Evaluation and management of traumatic pneumothorax: A Western Trauma Association critical decisions algorithm

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ABSTRACT: This is a recommended algorithm of the Western Trauma Association for the management of a traumatic pneumothorax. The current algorithm and recommendations are based on available published prospective cohort, observational, and retrospective studies and the expert opinion of the Western Trauma Association members. The algorithm and accompanying text represents a safe and reasonable approach to this common problem. We recognize that there may be variability in decision making, local resources, institutional consensus, and patient-specific factors that may require deviation from the algorithm presented. This annotated algorithm is meant to serve as a basis from which protocols at individual institutions can be developed or serve as a quick bedside reference for clinicians. (*J Trauma Acute Care Surg.* 2022;92: 103–107. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Consensus algorithm from the Western Trauma Association, Level V.

KEY WORDS: Algorithm; pneumothorax; trauma; pneumohemothorax.

This is a recommended algorithm of the Western Trauma Association for the management of a traumatic pneumothorax (PTX). The current algorithm and recommendations are based on available published prospective cohort, observational, and retrospective studies and the expert opinion of the Western Trauma Association members. The literature was reviewed after a search in PubMed and Google scholar using the following key words: pneumothorax, traumatic pneumothorax, trauma, thoracic trauma. The references that were deemed applicable were included in the discussion by the Western Trauma Association and are listed in the references of this manuscript. The algorithm (Fig. 1) and accompanying text represents a safe and reasonable approach to this common problem. We recognize that there may be variability in decision making, local resources, institutional consensus, and patient-specific factors that may require deviation from the algorithm presented. This annotated algorithm is meant to serve as a basis from which protocols at individual institutions can be developed or serve as a quick bedside reference for clinicians.

BACKGROUND

Penetrating and blunt trauma to the chest are common mechanisms of injury that can lead to PTXs or hemothoraces. Pneumothoraces, pulmonary contusions and rib fractures are the most common injuries encountered in the chest.[1,2] Historically, the treatment for any traumatic PTX was a standard large-bore chest tube. However, in the wake of ubiquitous use of computed tomography (CT) scanning the sensitivity to detect PTXs has increased substantially. This increased sensitivity has led surgeons to question whether tube decompression is necessary for smaller PTXs. There is also a trend towards small chest tubes which will be discussed below. The definition of significant PTX varies and the size of the chest tube used has decreased over time. This guideline is meant to provide a frame-work for individual institutions to develop their own protocols driven by local resources based on the best current evidence and/or expert opinion. It is meant to select with greater accuracy those patients who require chest tubes or who may be observed safely avoiding the additive morbidity of a chest tube. Chest tubes can be associated with up to a 20% incidence of morbidity and therefore should be used selectively in those patients who are most likely to benefit from the intervention.[3,4] This guideline is based on the available contemporary evidence and expert opinion of the Western Trauma Association guidelines committee to make recommendations focused on management of the traumatic PTX (Fig. 1).

Pneumothorax is defined radiographically as a lucency (air) noted on x-ray or CT scan between the parietal and visceral pleurae. An overt PTX is one that is noted on x-ray, whereas an occult PTX is not seen on an x-ray but identified on CT scan or ultrasound of the chest (given the greater sensitivity in detecting PTX of these modalities).[5] One half of traumatic PTXs are diagnosed via CT

