# Prevalence of Tension Pneumothorax in Fatally Wounded Combat Casualties

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**Background:** Tension pneumothorax is a potential cause of death in victims of penetrating chest trauma, but little is known about its actual prevalence.

**Methods:** Data that are part of the Vietnam Wound Data and Munitions Effectiveness Team study were analyzed to address this question. Radiographs of 978 casualties were examined for evidence of tension pneumothorax using standard radiologic criteria such as pleural separation, displacement of the mediastinum and diaphragm, trachea deviation, and compression of the contralateral lung

**Results:** Some or all of the radiographic changes were found in 198 casualties. Autopsy evidence indicated that 79 of these casualties died solely due to a chest wound. The fatal chest injury involved only the lungs in 55 casualties and caused a tension pneumothorax in 26. Fifteen of the 26 lived long enough to receive first aid from a medic or corpsman.

**Conclusion:** Tension pneumothorax was the cause of death in 3 to 4% of fatally wounded combat casualties. Some may be temporarily helped by battlefield thoracentesis.

**Key Words:** Tension pneumothorax, Penetrating chest wound, Thoracentesis, Trauma.

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Although tension pneumothorax is a recognized cause of death in victims of penetrating chest trauma, important epidemiologic data such as its prevalence are poorly documented. To some extent, the lack of data arises from the difficulty of diagnosing tension pneumothorax. Ideally, correlating circulatory parameters such as cardiac filling pressure and systemic oxygen delivery with pleural pressure would be diagnostic, but such physiologic measurements are hardly possible outside of an experimental laboratory. In living casualties, escape of air under pressure during needle thoracentesis followed by immediate relief of symptoms is presumptive evidence of tension pneumothorax but would need to be performed upon every victim of chest trauma to capture all cases of tension pneumothorax. This is hardly possible and in an attempt to limit the potential population, recourse is made to focusing on such clinical findings as respiratory and circulatory collapse. Unfortunately, they are nonspecific, whereas those that are more specific (such as tracheal deviation and a tympanic hemothorax) are inconstant. Pathologic diagnosis even in the dead is difficult unless special precautions are employed when performing an autopsy. Chest radiographic findings of a radiolucent pleural separation with significant mediastinal displacement and hemidiaphragmatic depression are accepted by radiologists as being indicative of tension pneumothorax, but, in most casualties, the need for immediate intervention precludes obtaining one.[1]

Thus, considerable doubt exists on the prevalence of this eminently treatable condition. Routine chest radiographs before autopsy of dead chest trauma victims might give some insight into the epidemiology of tension pneumothorax. Although we are not aware that such a policy has ever been implemented in civilian trauma practice, there is a unique military database that dates from the Vietnam War in which this was done. The Wound Data and Munitions Effectiveness (WDMET) study of 1967 to 1969 was chartered to evaluate the effectiveness of then-modern munitions and, in the process, collected detailed information regarding the circumstances and cause of injury for 7,801 American casualties. Of these, 1,151 casualties were classified as being killed in action. Chest radiographs were routinely taken before autopsy as part of the WDMET protocol.[2] Herein, we report our experience using the WDMET database to estimate the prevalence of tension pneumothorax in combat dead with penetrating chest injuries.

## METHODS

All radiograph material in the WDMET database was inspected for readable chest radiographs. Readability was defined as: 1) absence of fixation artifacts that might be mistaken for the visceral pleura, 2) absence of gross rotation

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**Table 1** Criteria for Quantitating Tension Pneumothorax

| Maximum Pleural Separation from Chest Wall | Score |
|---|---|
| > 1, < 2 cm | +1 |
| 2 to 4 cm | +2 |
| > 4 cm | +3 |
| **Mediastinal Shift as Indicated by Position of Right Heart Border Measured from Midline*** | **Score** |
| > 1, < 2 cm | +1 |
| 2 < 4 cm | +2 |
| > 4 cm | +3 |

