OR "Trauma" AND "Pigtail" OR "Pneumothorax" AND "Chest Tube" OR "Hemothorax" AND "Chest Tube" OR "Pneumothorax" AND "Pigtail" OR "Hemothorax" AND "Pigtail" OR "Small Bore Chest Tube" AND "Large Bore Chest Tube." Additionally, references of included studies were screened for study eligibility.

Eligibility Criteria and Study Selection

Inclusion and Exclusion Criteria. This study population included adult (≥18 years of age) trauma patients with blunt and/or penetrating thoracic injuries diagnosed with a traumatic pneumothorax, hemothorax, or hemopneumothorax who received a thoracostomy. Studies were included if they compared outcomes associated with the use of pigtail catheters (≤14Fr) and chest tubes (>16Fr) in the management of adult trauma patients with blunt and/or penetrating thoracic injuries. Studies that included at least 2 of the following outcomes of interest: failure rate, initial drainage output, ventilator days, ICU-LOS, H-LOS, and tube duration were utilized. Failure rate was defined by the need for second tube placement, video-assisted thoracoscopic surgery, or unresolved pneumothorax, hemothorax, or hemopneumothorax that required additional intervention, such as thrombolysis.[8–13] Initial drainage output was determined based on tube output within the first 30 minutes following insertion. Tube duration was defined by the number of days patients had a tube in place. Study designs consisted of randomized-controlled trials (RCT), prospective cohort studies, and retrospective cohort studies.

The following studies were excluded: Studies containing pediatric populations, and non-traumatic thoracic injuries resulting in pneumothorax, hemothorax, or hemopneumothorax. We excluded studies lacking sufficient quantitative data needed to perform a meta-analysis. Case reports, case series, systematic reviews, meta-analyses, commentaries, and non-English language studies were not included.

Data Collection Process. The initial literature search was performed by all authors who then screened relevant articles by title and abstract for exclusion. Secondary searches and full-text reviews of each included article were conducted by all authors. Lastly, all authors participated in data extraction from full-text studies after the final literature search was performed. All articles were screened upon collection for overall relevance. Any discrepancies in screened and selected articles were reviewed and resolved by collaboration and discussion among all authors. Microsoft Excel 2010 (Redmond Washington) was used to gather, screen, and collect information.

Quality of Evidence and Risk of Bias Assessment. The quality of evidence for the included studies was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group Criteria.[11] The quality of evidence was moderate to high in all studies (supplementary file: eTable 1). The risk of bias in retrospective and prospective cohort studies was evaluated using the Newcastle-Ottawa Scale (NOS). The randomized-controlled trials were evaluated through the Cochrane risk-of-bias tool for randomized trials (RoB 2). The risk of bias was low in 4[9,13–15] studies and moderate in 3[8,12,16] studies (supplementary file: eTable 2a/b).

Study Outcomes. The primary study outcome was the failure rate of the drainage tubes. Secondary outcomes included initial drainage output (in mL), ICU-LOS (days), H-LOS (days), ventilator days, and tube duration.

Data Synthesis. Meta-analysis was conducted using Microsoft Excel 2010 (Redmond Washington). All meta-analyses were performed for the indicated endpoints with either mean difference (for mean and median values) or relative risk (for proportions) being used to compare groups. Conversion of median to mean was performed by the method outlined by Greco et al.[17] All confidence intervals were 95%, and all significance levels were .05. A Cohen's Q test was used to assess heterogeneous effects on each meta-analysis endpoint. When this test was significant, a typical random effects model for approximately normal variables was applied.[18,19] Otherwise, a typical fixed-effects model for approximately normal variables was applied.[18,19] Heterogeneity in patient demographics was also assessed with the Cohen's Q test in patient populations among the included studies. This study was conducted in compliance with ethical standards, utilized publicly available data and is determined to be institutional review board exempted.

Results

The PRISMA guidelines of 2020 were followed in this study. A literature search identified a total of 2451 articles. After the elimination of duplicates, screening, and full-text review, 7 eligible studies remained (Figure 1). The studies consisted of 2 RCTs, 3 prospective studies, and 2 retrospective studies. All included studies were conducted in the United States. Regarding patient demographic heterogeneity for the pigtail group studies, they were found to be heterogeneous in age, chest Abbreviated Injury Scale (C-AIS), and proportion of blunt injuries. In the chest tube group, studies were found to be heterogeneous in age, C-AIS, ISS, percentage of males, and percentage of blunt injuries.[8,9,12–16]

For our primary outcome, six studies evaluated the failure rate of pigtail catheters vs chest tubes. All studies found no significant difference in the failure rate between pigtail catheters and chest tubes.[8,9,12–15] Regarding secondary outcomes, five studies evaluated the initial drainage output of pigtail catheters and chest tubes.[8,13–16] Three studies found no significant differences between groups.[8,14,15] Five studies evaluated the median number of ventilator days [Tables 1 and 2].[8,12–15] All five studies determined that the median ventilator days was 0, regardless of whether pigtail catheters or chest tubes were used. Five studies evaluated the ICU-LOS associated with pigtail catheter vs chest tube use [Tables 3].[8,12–15] No significant difference in ICU-LOS was found between pigtail catheter and chest tube use in any of the studies [Tables 1 and 2]. All seven studies evaluated H-LOS associated with pigtail catheter vs chest tube use. However, no significant differences were seen between groups [Table 3].[8,9,12–16] Lastly, seven studies in the meta-analysis compared the mean tube duration [Table 3].[8,9,12–16] Tube duration was found to be significantly lower for the pigtail catheter group.