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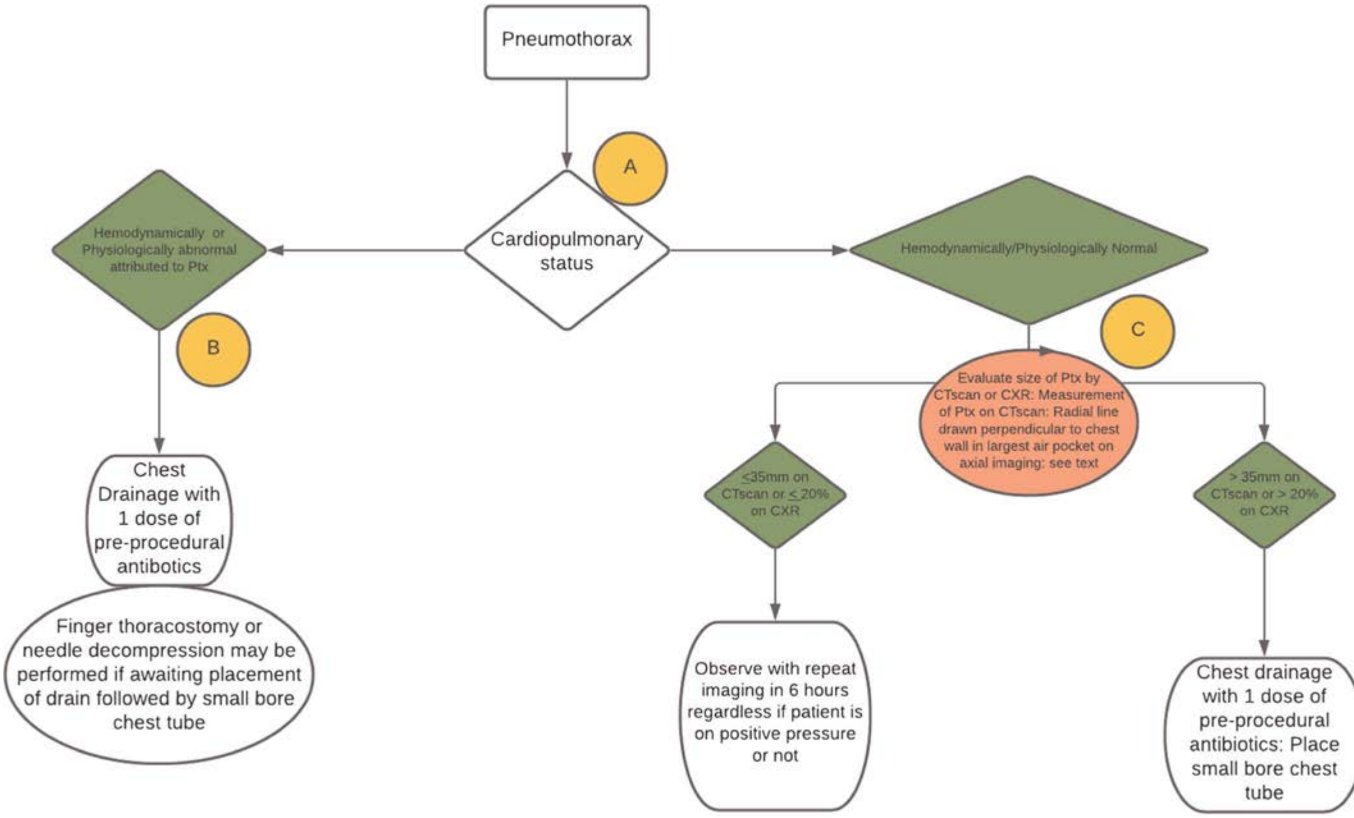

Figure 1. WTA algorithm for management of a traumatic PTX.

scan when compared to a chest x-ray in the modern era.[6] A PTX is defined by ultrasound primarily as the loss of pleural sliding with M mode patterns and several additional secondary ultrasound findings (comet tails, lung point, etc) that support the diagnosis (Fig. 2). For the purposes of this guideline there is no distinction made between the diagnostic modality used to determine the presence of a PTX and therefore it applies equally to occult as well as overt PTXs.

There are several studies dating back to the 1990s that suggest that occult PTXs may be observed.[7,8] These randomized trials demonstrated that approximately ten percent of occult PTXs may be observed safely. Brasel et al. extended that concept to patients receiving positive pressure ventilation.[8] The practice of observing occult PTX was applied to overt PTX in a retrospective study by Johnson et al.[9] Fifty-three patients were included, and 29 of them were observed initially. Of these, 27 resolved without the need for tube thoracostomy (93%).

