

The Relationship Between the Distance Between the Skin and the Pleura at the Level of the
Second Intercostal Space and Age, Sex, and Body Mass Index

Original Article

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ABSTRACT

Objective: The efficacy of standard cannula lengths (50 mm) in the management of tension pneumothorax (TP) remains a subject of debate. The objective of this study is to ascertain the skin-pleural distance (SPD) at the level of the midclavicular line in the second intercostal space (ICS) and to determine the relationship between this distance and age, gender, and Body Mass Index (BMI).

Materials and Methods This retrospective observational study encompassed 150 patients who underwent chest computed tomography (CT) scans. Consequently, CPM measurements were performed using both CT and ultrasound (USG) in two distinct arm positions (arms at the sides and above the head). The data were then subjected to a series of analyses that included categorizations based on age (i.e., young and old), gender, and VKE categories.

Findings: The sample included 58% male and 42% female participants, with an average age of 56.23 years. According to CT measurements, CPM was found to be significantly higher in women than in men ($p < 0.001$). While the CPM exceeded 50 mm in approximately 32–33% of female patients, this rate was only 2.3% in male patients. It was observed that the risk of procedural failure (CPM > 50 mm) increased as VKE increased. All ultrasound measurement methods demonstrated a positive and significant correlation with CT measurements. While a propensity for higher CPM was evident among the younger age group, no statistically significant disparities were observed between age demographics.

Conclusion: The utilization of standard-length cannulas is associated with an elevated risk of unsuccessful needle decompression, a phenomenon that is particularly salient in women, young patients, and individuals with high VKE. In women, the presence of breast tissue, which increases the distance, is a critical factor. In the domain of emergency medicine, the selection of material tailored to the specific needs of each patient is of paramount importance during TP interventions.

Keywords: Tension pneumothorax, needle decompression, distance between the skin and the pleura, computed tomography, ultrasonography

Introduction

Tension pneumothorax (TP) is a genuine life-threatening medical emergency that requires rapid diagnosis and urgent treatment. According to the prevailing clinical guidelines, the most commonly recommended method for the initial management of TP is needle decompression performed via a standard cannula inserted through the second ICS. The conversion of the pneumothorax to an open pneumothorax using this method is a rapid method of stabilizing the patient's hemodynamic status. It also provides critical time for definitive treatment via tube thoracostomy (1-3).

However, recent studies have begun to demonstrate that the efficacy of needle decompression employing standard cannulas can be compromised, particularly in certain individuals. The primary cause of this failure is the needle's inability to reach the pleural space, a situation that poses a direct threat to the patient's life. Therefore, it is imperative to select materials of the appropriate length, taking into account the patient's anatomical structure, to ensure optimal outcomes (4, 5).

However, the factors influencing the measurement of the distance between the skin and the visceral pleura at the second intercostal space using an ultrasound device have not been systematically investigated by emergency medicine physicians. The medical literature contains an insufficient amount of primary data regarding the potential effect of variables such as age, gender, and VKE on this measurement distance. The primary objective of this study is to determine whether the distance

between the skin and the visceral pleura at the level of the second intercostal space along the midclavicular line (mid-clavicle line) in supine individuals is associated with the patient's BMI, weight, height, gender, and age.

Materials and Methods

This study has a retrospective, observational, and single-center design. The study group consisted of patients who underwent chest computed tomography (CT) for any indication at Akdeniz University Hospital between August 1, 2016, and August 31, 2016. The study was conducted after obtaining approval from the relevant ethics committee. Inclusion criteria for the study were as follows: being 18 years of age or older, reading and signing the informed consent form to participate in the study, and not being intubated. Exclusion criteria were: failure to sign the informed consent form, being under 18 years of age, being pregnant, being on mechanical ventilation, and being in an unstable condition. An unstable condition was defined as a systolic blood pressure of less than 90 mmHg, a pulse oximeter reading of less than 90%, or being in a level of consciousness other than fully awake. A total of 150 patients were included in the study.

Measurement Procedures

The measurements obtained in this study were performed using the Sonoscape A6® ultrasound (USG) device and a linear probe. In order to standardize the USG and CT measurement sites, measurements were taken at a distance of 8 centimeters from the midclavicular line and the midline of the

sternum at the second ICS for each patient. This approach ensured a reliable comparison of the distance between the skin and the visceral pleura as measured by

ultrasonography (USG) and computed tomography (CT). As illustrated in Figure 1, the measurement methods employed in this study are as follows:



Figure 1: Ultrasound measurement: a: Ultrasound measurement with hands raised, b: Ultrasound measurement with hands lowered, c: CT measurement at the level of the midclavicular line in the second intercostal space

Ultrasound Measurement

Ultrasound measurements were performed on patients in two different supine arm positions: with arms at the sides and with arms raised above the head. The measurements were obtained by positioning a linear ultrasound probe over the second intercostal mid-clavicular line, with the probe oriented 8 centimeters to the right and left of the mid-sternal line. A gel pad was utilized, and distance measurements were recorded in B-mode without exerting excessive pressure on the probe. A comparison was made between the USG measurements and the CT measurements from the same patients.