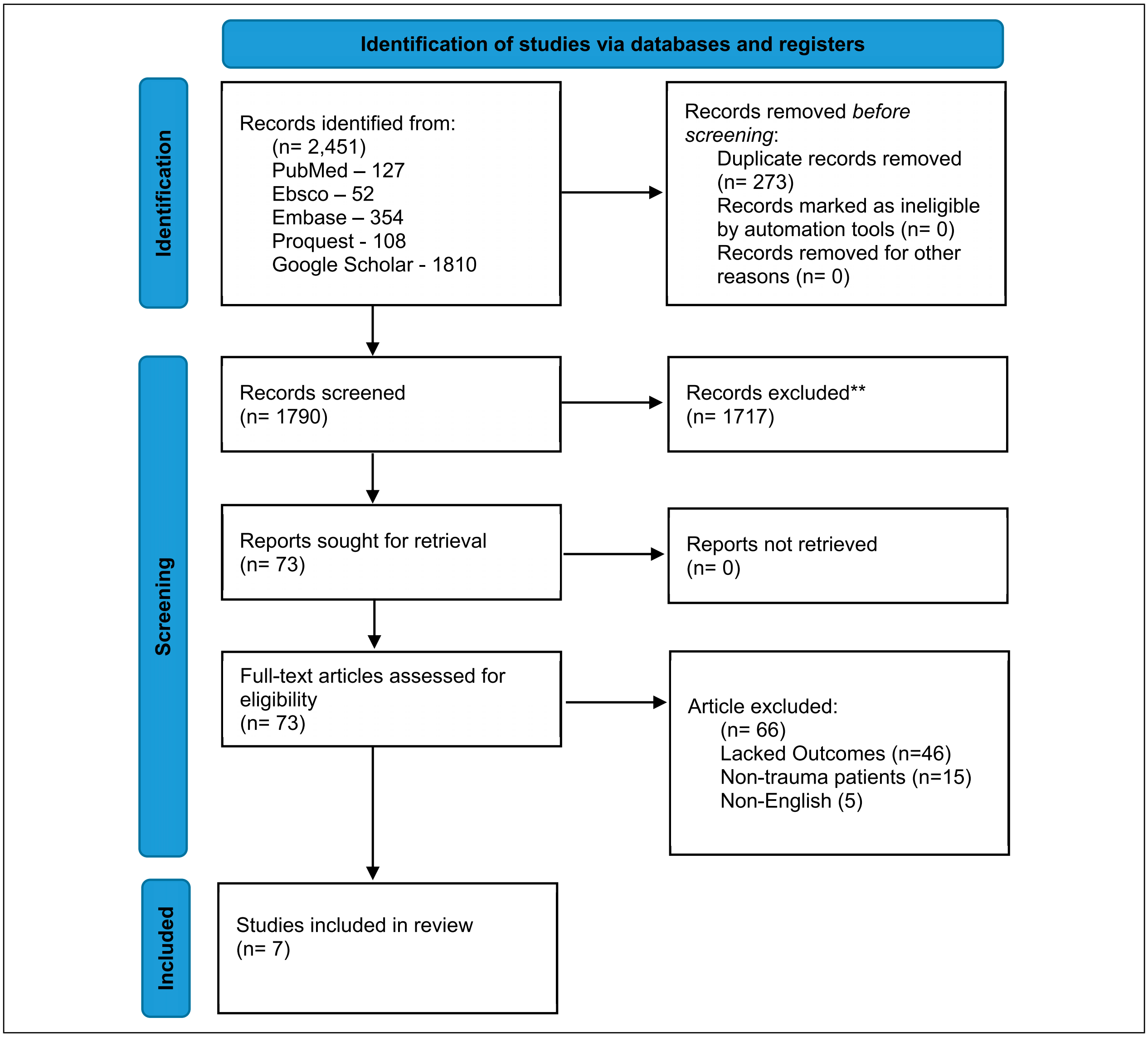

Figure 1. PRISMA flow diagram of included studies in the systematic review and meta-analysis.

Pigtail Catheters vs Chest Tubes - Failure Rate

Failure rates were compared between 750 patients with chest tubes and 393 patients with pigtail catheters, encompassing six studies.[8,9,12–15] The relative risk of failure rate of chest tubes compared to pigtail catheters was found to be 1.13 [95% CI: (.85-1.51), I^2:36%] [Table 2a/b]. This was done using fixed effects as Cohen's Q was not significant (P = .17).