In a retrospective study by Barrios et al., management without tube thoracostomy was attempted for 59 occult PTX and was successful in 86%. The success rate of those exposed to positive pressure ventilation was 80%. However, patients were only included in this study if their exposure to positive pressure ventilation was within 72 hours of admission. None of the patients successfully managed without tube thoracostomy (n = 16) died.[10] Many clinicians also associate positive pressure ventilation or various levels of alveolar pressures with PTX recurrence or expansion. A recent study by Tawil et al.[11] did not look at the relationship of PTX to positive pressure ventilation (PPV), but rather at the recurrence of PTX after chest tube removal while under PPV. They concluded that PPV was not associated with PTX recurrence.

One of the major limitations of the aforementioned studies was the lack of volumetric estimates and categorization of PTX by size. Beginning in 1991 there were several studies that have attempted to qualify the pneumothoraces by size.[12,13] In 2007, deMoya et al.[14] described a scoring system that was tied to clinical outcomes. However, this study did not use a criterion standard due to the lack of a criterion standard for PTX volumetrics on CT scans. To produce a criterion standard for PTX volumetric measurement an animal model was devised that involved injecting aliquots of 10 mL of air into the pleural space of a swine model with repeated CT scanning. Given these scans had precise measurements of the amount of air introduced into the pleural space with their correlated CT scan imaging a software was built to measure each CT scan axial image and connect the pneumothoraces to produce a specific volume in mL. This software was highly correlated with the injected known amounts of air. This software was then applied to the CT scans of a series of trauma patients who had chest CT scans and this produced the specific volume of each PTX.[15] The use of this CT-guided volumetric measurement was further explored and found to be the dominant parameter for decision-making in a series in 2012.[16] However, due to the lack of generalizability of the software to other institutions, other surrogate markers of volumetrics were tested against this new volumetric criterion standard. The measurement system used in the 2007 was further simplified due to the lack of significant differences in the area under the characteristic curve of the 2007 system versus the current recommended single measurement. The measurement described in the subsequent trials and in this manuscript, reflect the methods that were

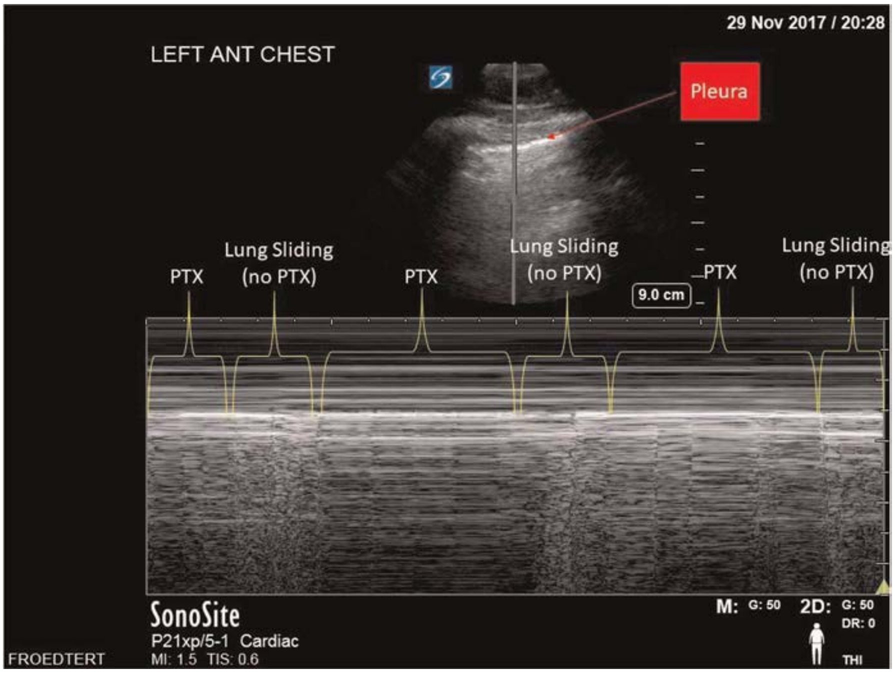

Figure 2. Ultrasound image of a pneumothorax on M-mode.