* For right sided injuries; for left sided injuries, displacement is measured from 4.6 cm to the right of midline. 4.6 ± 1.8 cm was the mean and SD found between midline and the right heart border in 50 randomly selected casualties without significant chest injury. Thus a score of +3 indicates that the right heart border was 8.6 cm or > 4 SD from the mean. Tracheal deviation from Midline: no = 0, yes = +1. Displacement of ipsilateral diaphragm: no = 0, yes = +1. Compression of contralateral lung: no = 0, yes: crowding of vessels = +1, absence of aeration = +2

of the thorax as shown by midline symmetry of the vertebral bodies and the clavicular heads, and 3) absence of postmortem decomposition that had caused obliteration of tissue planes. Acceptable chest radiographs were qualitatively screened by a trained surgeon and an assistant for the presence of radiologic criteria of possible tension pneumothorax such as mediastinal displacement or marked separation of the visceral and parietal pleura. Mediastinal displacement was considered to be present when the right heart border was displaced across the vertebral column (right-sided lesions) or when the left heart border was in proximity to the vertebral column (left-sided lesions). Both screeners were blinded to clinical and autopsy records during this initial process.

Records of casualties whose radiographs showed some or all of the radiographic criteria for tension pneumothorax were studied to see if the fatal wound was indeed in the chest or whether other potentially fatal wounds of lethality similar to the chest injury were also present. These casualties were excluded. Autopsy records were further studied to see if the heart or great vessels were the site of the fatal chest wound. These casualties were excluded. Finally, in those casualties in whom records showed that the fatal injury was to the lungs, a distinction was made between casualties in whom the pleural space was opacified (suggesting hemothorax) or radiolucient (suggesting pneumothorax). A board-certified radiologist, blinded to clinical and autopsy results, then applied a quantitative grading system based on all available radiographic criteria to those casualties who may have died from tension pneumothorax (Table 1). The maximum score was 10.

The quantitative grading system was based upon the following radiographic criteria[1]:

1. An air collection in the pleural space
2. Displacement of the mediastinium to the contralateral side
3. Compression of the contralateral lung

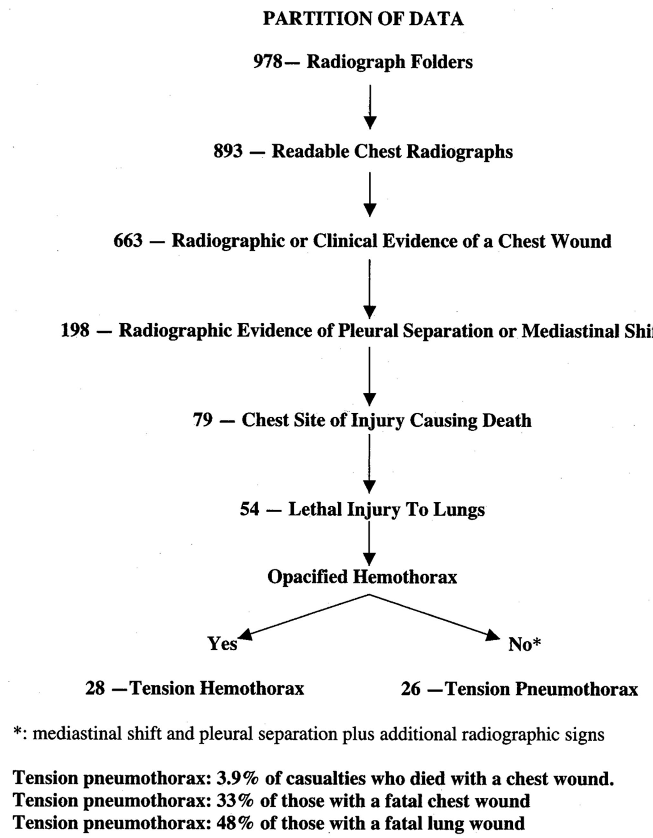


**Fig. 1.** *Schema for partitioning casualties used in this study.*

4. Depression of the ipsilateral diaphragm
5. Distension of the ipslateral hemithorax as shown by increased width of intercostal spaces
6. Displacement of the trachea to the contralateral side

To decide whether first aid specifically designed to treat tension pneumothorax would have been feasible, WDMET entries were accessed that gave specifics regarding the casualty's condition following wounding, the nature of the wounding agent (bullet or fragment from an explosive device), how long the casualty lived following wounding, and the presence or absence of actual field medical care.