Pigtail Catheters vs Chest Tubes - VATS

In a sub-analysis of the five studies recording the proportion of patients requiring VATS, it was found that patients in the chest tube group (n = 656) had a significantly higher risk of requiring VATS compared to those in the pigtail group (n = 492), with a relative risk (Chest Tube/Pigtail) of 2.77 [95% CI: (1.50 - 5.11), I^2: 38%].[8,13–16] This was done using fixed effects as Cohen's Q was not significant (P = .17). A forest plot for VATS outcomes can be found in Figure 2.

Pigtail Catheters vs Chest Tubes - Initial Drainage Output

Five studies comparing the initial drainage output (mL) of 461 patients with a pigtail catheter and 644 patients with a chest tube were included in the meta-analysis.[8,13–16] Mean output for the pigtail catheters ranged from 425 to 810.9 mL, and 300 to 738 mL for the chest tubes. The pigtail catheter group had a significantly higher initial output volume vs the chest tube

Table 1. Demographic Characteristics of the Chest Tube Cohort in the Included Studies.

Demographic Characteristics of the Chest Tube Cohort in the Included Studies

Study (Year)	Study design	Country	Level of trauma Center(s)	Number (n)	Age (SD)	Gender (male)	Catheter size	Type of injury n (%)		C-AIS [IQR](SD)	ISS [IQR](SD)
								Blunt	Penetrating		
Orlando et al (2020)	Retrospective cohort study	US	Level I (6 centers)	60	≥18	51/60 (85%)	32 Fr [28-32][a]	54/60 (95%)	3/60 (5%)	≥3: 43/60 (91%)	9 to 15: 21/60 (35%)
Bauman et al (2021)	Randomized clinical trial	US	Level I (single-center)	23	55 (18)[b]	22/23 (96%)	28-32 Fr	17/23 (74%)	NR	4 [3-4][a]	15.8 (5.9)[b]
Kulvatunyou et al (2014)	Randomized clinical trial	US	Level I (single-center)	20	46 (4)[b]	16/20 (80%)	28 Fr	16/20 (80%)	NR	3 [1-4][a]	12.2 (1.2)[b]
Kulvatunyou et al (2021)	Prospective randomized clinical trial	US	NR	63	54 (19)[b]	51/63 (81%)	28-32 Fr	47/63 (75%)	NR	4 [3,4][a]	17.3 (6.8)[b]
Bauman et al (2018)	Prospective study	US	Level I (single-center; UA)	307	42 (19)	236/307 (77%)	32-40 Fr	55%	NR	3 [3,4][a]	18.5 [11-29][a]
Kulvatunyou et al (2012)	Prospective study (pigtail); retrospective study (chest tube)	US	Level I (single-center)	191	41 (1.4)[b]	139/191 (73%)	32-40 Fr	118/191 (62%)	NR	3.3 (.1)[b]	21 (.8)[b]
Kulvatunyou et al (2011)	Retrospective cohort study	US	Level I (single-center)	386	40 (18)[b]	115/164 (79%)	32-40 Fr	143/164 (87%)	NR	3.3 (.8)[b]	21 (14)[b]

Age is reported as mean (SD) and C-AIS and ISS are reported as mean (SD) or median [IQR]; NR (Not Reported).
[a]Median [IQR].
[b]Mean (SD).

Table 2. Demographic Characteristics of the Pigtail Catheter Cohort in the Included Studies.

Demographic Characteristics of the Pigtail Catheter Cohort in the Included Studies

Study (Year)	Study design	Country	Level of trauma center(s)	Number (n)	Age (SD)	Gender (male)	Catheter size	Type of injury n (%)		C-AIS [IQR](SD)	ISS [IQR](SD)
								Blunt	Penetrating		
Orlando et al (2020)	Retrospective cohort study	US	Level I (6 centers)	160	≥18	112/160 (70%)	12 Fr [12-14][a]	158/160 (99%)	2/160 (1%)	C-AIS ≥3: 117/160 (85%)	9 to 15: 68/160 (43%)
Bauman et al (2021)	Randomized clinical trial	US	Level I	20	62 (13)[b]	17/20 (85%)	14 Fr	19/20 (95%)	NR	3.5 [3-4][a]	17.5 (6.6)[b]
Kulvatunyou et al (2014)	Randomized clinical trial	US	Level I	20	46 (4)[b]	17/20 (85%)	14 Fr	17/20 (85%)	NR	3 [2-4][a]	14.5 (1.1)[b]
Kulvatunyou et al (2021)	Prospective randomized clinical trial	US	NR	56	56 (17)[b]	47/56 (84%)	14 Fr	49/56 (87.5%)	NR	4 [3,4][a]	17.8 (6.8)[b]
Bauman et al (2018)	Prospective study	US	Level I	189	52 (21)[b]	144/189 (76%)	14 Fr	86%	NR	3 [3,3][a]	16 [10,25][a]
Kulvatunyou et al (2012)	Prospective study (pigtail); retrospective study (chest tube)	US	Level I	36	53 (4)[b]	27/36 (75%)	14 Fr	30/36 (83%)	NR	3.1 (.9)[b]	18 (1.5)[b]
Kulvatunyou et al (2011)	Retrospective cohort study	US	Level I	94	43 (21)[b]	34/75 (64%)	14 Fr	62/75 (83%)	NR	3.2 (.8)[b]	17 (11)[b]

