Chest Wall Thickness in Military Personnel: Implications for Needle Thoracentesis in Tension Pneumothorax

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Abstract

Needle thoracentesis is an emergency procedure to relieve tension pneumothorax. Published recommendations suggest use of angiocatheters or needles in the 5cm range for emergency treatment. Multidetector computed tomography scans from 100 virtual autopsy cases were used to determine chest wall thickness in deployed male military personnel. Measurement was made in the second right intercostal space at the midclavicular line. The mean horizontal thickness was 5.36cm (SD = 1.19 cm) with angled (perpendicular) thickness slightly less with a mean of 4.86cm [SD 1.10cm). Thickness was generally greater than previously reported. An 8cm angiocatheter would have reached the pleural space in 99% of subjects in this series. Recommended procedures for needle thoracentesis to relieve tension pneumothorax should be adapted to reflect use of an angiocatheter or needle of sufficient length.

Introduction

Advanced Trauma Life Support guidelines and combat casualty care doctrine recommend the use of needle thoracentesis (needle thoracostomy) for the emergency treatment of tension pneumothorax. The second intercostal space in the midclavicular line is the preferred location.[1] For successful placement, the angiocatheter (or needle) must be of sufficient length to pass through the chest wall and enter the pleural space. However, if the angiocatheter is too long, it may puncture the lung.

McPherson et al.[2] estimate that tension pneumothorax was the cause of death in 3% to 4% of fatally wounded combat casualties in the Vietnam War. In the study of a continental U.S. military trauma center population, Givens et al.[3] reported computed tomography (CT) measurements of chest wall thickness and concluded that a 5cm catheter would reliably penetrate the pleural space in only 75% of patients. Since these data may not be valid in combat zone casualties, a study of chest wall thickness in a forward-deployed tri-service population was undertaken through the retrospective analysis of multidetector CT (MDCT)-assisted autopsies performed on combat casualties at the Armed Forces Institute of Pathology.

Methods and Materials

The study was performed with the approval of the institutional review board of the Armed Forces Institute of Pathology and was compliant with the Health Insurance Portability and Accountability Act. The Armed Forces Medical Examiner Tracking System was used to identify a series of 124 consecutive military male trauma deaths that underwent total body MDCT scanning before complete autopsy at the Dover mortuary from January 2006 through March 2006. Twenty-one subjects were excluded from the study because the wounds sustained resulted in thoracic deformity that would alter measurement of the chest wall. In two cases, the images could not be retrieved. The final study population consisted of 101 male subjects (19 - 48 years of age: mean = 25.7 years). The subjects were servicemembers from the Army (*n* = 56), Marine Corps (*n* = 41), Air Force (*n* = 2), and Navy (*n* = 1).

Total body MDCT scans were obtained on a GE Lightspeed 16 (General Electric Medical Systems. Milwaukee, Wisconsin) within 2 to 4 days after death. Subjects were scanned with 16 x 5mm collimation, pitch 1.375:1. rotation speed of 0.6 seconds, and table speed of 27.5 mm/rotation, or with 16 x 5mm collimation, pitch 0.562:1, rotation speed of 0.6 seconds, and table speed of 11.2mm/rotation. No contrast material was administered. Images were retrospectively reconstructed at the CT console to a slice thickness of 1.25mm before being sent to a GE Advantage Workstation (software version 4.2: General Electric Medical Systems), images were viewed and measured on the workstation using two-dimensional axial, coronal, oblique, and sagittal data sets.