## RESULTS

The WDMET database contains 978 radiograph folders, of which 893 had readable chest radiographs. All but a few of the radiographs were of fatally wounded casualty. We could find no description in the WDMET abstract volumes of the technique used to take the chest radiographs. It is unknown whether the radiographs were taken shortly after death or at the time of autopsy up to 4 days after death. We assume that the great majority are probably supine anteroposterior films. Occasional cross-table lateral films had been taken but were not found to be helpful in this study. In all, 663 of the 893 casualties had radiographic and/or clinical evidence of a chest injury. Our partition of causalities is shown in Figure 1.

**Table 2** Quantitative Assessment of Individual Casualties

| # | Separation* | | Mediastinal Shift† | | TD‡ | Diap§ | Comp¶ | Score |
|---|---|---|---|---|---|---|---|---|
| | cm | Score | cm | Score | Score | Score | Score | Total |
| 1 | 5 | +3 | 4 | +3 | +1 | +1 | +2 | +10 |
| 2 | 4 | +3 | 5 | +3 | +1 | +1 | +1 | +9 |
| 3 | 4.5 | +3 | 4.5 | +3 | +1 | +1 | +1 | +9 |
| 4 | 5 | +3 | 4 | +3 | +1 | +1 | +1 | +9 |
| 5 | 4.5 | +3 | 3 | +2 | +1 | +1 | +1 | +8 |
| 6 | 5 | +3 | 5 | +3 | +1 | +1 | 0 | +8 |
| 7 | 3 | +2 | 3 | +2 | +1 | +1 | +2 | +8 |
| 8 | 10 | +3 | 5 | +3 | +1 | +1 | 0 | +8 |
| 9 | 5 | +3 | 4 | +2 | 0 | +1 | +2 | +8 |
| 10 | 3.5 | +2 | 5 | +3 | 0 | 0 | 0 | +5 |
| 11 | 6 | +3 | 4.5 | +3 | 0 | +1 | 0 | +7 |
| 12 | 6 | +3 | 3 | +2 | +1 | +1 | 0 | +7 |
| 13 | 5 | +3 | 5 | +3 | 0 | +1 | 0 | +7 |
| 14 | 3 | +2 | 3 | +2 | +1 | +1 | +1 | +7 |
| 15 | 6 | +3 | 4 | +3 | 0 | +1 | 0 | +7 |
| 16 | 6 | +3 | 3 | +2 | 0 | +1 | +1 | +7 |
| 17 | 9 | +3 | 2 | +2 | 0 | +1 | 0 | +6 |
| 18 | 4 | +3 | 3 | +2 | 0 | +1 | +1 | +6 |
| 19 | 2 | +2 | 1.5 | +1 | 0 | +1 | +2 | +6 |
| 20 | 2 | +2 | 3 | +2 | 0 | 0 | +1 | +6 |
| 21 | 6 | +3 | 4 | +3 | 0 | +1 | 0 | +6 |
| 22 | 4 | +2 | 2 | +2 | +1 | +1 | 0 | +6 |
| 23 | 4 | +2 | 5 | +3 | 0 | 0 | 0 | +6 |
| 24 | 4 | +2 | 3 | +2 | +1 | 0 | 0 | +5 |
| 25 | 6 | +3 | 3.5 | +2 | 0 | 0 | 0 | +4 |
| 26 | 3.5 | +2 | 2 | +2 | 0 | 0 | 0 | +4 |

*Maximum separation of visceral pleura measured from the inside of the chest wall.
†Maximum displacement measured from midline of the spine to right heart border.
‡Tracheal displacement.
§Abnormal position of diaphragm; e.g., depression of right hemidiaphragm compared to left.
¶Crowding of vessels in contralateral lung; infiltration of portion of contralateral lung.