Age is reported as mean (SD) and C-AIS and ISS are reported as mean (SD) or median [IQR]; NR (Not Reported).
[a]Median [IQR].
[b]Mean (SD).

Table 3. Compared Outcomes of the Chest Tube and Pigtail Cohorts from Included Studies.

Outcomes of the Chest Tube and Pigtail Cohort in the Included Studies							
Study (Year)	Complications						
Insertion related complications	Ventilator days	Failure rates	Required VATS	Initial output (mL)	ICU-LOS days mean (SD) [median (IQR]	H-LOS days mean (SD) [median IQR]	Tube days mean (SD) [median (IQR]
Orlando et al (2020)	CT: NR Pigtail: NR	CT: NR Pigtail: NR	CT: 4/72 (6%) Pigtail: 0	CT: 738[b] Pigtail: 810.9[b]	CT: NR Pigtail: NR	CT: 15.1 (SE .73) Pigtail: 15.1 (SE 28.80)	CT: 144.6 (SE 50.05) Pigtail: 86.5 (SE 28.80)
Bauman et al (2021)	CT: 0 [0-0][a] Pigtail: 0 [0-.5][a]	CT: 4/23 (17%) Pigtail: 2/20 (10%)	CT: 2/23 (9%) Pigtail: 1/20 (5%)	CT: 400 [240-700][a] Pigtail: 650 [375-1087][a]	CT: 0 [0-3][a] Pigtail: 0 [0-3.5][a]	CT: 8 [5-12][a] Pigtail: 8.5 [5.5-15][a]	CT: 4 [2-7][a] Pigtail: 4 [3-5.5][a]
Kulvatunyou et al (2014)	CT: NR Pigtail: NR	CT: 2/20 (10%) Pigtail: 1/20 (5%)	CT: NR Pigtail: NR	CT: NR Pigtail: NR	CT: NR Pigtail: NR	CT: 4 [3-7]† Pigtail: 4 [3-7][a]	CT: 2 [2-6]† Pigtail: 2 [2-3][a]
Kulvatunyou et al (2021)	CT: 0 [0-0][a] Pigtail: 0 [0-2][a]	CT: 8/63 (13%) Pigtail: 7/56 (11%)	CT: 3/63 (5%) Pigtail: 4/56 (7%)	CT: 400 [250-650][a] Pigtail: 600 [375-1037][a]	CT: 2 [0-4][a] Pigtail: 2.5 [0-3.5][a]	CT: 7 [3-9][a] Pigtail: 6.5 [4.5-10][a]	CT: 5 [3-7][a] Pigtail: 4 [3-6][a]
Bauman et al (2018)	CT: 0 [0-3][a] Pigtail: 0 [0-1][a]	CT: 73 (24%) Pigtail: 39 (21%)	CT: 39/307 (13%) Pigtail: 7/189 (4%)	CT: 300 [150-500][a] Pigtail: 425 [200-800][a]	CT: 2 [0-6][a] Pigtail: 1 [0-5][a]	CT: 8 [5-14][a] Pigtail: 7 [4-14][a]	CT: 5 [4-7][a] Pigtail: 4 [2-6][a]
Kulvatunyou et al (2012)	CT: 0 [0-3][a] Pigtail: 0 [0-1][a]	CT: 45/191 (24%) Pigtail: 3/36 (8%)	CT: 29/191 (15%) Pigtail: 1/36 (3%)	CT: 426 (37)[b] Pigtail: 560 (81)[b]	CT: 2 [0-5][a] Pigtail: 2 [.5-5.5][a]	CT: 8 [4-13][a] Pigtail: 10 [6-12][a]	CT: 6 (.3)Φ Pigtail: 5 (.8)
Kulvatunyou et al (2011)	CT: 0 [0, 3][a] Pigtail: 0 [0,2.5][a]	CT: 6/146 (4%) Pigtail: 8/72 (11%)	CT: NRv Pigtail: NR	CT: NR Pigtail: NR	CT: 2 (0-5)[a] Pigtail: 0 [0,5][a] Pigtail: 6 [3,10][a]	CT: 15 [9-24][a]	CT: 4.4 (2.3)[b] Pigtail: 4 (1.6)

Ventilator days, Initial output, and Intensive Care Unit Length-of-Stay (ICU-LOS) is recorded as mean (SD) or median [IQR]; NR (Not Reported).
[a]Median [IQR].
[b]Mean (SD).

group, with a mean difference (Pigtail minus Chest Tube) of 114.7 mL [95% CI: (70.6 mL-158.8 mL), I^2: 59%]. This was done using random effects as Cohen's Q was significant (P = .04). A forest plot for initial drainage output outcomes is found in Figure 3.