Chest wall thickness was measured in the right second intercostal space, midclavicular line, using a two-step process. Step 1 determined the clavicular and interspace location from a coronal multiple intensity projection (MIP) image reconstructed on the GE Advantage Workstation (Fig. lA). This point provided the location for measurement on a sagittal image linked to the

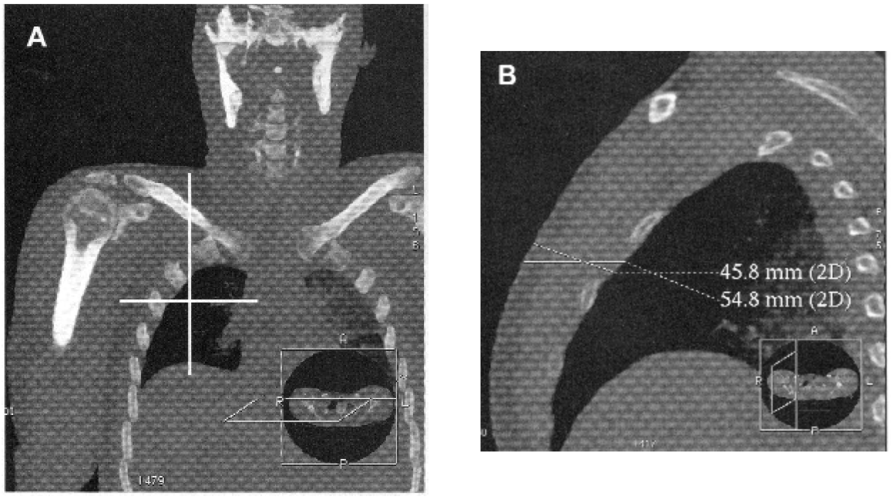

Figure 1. (A) Coronal MIP image of the upper thorax showing the right clavicular and anterior ribs. The intersecting lines show the location of the second intercostal space in the midclavicular line. (B) Linked sagittal image of the thorax at the point determined in (A). The horizontal measurement is indicated by a solid line: the angled (perpendicular) measurement is indicated by the dotted line.

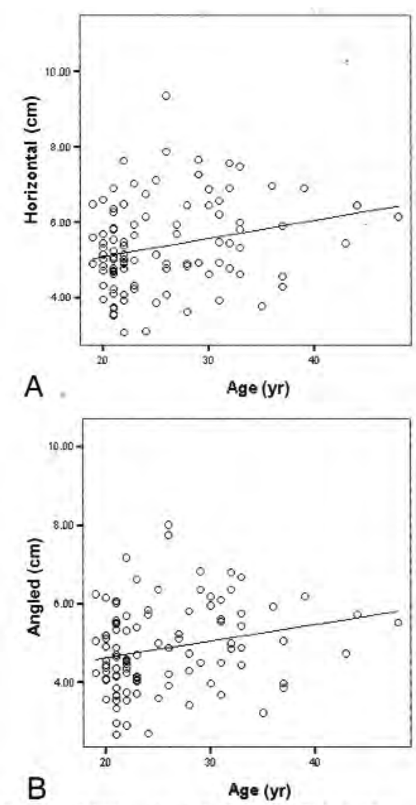

Figure 2. Chest wall thickness by age. (A) Horizontal, (B) Angled. Linear regression lines show the trend for each measurement to increase with age.

exact location on the coronal image. In step 2, linear distance software (two-dimensional) was used to make two measurements of chest wall thickness. A horizontal measurement was made in the mid-second interspace. The second measurement was done perpendicular to the chest wall and angled to pass above the third rib (Fig, 1B). Measurements are reported in millimeters to the nearest 0.1.

Statistical analysis was performed using SPSS for Windows (version 14,0: Chicago. Illinois). A scatterplot of horizontal versus angular measurement in the initial 101 cases revealed one outlier, which turned out to be an obese Navy sailor. All subsequent analysis was done excluding this individual: therefore, 100 cases are the basis for this report.

Results

Mean horizontal chest wall thickness was 5.36cm (SD = 1.19cm), with a range of 3.07cm to 9.35cm. The mean angled (perpendicular) thickness was 4.86cm (SD = 1.10cm), with a range of 2.66cm to 8.02cm. There was a statistically significant correlation of increasing chest wall thickness with age for both horizontal and angled measurements (Fig. 2). We were able to compare chest wall thickness between Army and Marine Corps subjects but had insufficient numbers for sailors and airmen. The mean horizontal thickness for Army subjects of 5.51cm was statistically different from the 5.1cm mean observed in Marine Corps subjects. The calculated confidence interval (0.72 - 0.89) was obtained using a (test for equality of means.