In total, 198 casualties had radiographs that showed mediastinal displacement and/or pleural separation. We found no evidence of mediastinal displacement in the absence of pleural separation. The converse was not true because pneumothorax without mediastinal displacement was occasionally observed. Not included in this group were four casualties whose radiographs were complicated by postoperative changes.

The WDMET autopsy reports that are part of the clinical files on each casualty indicated that in 79 casualties the fatal injury had occurred in the thorax. In the remainder, the thorax injury coexisted with a fatal injury in another part of the body. The Abbreviated Injury Scale (AIS 90) classification was utilized to exclude casualties with coexisting fatal injuries.[3] Most often, the coexisting injury was to the brain, a fact confirmed by the large number of radiograph folders that, in addition to the chest film, contained radiographic evidence of a severe head wound.

Autopsy reports indicated that the fatal chest injury involved the heart and/or great vessels in 25 casualties. The actual number of fatal heart or great vessel wounds was greater because radiographs of such casualties did not necessarily show evidence of mediastinal displacement or even gross hemothorax.

Of the remaining 54 radiographs, all of which showed both marked mediastinal displacement and pleural separation in addition to other radiographic findings of tension pneumothorax, we found that in 28 the pleural space was opacified, suggesting the presence of a hemothorax. In the remaining 26 files, the pleural space was radiolucent, suggesting that air was present. In six of the latter casualties, the chest radiograph had a hazy appearance probably indicative of blood in addition to air. Air fluid levels, however, were not seen, a fact consistent with our interpretation that the radiographs were taken with the casualty in a supine position.

One-half of the 26 radiographs showed air in the soft tissue external to the rib cage. However, in all but two instances, the amount of air was minuscule. In the two casualties in whom significant collections of air were seen outside of the pleural space, the injury was due to a destructive wound of the shoulder in which the bullet continued into the pleural space. They were the only casualties in which the anatomy suggested an open sucking chest wound. Eighty percent of the wounds were created by military small arms.

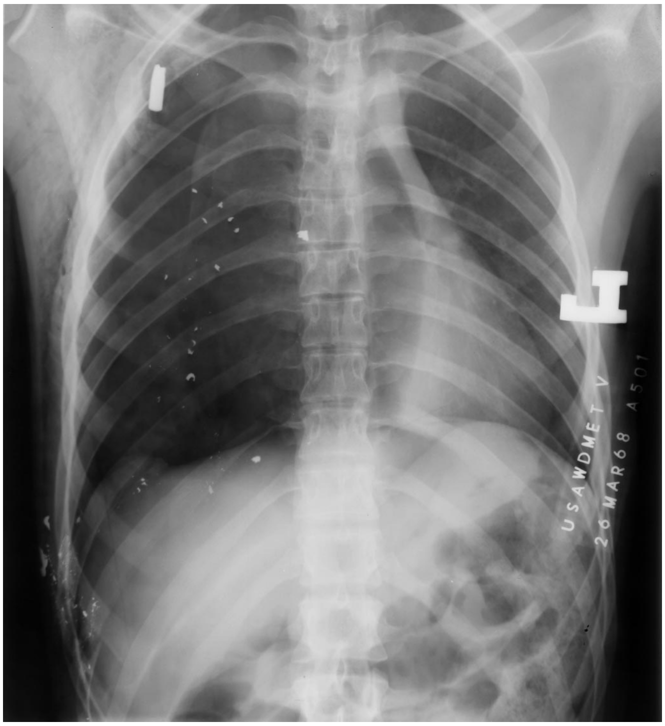


**Fig. 2.** *Fatal tension pneumothorax in a casualty who had a bullet wound of the right side of the chest.*


**Fig. 3.** *Fatal tension pneumothorax in a casualty who had a thru-and-thru gunshot wound of the right lung.*

An expected finding was that all of the bullets injured peripheral lung and not the hilum.

Table 2 shows the results of applying the grading system of Table 1 to the 26 casualties that we believe died of a tension pneumothorax. Scores range between 4 and 10 with a mean of 6.6 and a median of 7.