Pigtail Catheters vs Chest Tubes—Ventilator Days

Among the five studies that compared the number of ventilator days between the use of a pigtail catheter or chest tube, the mean number of ventilator days was .0 [95% CI: (−.2-.2), I^2:0%].[8,12–15] No significant differences were found in days spent on a ventilator between the two groups [Table 3]. This was done using fixed effects as Cohen's Q was not significant (P = 1).

Pigtail Catheters vs Chest Tubes—ICU-LOS and H-LOS

Five studies in the meta-analysis compared the mean ICU-LOS with a total of 395 patients with a pigtail catheter and 952 patients with a chest tube.[8,12–15] The mean ICU-LOS

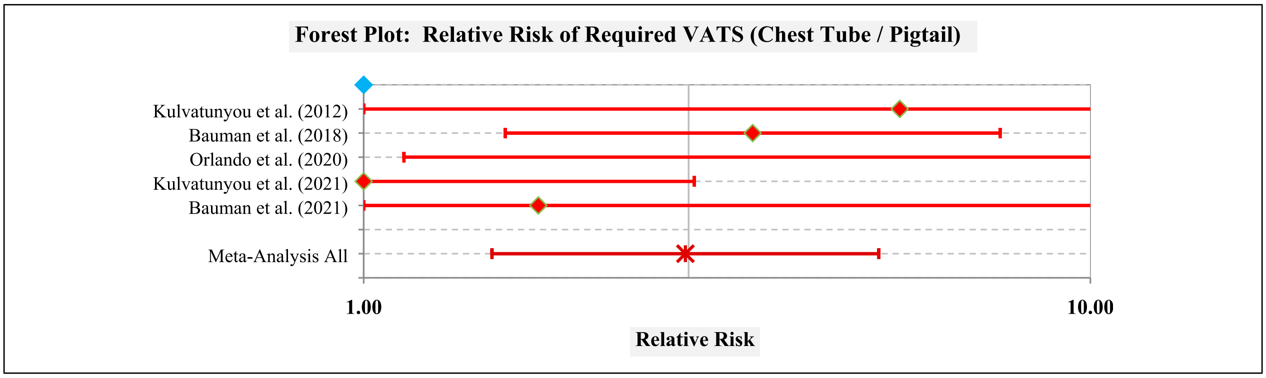

Figure 2. Forest Plot of 95% Confidence Intervals for the relative risk of having a required VATS (Chest Tube / Pigtail), and the Meta-Analysis Confidence Intervals across all studies. The x-axis represents the relative risk. The red lines represent the confidence intervals.

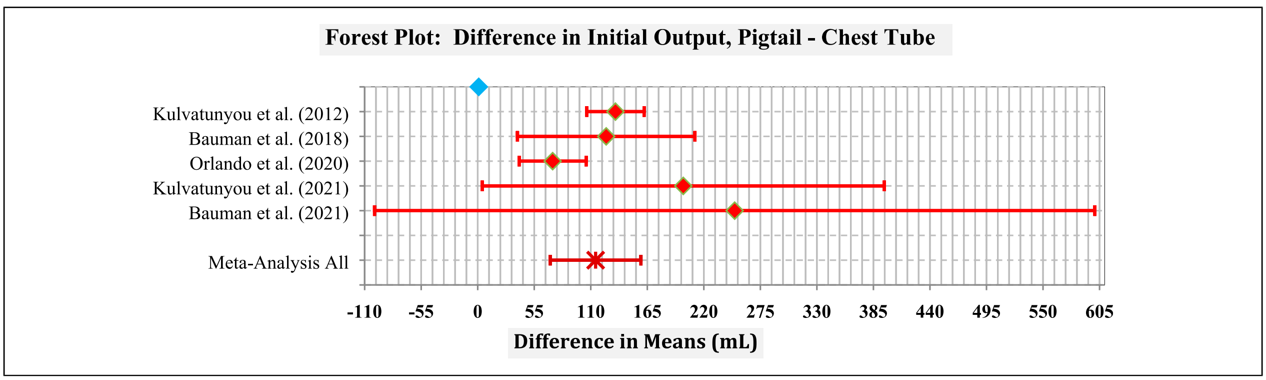

Figure 3. Forest Plot of 95% Confidence Intervals for differences (Pigtail—Chest Tube) in mean Initial Output (mL), and the Meta-Analysis Confidence Intervals across all studies. The x-axis represents the difference in means. The red lines represent the confidence intervals.

ranged from 0 to 2.5 days when using a pigtail catheter and 0 to 2 days when using a chest tube. No significant differences were seen between the two groups (difference in mean: −.5 days [95% CI: (−1.2-.2), I^2:44%] [Table 3]. This was done using fixed effects as Cohen's Q was not significant (P = .13).