TABLE I

COMPARISON OF ANGLED AND HORIZONTAL MEASUREMENTS BY PERCENTILE

	Angled		Horizontal	
Percentile	Centimeters	Inches	Centimeters	Inches
2.5th	2.80	1.1	3.32	1.31
25th	4.08	1.6	4.62	1.82
50th	4.71	1.85	5.13	2.02
75th	5.67	2.23	6.19	2.44
97.5th	7.46	2.94	7.77	3.06

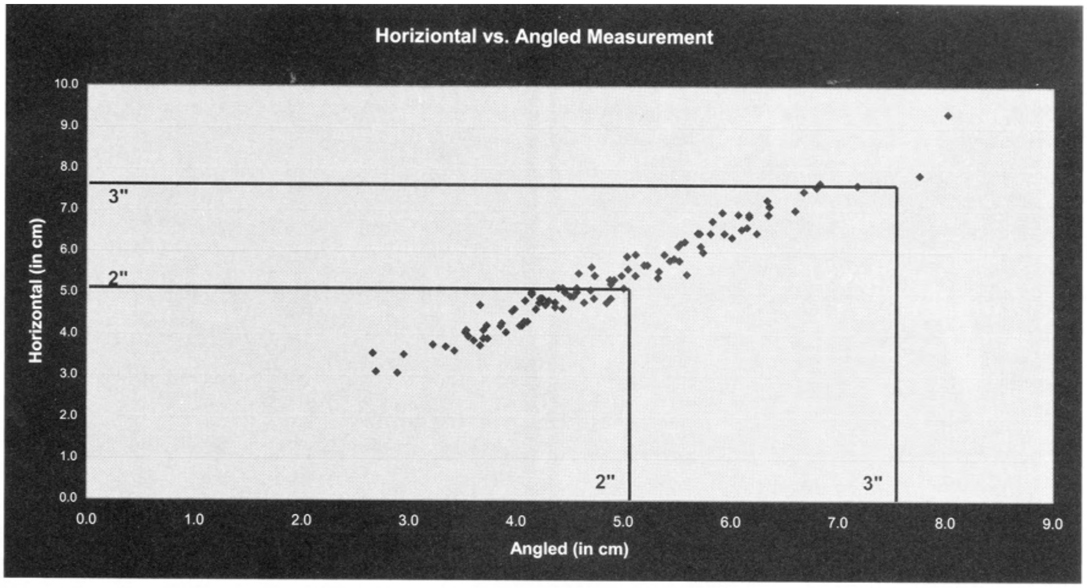

Figure 3. Plot of horizontal versus angled measurement in centimeters for the 100 subjects. Note that only 1 subject measurement exceeds 8.0cm. Note also that this presentation reflects the full range of lengths which would be encountered regardless of the angle of entry for needle decompression. It also indicates the consistent trend for both measures.

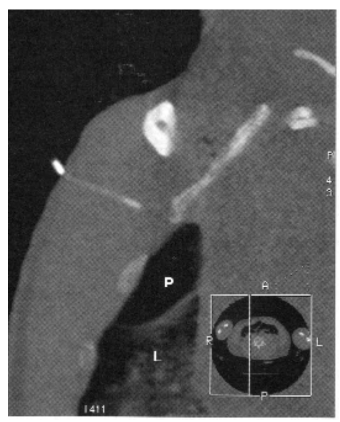

Figure 4. Sagittal MIP HDCT image of the right hemithorax obtained postmortem shows a needle thoracentesis catheter (arrow) that does not reach the pleural space. The needle thoracentesis was performed with a 5cm angiocatheter. Note that the catheter tip does not reach the anterior pneumothorax (P). Free air is anterior to the right lung (L).