WDMET casualty records also include witness or chain of command statements detailing circumstances of how the casualty was wounded. WDMET clinical records typically had two or more entries concerning the immediate consequence of wounding (casualties behavior), what care was provided in the battlefield, and if and when evacuation from the battlefield took place. On the basis of these data, we can state that 15 casualties received first aid from a medic/corpsman and/or were evacuated by helicopter and three casualties were clinically dead before the arrival of a medic. Data were absent or contradictory in eight of the 26 casualties (e.g., casualty died "immediately" compared with "casualty lived 1–3 hours"). First aid usually consisted of dressing the wound, but in three instances mouth-to-mouth resuscitation was carried out. No instance of needle decompression was recorded. Only two casualties were reported as being in respiratory distress: one was recorded as saying "I think I have a punctured lung," whereas the second was said to be "breathing heavily."

Representative radiographs showing the spectrum of our findings together with clinical data are shown in Figures 2 to 5. Only the first two casualties are included in the 26 who were assumed to have had a treatable tension pneumothorax.

In Figure 2, mediastinal displacement and a substantial pneumothorax are obvious as is displacement of the right hemidiaphragm. The bullet fragmented after striking the casualty. The bullet entered through lower right chest wall at the mid-axillary line and penetrating through the liver, diaphragm, and lung. After wounding he crawled to a protected area where an armored personnel carrier shielded him. He received first aid but was described as being in a coma 20 minutes after being wounded. Autopsy showed 550 mL of blood in the right hemithorax and 100 mL of blood in the abdominal cavity. Using the scoring system shown in Table 1, we calculate a score of 8 for this casualty.

In Figure 3, mediastinal displacement and a substantial pneumothorax are obvious as is displacement of the trachea but not the right hemidiaphragm. Separation of the ribs on the side of injury appears to be increased. The bullet entered through right anterior chest wall in the first intercostal space, after which it perforated through the right upper and lower lobes before exiting posterior above the diaphragm where it fractured several ribs. The casualty was initially unconscious but regained consciousness 3 to 4 minutes after being wounded. He was evacuated shortly afterward but was pronounced dead upon reaching a Medical Company. Autopsy revealed "right hemo-pneumothorax" but the volume of blood was not recorded. Using the scoring system shown in Table 1, we calculate a score of 5 for this casualty.

In Figure 4, mediastinal displacement and a substantial pneumothorax are obvious as is displacement of the right

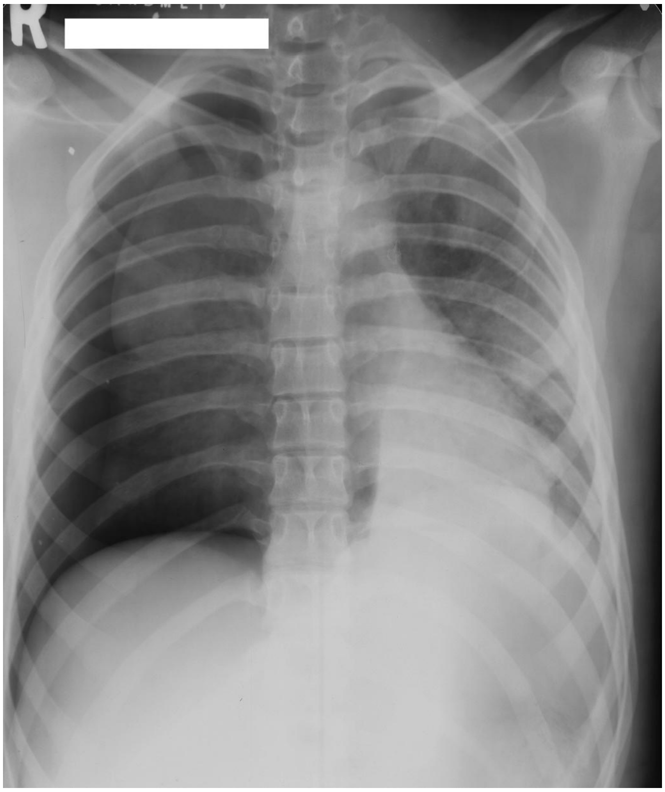

**Fig. 4.** *Tension pneumothorax in a casualty who sustained multiple fragment wounds including a fatal wound of the brain.*