All seven studies in the meta-analysis compared the mean H-LOS with a total of 575 patients with a pigtail catheter and 1032 patients with a chest tube.[8,9,12–16] The mean H-LOS ranged from 4 to 15.1 days when using a pigtail catheter and 4 to 15.1 days when using a chest tube. No significant differences were seen between the two groups (difference in mean: −1.2 days [95% CI: (−4.6-2.2), I^2:92%] [Table 3]. This was done using a random effects model as Cohen's Q was significant ($P <$ .01).

Pigtail Catheters vs Chest Tubes—Tube Duration

All seven studies in the meta-analysis compared the mean tube duration with a total of 575 patients with a pigtail catheter and 1032 patients with a chest tube.[8,9,12–16] The mean tube duration ranged from 2 to 5 days when using a pigtail catheter and 2 to 6 days when using a chest tube. Tube duration was significantly lower for the pigtail catheter group (difference in mean: −.8 days [95% CI: (−1.0 to −.6), I^2:33%] [Table 3]. This was done using a fixed-effects model, as Cohen's Q was not significant (P = .18). A forest plot for tube duration outcomes is found in Figure 4.

Discussion

We performed a systematic review and meta-analysis of studies that compared pigtail catheters to chest tubes in adult thoracic trauma patients on measures of failure rate, initial drainage output, ICU-LOS, H-LOS, ventilator days, and tube duration. Pigtail catheters were found to have a significantly lower incidence of VATS when compared to chest tubes, reducing the need for further intervention. Additionally, pigtail catheters had a greater initial output than chest tubes, challenging the

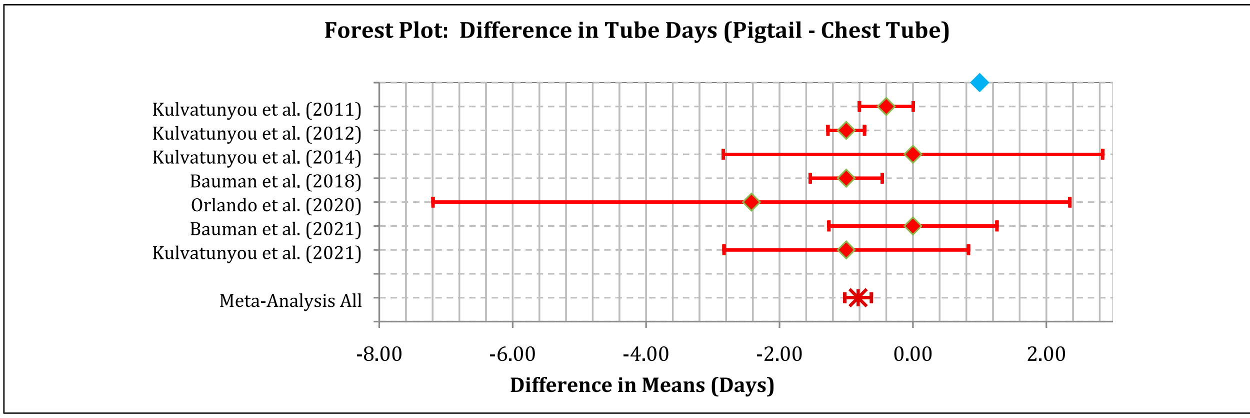

Figure 4. Forest Plot of 95% Confidence Intervals for differences (Pigtai—Chest Tube) in mean Tube days and the Meta-Analysis Confidence Intervals across all studies. The x-axis represents the difference in means. The red lines represent the confidence intervals.

notion that a larger tube results in greater output. Pigtail catheters also had a significantly shorter tube duration compared to chest tubes. Pigtail catheters may be as efficacious, if not more, than chest tubes for draining viscous fluids. Utilization of pigtail catheters was not associated with a significant difference in failure rate, ICU-LOS, H-LOS, or ventilator days when compared to chest tubes.

Failure rate is a common concern when selecting a pigtail catheter or chest tube for utilization in a thoracostomy.[14] It is assumed that the smaller French size of pigtail catheters has an increased susceptibility to mechanical obstruction when compared to chest tubes.[20,21] However, Chang et al. found no significant difference in failure rate between pigtail catheters and chest tubes in the treatment of a pneumothorax.[21] Results from our meta-analysis further contribute to these findings, revealing no significant difference in the failure rate of pigtail catheter utilization when compared to chest tubes in trauma patients diagnosed with pneumothorax, hemothorax, or hemopneumothorax. This suggests that pigtail catheters may provide similar failure rates compared to chest tubes, regardless of thoracic injury.