practical and easy to use for any CT scan–proven PTX. We did not find value in measuring the exact volume of the PTX but rather it was adequate to have a validated surrogate of the volume as described in this review. This work was subsequently repeated and used a cut-off of 35 mm which was studied in two prospective series.[17,18] The first of these trials in 2015 by Cropano et al.[17] tested the 35-mm rule on 165 pneumothoraces and found that the 35-mm rule had a negative predictive value of 95.7% with an area under the receiver operating characteristic curve of 0.90 to predict successful observation of a PTX. Subsequently in 2019, Eddine et al.[18] tested the 35-mm rule in 257 patients with either blunt and penetrating traumatic pneumothoraces as a cutoff for observation. Again, they found the cutoff had a 90.8% positive predictive value to predict successful observation and that a PTX of 35 mm or less was an independent predictor of successful observation for both blunt and penetrating trauma. Of note, a large retrospective American Association for the Surgery of Trauma Multi-Institutional trial done by Moore et al.[19] did not find a correlation between size and the need for a chest tube; however, again, there was no standardized approach to PTXs across institutions. This may have led to a number of chest tubes being unnecessarily placed for small PTXs.

Algorithm: See Figure 1

(A) Identification of Pneumothorax and Physiology

Once the PTX is diagnosed by chest x-ray, chest CT scan, or ultrasound, the cardiopulmonary status of the trauma patient is evaluated. Of note, the PTXs may be either overt or occult. This algorithm applies to both types of pneumothoraces. The condition of the patient is determined by a combination of hemodynamic and physiologic measurements. If deemed to have abnormal physiology and that the instability is a result of a PTX, the PTX should be drained. The definition of abnormal physiology was debated as there is a spectrum of abnormality. Suffice it to say that if the patient demonstrates persistent tachycardia greater than 120 bpm, tachypnea greater than 30 bpm, systolic pressure less than 90 mm Hg, or base deficit greater than 4, there is little debate that the patient is unstable and will benefit from intervention. Often, it is unclear whether the physiologic instability is the direct result of the PTX, and in these circumstances, it is safer to treat the PTX with a drain. However, in those with a small, that is, less than 1 cm on CXR or less than 10 mm on CT scan, the impact of the PTX on the patient's physiology is likely negligible.

(B) Immediate Drainage Indicated

Prophylactic antibiotics are suggested based on randomized controlled trials and a recent 2019 meta-analysis that demonstrated a decrease in empyema (1% vs. 7.2%) and pneumonia (4.4% vs. 10.7%) in those randomized to prophylaxis.[20] This confirmed another meta-analysis in 2006 that also found a decreased incidence of empyema and pneumonia with the use of antibiotic prophylaxis for chest tube insertion.[21] The committee thought that the timing of the antibiotic is ideally given prior to the insertion of the chest tube based on prophylactic antibiotic guidelines for other surgical procedures; however, placement of the tube should not be delayed in those patients who may have cardiopulmonary compromise from the pneumothorax. The duration and type of antibiotics is unclear but there does not seem to be a difference between those randomized trials with 24 hours versus longer duration. The effect of the antibiotic if given after the procedure is debatable, but at this time, we recommend giving the dose either prior to or as soon as possible postprocedure. In situations where the vital signs of the patients are significantly deteriorating, it is acceptable to perform a finger thoracostomy. A needle decompression may be performed; however, because of the variable success of needle thoracostomy, a finger thoracostomy is the preferred method for rapid decompression. This is always followed by insertion of a chest tube.