When horizontal and angled measurements by percentile were compared, the horizontal measurement was always slightly greater than the angled measurement (Table 1). The angled measurement was <8.0cm in all 100 cases, and the horizontal measurement was <8.0cm in all but 1 case (Fig. 3).

Discussion

Emergency situations require a reproducible, simple, and effective response for treatment of life threatening pneumothorax. If needle thoracentesis is attempted with an angiocatheter or needle of insufficient length, the procedure will fail. Knowledge of chest wall thickness in the population being supported will enable addition and designation of appropriate cannulas to emergency bags for the procedure. Treatment sets routinely contain angiocatheters for vascular access, and these are usually 5cm (2in) in length. This is in keeping with the Advanced Trauma Life Support recommendations.[1] We have observed several cases where thoracentesis has been performed with these angiocatheters and the tips did not reach the pleural space (Fig. 4).

The medical literature contains several reports of chest wall thickness as the basis for angiocatheter selection. Britten et al,[4] used ultrasound to determine the chest wall thickness at the second intercostal space in 54 patients, ages 18 to 55 years. The thickness exceeded 4.5cm in only two patients (4%). In our military population, the mean chest wall thickness in two planes exceeded this value. This confirmed our expectation that males serving in a combat zone require a different standard. We suspected that military-age males in the Army and Marine Corps would exhibit greater-than-average chest wall thicknesses because they are a selected segment of the population in a field emphasizing strength and fitness.

The study by Givens et al.[3] used CT to determine thickness in 111 patients. Although the results were obtained in a military hospital, they reflect a mixed population of both men and women. Their mean chest wall thickness of 4.2cm is less than the mean chest wall thickness in our study. We know that the axial measurement technique used in their study does not differ from the sagittal technique we used because we validated our sagittal data by measuring the same point on a corresponding axial slice and found no difference. It is of note that women in their report had a mean chest wall thickness greater than men. This may reflect more subcutaneous fat in their female population. We also feel that increased subcutaneous fat explains the increase in chest wall thickness with increasing age that we observed in our series. In our study, the mean age for Marines was less than that for Army personnel. It is our opinion that these age differences in Army and Marines accounted for the thicker Army measurements and that the thickness was related to increased subcutaneous fat.

The recommended anatomic location to insert a needle thoracentesis catheter for emergency treatment of a pneumothorax is the second intercostal space at the midclavicular line.[1] When access to the second intercostal space midclavicular line is prevented by field conditions such as wound location, equipment, or position of the casualty, needle thoracentesis may need to be done at an adjacent location. The chest wall thickness may vary, but we have not observed appreciable increases at adjacent interspaces. Variation in catheter placement within an interspace may occur. Placing the needle closer to the superior margin of the third rib is optimal because the intercostal vessels run in a groove along the inferior aspect of each rib. Consequently, needle placement adjacent to the superior margin of the third rib minimizes the potential of vascular injury. We selected horizontal and angled measurements to determine if there was variability in needle distance based upon angulation. Inserting the needle perpendicular to the chest wall results in a slight inferior angulation and a shorter chest wall thickness. For emergency response in a combat zone, it is preferable to have a single angiocatheter available that will be effective in the majority of situations. This avoids the need to find and try multiple catheters or to apply a "rule-of-thumb" based upon parameters such as size and age. Britten et al.[4] recommend a 4.5cm length and Givens et al.[3] recommend a catheter longer than 5cm. Our results show that in a deployed military population, a 5cm angiocatheter under optimal conditions would have reached the pleural space in >50% of our subjects, and an 8cm angiocatheter would have reached the pleural space in 99% of our subjects. It is hoped that these data will assist military trauma surgeons in making an updated recommendation for the performance of needle thoracentesis.

Conclusions

Our study shows that chest wall thickness in deployed military personnel is generally greater than previously reported. Recommended procedures for needle thoracentesis to relieve tension pneumothorax should be adapted to reflect use of an angiocatheter or needle of sufficient length. An 8cm angiocatheter would have reached the pleural space in 99% of the cases in this series.

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