Early video-assisted thoracoscopy is the current secondary treatment recommendation for patients with chest tube or pigtail catheter failure resulting in retained hemothorax.[14,22] Use of Video-Assisted Thoracoscopic Surgery (VATS) is designated as a complication after chest tube or pigtail catheter failure, and its use is frequently associated with complications of its own, namely prolonged air leak, bleeding, infection, post-operative pain, and recurrence at the port site in malignant disease.[23] While pigtail catheters and large-bore chest tubes both bear unique risks and benefits, studies such as Orlando et al. have demonstrated that patients with traditional chest tubes have a significantly larger risk of requiring VATS than patients with small-bore pigtail catheters, and subsequently suffer more VATS-related complications.[16] The results of our meta-analysis are consistent with these findings, showing that patients receiving a pigtail catheter were at a decreased risk for requiring VATS compared to patients receiving a chest tube. Thus, the selection of a pigtail catheter rather than a large-bore chest tube may be beneficial in reducing the risk of further intervention with VATS and its associated complications. In turn, the reduction of this risk may result in the optimization of other outcomes, such as hospital length-of-stay (H-LOS), ICU-LOS, and overall costs. However, while many studies excluded emergent tube placements, some studies included in our meta-analysis were more likely to place chest tubes in emergent settings and in patients suffering penetrating trauma, possibly increasing the likelihood of requiring VATS. Despite this, we believe our findings support the current literature that the failure rates of pigtail catheters and chest tubes are equivalent in the trauma setting.

Though it is reasonable to assume that a larger-bore tube would allow for greater drainage output based on Poiseuille's Law, this does not appear to be the case when comparing the drainage output of pigtail catheters and chest tubes in thoracic trauma management. Russo et al. compared drainage by placing pigtail catheters and chest tubes in pigs with induced hemothorax, concluding no significant difference in drainage.[24] Liang et al. built upon this concept by noting that pigtail catheters may be more efficacious for drainage in the settings of traumatic hemothorax and serous effusions.[25] As the pigtail catheter group in our study had a significantly higher initial output volume compared to the chest tube group, our meta-analysis findings further contribute to the existing literature favoring pigtail catheters for improved initial drainage output. However, it should be noted that pigtail catheters tend to be placed in less emergent situations and in a delayed time frame (allowing more time for fluid to accumulate) when compared to chest tubes. Therefore, these factors could have played a role in our findings that pigtail catheters had a significantly higher output compared to chest tubes. Additional differences such as area of tube placement and procedural differences may also have contributed to these counterintuitive findings. Future studies comparing the initial fluid output of pigtail catheters and chest tubes in draining fluids of varying viscosity, such as old blood vs new blood via timing of tube insertion, are warranted to further explore this finding.[25,26]

Utilization of a pigtail catheter was not associated with a significant increase in ventilator days, ICU-LOS, or H-LOS. These findings differ from a review of patients with a pneumothorax, in which patients receiving a pigtail catheter had a significantly lower H-LOS compared to those that received a chest tube.[21] Reported pain level may play a factor in H-LOS, as patients receiving a pigtail catheter often describe a significantly lower amount of pain compared to those receiving a chest tube.[9] Additionally, although ICU-LOS and H-LOS had no significant differences between the two groups, it is important to highlight some potentially confounding variables. Large-bore chest tubes seemed to be placed in more emergent situations and in those with penetrating trauma leading to potentially a longer hospital or ICU-LOS. Therefore, these factors could have impacted our findings. Further studies are needed to help resolve this discrepancy and may elaborate on the impact of pain and other factors on H-LOS.

Recent guidelines (2020) by the Eastern Association for the Surgery of Trauma (EAST) conditionally recommend the use of pigtail catheters in patients that are hemodynamically stable over a standard large-bore chest tube to decrease the rate of retained hemothorax and the need for additional intervention.[22] However, they state that evidence for the use of a pigtail catheter over chest tubes is weak based on data belonging to the same institution over an overlapping time period. Additionally, they add that this data may be subject to selection bias because the placement of pigtail catheters was delayed and trended towards placement in older patients with less severe injuries. Regardless of these drawbacks, EAST gives the conditional recommendation based on their meta-analysis findings that there was a statistically significant decrease in the need for additional operative intervention with the pigtail catheters vs chest tubes, with no statistical difference in retained hemothorax rates. Together with the existing data, the results of our study may strengthen this recommendation and improve concerns about both internal and external validity.