The size of the drain used has evolved over the last decades. Inaba et al.[22] demonstrated no difference in performance between smaller chest tubes (28–32 Fr) when compared with larger chest tubes (36–40 Fr). In addition, Kulvatunyou et al.[23] published a randomized trial using 14-Fr pigtail catheters for PTXs and found no difference in ability to drain the PTX and better pain scores in those with pigtail catheters. Therefore, the smallest caliber chest tube on-hand should be used; however, it is recommended that a thick-walled tube is used rather than a small-caliber thin-walled argyle tube. This limits the degree of kinking and twisting associated with smaller diameter tubes. However, because of the emphasis in the randomized trial on uncomplicated traumatic pneumothoraces, if there is a significant component of hemothorax, one may consider a larger (28Fr) chest tube. Many institutions are now using pigtails for hemothoraces as well, and this is discussed in the WTA hemothorax algorithm.

(C) Hemodynamically Normal Patient and Pneumothorax

In patients without hemodynamic compromise a more objective measure of the PTX should be made to guide the decision to drain. If the PTX is greater than 20% of the chest volume on chest x-ray, which some have advocated is associated with approximately 2 cm distance from the chest wall or if the measurement on CT scan is greater than 35 mm, a drain should be empirically placed. It is important to note that the line drawn to measure the PTX on chest CT scan is a radial line drawn perpendicular to the chest wall of the largest air pocket, see Figure 3 as an example. However, if the PTX is less than 35 mm or 20% volume, then it is safe to observe recognizing that approximately 10% of these patients will fail observation.[17] There does not seem to be any difference in failure rates for those on positive pressure ventilation or those with penetrating versus blunt mechanisms, and therefore, the committee consensus was that ventilated patients may be observed as well if stable. All patients who are observed must have a follow-up imaging performed, typically a chest x-ray within 6 hours and repeated as needed. Some have advocated that pneumothorax resolution or expansion can be monitored with ultrasound,[24] but currently, the literature is vague. Therefore, we currently recommend chest x-ray for follow-up imaging. If there is minimal expansion on follow-up x-rays, one should continue to use the algorithm to guide the decision to place a drain or not. It should be noted that those in low resource situations or who require prolonged transport times or those who are unable to be monitored closely, that is, a patient prone for many hours for a spine fixation soon after arrival, one should consider a chest tube placed prophylactically in those situations.

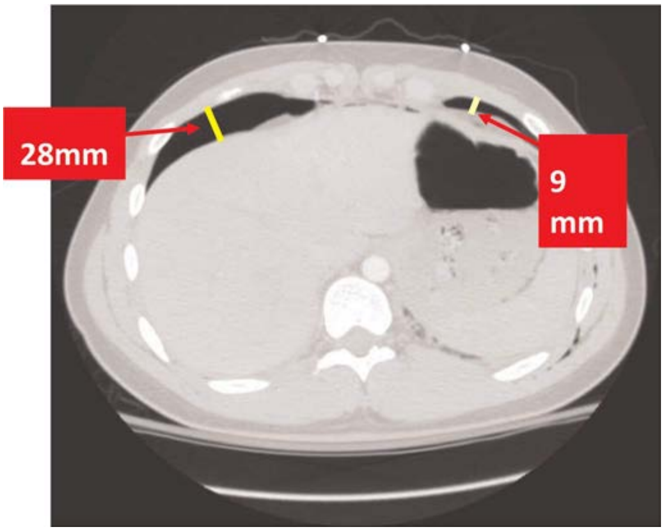

Figure 3. Measurement of pneumothorax on chest CT scan with a line in the largest air pocket on axial imaging drawn perpendicular or radial to the chest wall.

TABLE 1. Knowledge and Research Gaps Related to Management of Traumatic Pneumothorax

Topic or Research Gap	Algorithm Section
(1) Physiologic impact of size of pneumothorax	A
(2) Whether penetrating mechanisms should be managed differently than pneumothoraces from blunt mechanisms	A
(3) Timing and duration of prophylactic antibiotics	B
(4) How to objectively measure pneumothorax on chest x-ray or ultrasound/reliability of ultrasound to detect and quantify PTX	B
(5) Type of small-bore catheter used for drainage (pigtail vs. straight)	B, C
(6) Value of more specific volumetric measurements on CT scan	B, C

AREAS OF CONTROVERSY AND EXISTING KNOWLEDGE/RESEARCH GAPS

It is also important to note that there are many areas of this algorithm that lack high-quality evidentiary support and where further focused research is required. Table 1 provides a list of the most important specific topics or existing research gaps related to this topic that were identified by the authors during the development of this algorithm.