hemidiaphragm. He was struck by multiple fragments from an explosive devise in the head, right side of chest and legs. After wounding, the casualty was noted to be kicking and yelling. After 20 to 25 minutes, he became unconscious. He died after evacuation to a medical treatment facility. Autopsy showed fragment wounds of the temporal and parietal lobes with extension into the third ventricle. No mention is made of a thoracic injury. Using the scoring system shown in Table 1, we calculate a score of 7 for this casualty.

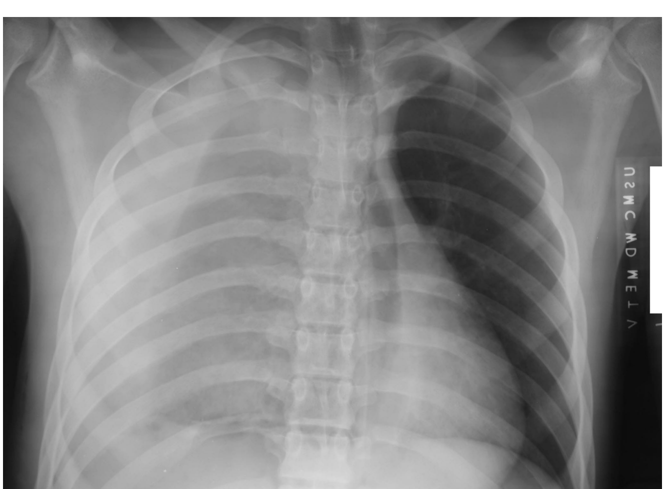

**Fig. 5.** *Fatal tension hemopneumothorax in a casualty who had a bullet wound of the right side of the chest.*

In Figure 5, there is obvious displacement of the mediastinum, trachea and diaphragm. The bullet entered the right lower chest and exited though the right flank. A corpsman arrived within 30 seconds. The casualty became unresponsive 5 minutes after being wounded and did not improve when given mouth-to-mouth resuscitation. In all, 3600 mL blood was measured in the right hemithorax at autopsy. There was an extensive laceration of the right lung.

## DISCUSSION

We are aware that using postmortem chest radiographs for diagnostic purposes is fraught with the possibility of errors arising from artifacts. Unfortunately, little is known about what is a “normal” chest radiograph in a corpse and how it changes with time after death. We are aware of only one published study in which post-mortem radiographs were used to diagnose tension pneumothorax.[4] Of note is the fact that the authors, who are pathologists, did not comment on the possible presence of artifacts in these postmortem chest radiographs. We believe that is reasonable to assume that, given a casualty who died shortly after receiving a penetrating chest wound, who had radiographic evidence (albeit postmortem) of a tension pneumothorax, and whose autopsy shows no evidence of another fatal wound, death was due to a tension pneumothorax.

We attempted to the explore our argument that the radiographic changes observed were probably real rather than artifactual by looking for additional radiographic findings of tension pneumothorax and then combining all findings into a quantitative assessment tool (Table 1). The rationale for the individual components is as follows. Clearly, primacy must be given to the combination of air in the pleural space in association with mediastinal displacement to the contralateral side. The latter phenomenon correlates most closely with the potentially fatal pathophysiology. From one to three points were awarded for the both the magnitude of the pleural separation and the magnitude of mediastinal displacement. We judged these findings more reliable than ipsilateral diaphragm depression because we were evaluating supine radiographs. Compression of the contralateral lung is also likely to be an important determinant of outcome since it may correlate with residual pulmonary function. We recognized two degrees of contralateral lung embarrassment: compression of vessels (+1) and lack of aeration of peripheral lung (+2). Indices such as tracheal and diaphragmatic displacement are mechanical correlates of rising pressure in the ipsilateral hemithorax. We used only a qualitative assessment (present or absent). Recognizing separation of the ipsilateral ribs was difficult to apply because of the rib fractures and probable splinting premortem of the chest wall. We recognize that this scoring system may or may not be applicable to living victims with tension pneumothorax and that any predictive value of its individual components will be necessarily dependent upon a prospective study in which the diagnosis of tension pneumothorax can be established with certainty.