Management algorithms from the Western Trauma Association concerning the type of chest tube placement are broken down by traumatic hemothorax or pneumothorax.[27] The Western Trauma Association recommends that all patients who are hemodynamically unstable due to a hemothorax have a standard, large-bore chest tube placed, with consideration for pleural lavage. In patients who are hemodynamically stable, they recommend that patients with a hemothorax of significant size (>300-500cc) be treated with either a pigtail catheter or traditional chest tube, as that there is no significant difference between them.[23] For traumatic pneumothoraces in patients who were hemodynamically unstable, if using an open technique, small-bore chest tubes such as a 20-28Fr or percutaneous pigtail tubes were recommended, whereas hemodynamically stable patients with large pneumothoraces (>35 mm on CT or >20% on CXR) could use even smaller pigtail catheters if the pneumothorax was isolated.[29] As there is a relative lack of data on hemodynamically unstable patients requiring tube thoracostomy compared to the literature on those who are hemodynamically stable, EAST, WTA, and other trauma societies should further evaluate the use of pigtail catheters in a wider variety of situations of hemodynamically unstable patients to better support these guidelines.[22,27,28]

Future Recommendations

Given the improved outcomes with the utilization of pigtail catheters demonstrated by this study and others, we offer several recommendations. First and foremost, the conduction of randomized-controlled trials directly comparing the two catheters would provide high-quality evidence to further evaluate their impact on outcomes in trauma patients. Additionally, as many current studies conglomerate data on thoracostomy tube use for various traumatic chest pathologies, such as hemothoraces and pneumothoraces, future studies should instead seek to compare these catheters in more specific clinical scenarios (ie, hemothorax only) to better identify the conditions in which patients are most likely to benefit from the use of one tube over the other. Second, due to the paucity of literature surrounding the use of pigtail catheters in hemodynamically unstable patients or those sustaining penetrating trauma, future investigations should seek to explore their utility in this patient population. Previous literature has looked at chest tube size related to mortality and the use of larger-bore tubes for severe thoracic injuries, although it lacks epidemiology data to indicate the adverse events associated with mortality.[29,30] Thus, these studies may wish to include inpatient mortality as an outcome evaluated in their study design, as there is a paucity of data surrounding the effectiveness of these treatment modalities on mortality. Additionally, although no difference in failure rates was found in this study, future studies should further evaluate this relationship, as variable results have been demonstrated in the current body of literature. The definition of failure should be clearly stated, as the definition was not homogenous between the studies included in this analysis and the studies which were excluded. Finally, as EAST has cited the lack of evidence in patients sustaining severe injuries as a barrier to the incorporation of pigtail catheters into current trauma management algorithms, future investigations may wish to include a patient population in which severe injuries were sustained, such as those with higher ISS or chest AIS.[22] Similarly, investigators may wish to stratify their patient population by hemodynamic stability, as pigtail catheters have demonstrated improved drainage rates, and the selection of tube sizing has been recommended to be based on the patient's hemodynamic status.[27] Further exploration into the relationship between the use of pigtail catheters and chest tubes and their relation to failure rates and patient mortality in different patient populations will allow for adjustment of current thoracic trauma guidelines in the optimization of patient care.

Limitations

Data from the studies included in the meta-analysis were collected from two institutions across the 7 papers, decreasing the external validity of our study and subsequently limiting robust assessment. Furthermore, many of these studies have overlapping years and it is, therefore, possible the same patients were counted in multiple studies. Heterogeneity was present in multiple data points, including age and C-AIS for both pigtails and chest tube groups. Heterogeneity was found in the proportion of blunt injuries for the pigtail group and ISS, percentage of males, and percentage of blunt injuries in the chest tube group. Similarly, initial drainage output was collected 30 minutes after insertion in all studies except for Orlando et al, who did not specify a timeframe for initial drainage output measurement. Outcome reporting in our studies was variable on measures of failure rate and need for VATS, likely due to a lack of standardization in the definitions of those variables across institutions and individual providers. In addition, we were not able to separate outcomes based on whether the pigtail catheter or chest tube was placed for pneumothorax, hemothorax, or hemopneumothorax due to the lack of recorded outcomes in each of the associated studies. Therefore, future reviews should consider reporting outcomes for each of these separately. Finally, studies did not stratify outcomes by the mechanism of injury, ISS, or hemodynamic status, all of which are utilized in determining the appropriate drainage tube for management, which limited our ability to assess the aforementioned variables.

Regardless, this study offers a comprehensive overview of the existing literature regarding outcomes associated with the use of pigtail catheters or chest tubes in the management of thoracic trauma. As nearly 25% of trauma cases involve thoracic injuries, improvement of evidence-based guidelines surrounding the utilization of pigtail catheters may assist in improving trauma patient outcomes.[2]

Conclusion

This systematic review and meta-analysis found that pigtail catheters may be a safe and reliable alternative to chest tubes in adult trauma patients with pneumothorax or hemothorax, given the similar rates of failure, ventilator days, and ICU-LOS. Additionally, pigtail catheters may provide benefits such as the decreased requirement for intervention with VATS, greater drainage output, and fewer days with a tube in place. Given these findings, trauma societies and hospital institutional policies should consider increased utilization of pigtail catheters in the management of thoracic trauma patients.

Author Contributions

Study design and conception: AE
Data collection, analysis, and interpretation: MN, RZ, RA, GB, AK, RS, AE
Manuscript preparation and drafting: MN, RZ, AK, GB, TB, RA, RS, AE
Critical revision of the manuscript: MN, GB, TB, RA, RS, AE
All authors read and approved the final manuscript.

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Supplemental Material

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