A. There is often ambiguity regarding the pneumothorax's impact on the patient's physiology because there are often many reasons for the patient to be compromised. One pitfall is to attribute the patient's compromised condition to the PTX while failing to recognize other causes of hemodynamic instability such as occult hemorrhage.
B. In sections B and C, there was debate regarding the use of prophylactic antibiotics, but after careful review of the literature, it appeared that there was sufficient evidence to suggest benefit. In 2004, Maxwell et al.[25] performed a multicenter trial exploring the impact of the use of prophylactic antibiotics to prevent empyema. They studied 224 patients and found no difference in incidence of empyema. However, since this 2004 study, as referenced above, there have been a number of randomized trials, 12 total that were reviewed and a meta-analysis done that suggested a benefit in the use of prophylactic antibiotics. However, the optimal dosing and schedule remains an area of debate, with the majority supporting either single-dose periprocedural prophylaxis or a 24-hour duration. The available evidence clearly supports no benefit of antibiotics beyond 24 hours for routine chest tube placement.

There was debate regarding the perceived differences between penetrating and blunt mechanisms and little evidence to guide recommendations. However, a trial referenced above demonstrated no appreciable difference between the two mechanisms in pneumothorax extension but more study is needed. There was general agreement about the need to use some sort of objective measure of the pneumothorax to guide decision making. The most contemporary measure is the 35-mm rule but is limited to those with CT scans. The volumetric measurements on chest x-ray do not exist because of the highly variable nature of imaging on x-ray due to patient positioning and angle to chest. However, there was debate about the use of size criteria alone versus the presence of absence of any associated symptoms, such as chest pain, tachypnea, shortness of breath, or desaturations.

The exact cutoff values to define signs or symptoms indicating a physiologic impact of the pneumothorax were debated among the committee members. Because there have been no high-level studies that have identified exact definitions for factors, such as tachycardia or tachypnea related to a symptomatic pneumothorax, and in recognition that these changes will vary greatly between patient populations, we selected commonly used cutoff values including heart rate greater than 120 beats/minute and respiratory rate greater than 30 bpm. The committee also agreed that these should be used as guidance parameters and not as exact or inflexible criteria to define symptomatic versus not symptomatic.

SUMMARY AND CONCLUSIONS

Pneumothoraces are common following trauma and require an objective approach. Using a more objective measure will help to guide the practitioner. The use of smaller bore chest tubes has been well established for PTXs, and the presence of a small hemothorax was thought to not have any bearing on type of tube to be used. There are many areas of controversy that remain and will require ongoing investigations. However, the literature and this algorithm strongly support an individualized approach, the avoidance of routine large-bore chest tube placement for simple PTX, and the safety and efficacy of observation only for select patients based on clinical symptoms and PTX size.

AUTHORSHIP

All authors meet authorship criteria for this article as described below. All authors have seen and approved the final article as submitted. The senior author (M.dM.) had full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. M.dM., C.V.R.B., K.I. participated in the conception and design. M.dM., M.J.M., C.V.R.B. participated in the acquisition of data. M.dM., M.J.M., E.E.M., K.A.P., and E.J.L. participated in the analysis and interpretation of data. M.dM., M.J.M., and K.I. participated in the drafting of the article. M.dM., J.S., A.G.R., N.G.R., J.A.W., J.L.H. participated in the critical revision of the article. M.dM. E.E.M. participated in the statistical expertise. M.dM. participated in the administrative, technical, or material support. M.dM., M.J.M., and K.I. participated in the supervision.

DISCLOSURE

The authors declare no conflicts of interest.
The results and opinions expressed in this article are those of the authors, and do not reflect the opinions or official policy of any of the listed affiliated institutions, the United States Army, or the Department of Defense.

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