As we previously stated, the prevalence of tension pneumothorax in a population of victims of chest trauma is unknown.

If the reported need for needle or tube decompression in the prehospital setting is any indication, it is probably no more than 5%.[5–7] The WDMET database states that 1.2% of casualties seen alive at the hospital level with penetrating chest wounds complained of respirator distress and some of these may have had a tension pneumothorax (an addition 2.7% had "shortness of breath" due to an injury to the chest wall).[8] A World War II report cites a figure of 0.9% for tension pneumothorax and suggests that even this number may be too high.[9] A more relevant recent observation indicates that the prevalence of pneumothorax in patients who died in a hospital was 2.2% with evidence of tension being present in one-half of these deaths.[3] These data were collected by taking radiographs before autopsy. The etiology in most cases was ventilator barotrauma or from rib fractures associated with cardiopulmonary resuscitation. These data applies to hospitalized patients, whereas this paper addresses the related topic of how many victims of chest trauma might have died before reaching medical care.

Assuming that the changes observed by us were indeed real and not artifactual, we calculate that approximately 3 to 4% of fatally wounded casualties recorded in the WDMET database died from or with a tension pneumothorax. Some of these casualties had a potentially treatable injury. Of course, treating a pneumothorax is no guarantee of ultimate survival. For instance, the air leak may be from a laceration of the tracheobronchial tree that requires emergent surgical control for successful management. Nevertheless, decompression of a tension pneumothorax might allow survival long enough for evacuation of the casualty to a medical facility capable of providing the needed care.

The number of treatable casualties seems small but it should be appreciated that we have excluded an unknown number of casualties who died with tension pneumothorax but also had other fatal conditions. Furthermore, the number who died of tension pneumothorax needs to be placed in the context of the total population of potentially salvageable casualties who were killed in action. Most fatally wounded casualties (perhaps 80–85%) have injuries of such severity that no current lifesaving battlefield intervention offers any realistic hope of being successful. In addition to tension pneumothorax, only casualties who have fatal exsanguination from an extremity wound or those who suffocate from a facial or neck wound are likely candidates for life saving battlefield first aid. Perhaps 10% of dead casualties recorded in the WDMET database were theoretically treatable by control of exsanguinating hemorrhage from a peripheral site.[10] Given that adverse battlefield conditions would prevent care being given in at least one-half of these casualties, a realistic assessment would be that 5% of the dead might have been effectively treated. The number of casualties who die primarily because of upper-airway obstruction is much smaller—probably less than 1% (we found only one casualty in this study who clearly died because of such an injury). Thus, perhaps one-third of the potential for lifesaving first aid could be realized by emergency treatment of tension pneumothorax.

How best to initially treat a tension pneumothorax on the battlefield cannot be decided here. Nor can we address aspects of training of field medical personnel or even whether formal training to recognize and to treat tension pneumothorax is a valid option. Needle thoracentesis would certainly be the easiest treatment option, although we are aware of reports indicating that success is critically dependent upon needle length in relation to chest wall thickness.[11] Life-threatening complications such as massive hemorrhage have also been reported with needle thoracentesis.[12] Perhaps the use of the fifth intercostal space anterior mid-axillary line rather than the more standard second intercostal space midclavicular line needs to be considered. Tube thoracostomy, although much more likely to be successful, is not an attractive option outside of a medical treatment facility. The establishment of indications for needle thoracentesis is needed for treatment of combat casualties with penetrating chest trauma. We believe that the criteria might include these: a decompensating victim of penetrating chest trauma with a peripheral site of injury in the chest wall and the absence of a serious head wound. We are aware that although such an approach might have a useful degree of sensitivity, its application would be associated with a vast number of false-positive results.

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