Categorizing Data

Given that the standard cannula length utilized for needle decompression in routine medical practice and in cases of tension pneumothorax is 50 millimeters, subjects with a distance of 50 millimeters or more were designated as a distinct subgroup in

the measurements. The effect of patient age on study results was determined by classifying patients aged 65 and older as the elderly group, while those under 65 were classified as the young group. Furthermore, patients were categorized according to the World Health Organization (WHO) Body Mass Index (BMI) classification as follows: The following classification system is employed: underweight (0–18.4), normal (18.5–24.9), overweight (25–29.9), obese (30–34.9), and morbidly obese (over 35).

Statistical Analysis

The data obtained from the patients included in the study were entered into the SPSS 10.0 program for analysis. Frequency analyses were performed on the demographic data. The Kolmogorov-Smirnov test was employed to ascertain whether the ultrasound data, recorded in millimeters, followed a normal distribution. For data that did not follow a normal distribution, the Mann-Whitney-U test was employed, as it is a nonparametric test

designed to compare two hypotheses. For data that followed a normal distribution, the Student's t-test was used, as it is a parametric test for comparing two hypotheses. For both tests, a p-value of less than 0.05 was considered to be statistically significant.

Furthermore, correlation analyses were conducted to ascertain the relationship between ultrasound and computed tomography measurements. The Bland-Altman plot, a graphical method for comparing the two measurement methods (ultrasound and computed tomography), was also applied.

Results

A total of 150 patients were enrolled in this study at Akdeniz University Hospital during the specified time periods. Of the 150 patients enrolled in this study, 87 (58%) were male and 63 (42%) were female. The mean age of the patients was 56.23 years, with a standard deviation of ± 16 years, and the median age was 58.5 years. The descriptive findings are presented in Table 1. A comparative analysis was conducted on the distances measured from the participants' CT images according to weight and gender. The results of this analysis are presented in Table 2.

Table 1: Descriptives variables

	Variables
Age (Ort. \pm ss)	56,23 \pm 16
Sex	
Male	87 (58%)
Female	63 (42%)
Young – Elderly	
- Young 65 <	97 (%64.7)
- Elderly \geq 65	53 (%35.3)
Height (Ort. \pm ss)	164.90 \pm 7.1
Weight (Ort. \pm ss)	67.17 \pm 6.5

Table 2: CT measurement comperation

Variables	Group	n	mean \pm SD	p-Value
CT-Right	Normal	72,00	34,7 \pm 12,67	0,19
	Owerweight	78,00	37,5 \pm 13,42	
CT-Left	Normal	72,00	32,3 \pm 12,96	<0,001
	Owerweight	78,00	36,9 \pm 13,10	
CT-Right	Female	63,00	43,11 \pm 13,74	<0,001
	Male	87,00	31,26 \pm 10,11	
CT-Left	Female	63,00	37,7 \pm 14,01	<0,001
	Male	87,00	33,3 \pm 10,82	

A Spearman correlation analysis was performed to evaluate the relationship between different measurement methods of the distance between the skin and the pleura at the level of the second intercostal space, as well as the relationship between these measurements and computed tomography (CT) findings. The analysis results indicated a substantial correlation between all ultrasound (USG) measurement methods and both CT measurements and one another. A high-level, positive, and significant relationship was identified on the left side between the USG measurement taken with the hands in the up position and the USG measurement taken with the hands in the down position ($r=.826$, $p0.001$). A similar correlation was observed between USG

measurements obtained with the hands in the up and down positions on the right side ($r=.843$, $p0.001$). The right-side CT measurement exhibited a low-level, positive, and significant correlation with the USG measurement obtained on the left side in the hands-up position ($r=.232$, $p=.004$) and with the USG measurement obtained in the hands-down position ($r=.228$, $p=.005$). The left CT measurement demonstrated a weak yet positive and statistically significant correlation with the USG measurement on the left side with hands in the up position ($r = .209$, $p = 0.011$) and with the USG measurement with hands in the down position ($r = .191$, $p = 0.019$). This phenomenon is demonstrated in Table 3.

Table 3: Correlation analysis

Variable	1. Left USG, Arms Up	2. Left USG, Arms Down	3. Right USG, Arms Up	4. Right USG, Arms Down	5. Right CT	6. Left CT
1. Left USG, Arms Up	1.000	0.826 ^{**}	0.869 ^{**}	0.759 ^{**}	0.221 [*]	0.209 [*]
2. Left USG, Arms Down		1.000	0.822 ^{**}	0.860 ^{**}	0.228 [*]	0.191 [*]
3. Right USG, Arms Up			1.000	0.843 ^{**}	0.232 [*]	0.212 [*]
4. Right USG, Arms Down				1.000	0.200 [*]	0.156\$
5. Right CT					1.000	0.892 ^{**}
6. Left CT						1.000
N	150	150	150	150	149	149

USG = Ultrasonography; CT = Computed Tomography.

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Discussions

Thoracic trauma, a prevalent condition in emergency departments, encompasses a wide spectrum of severity, ranging from minor injuries to life-threatening conditions. Conventional chest X-rays have historically been the most prevalent diagnostic modality. However, numerous studies have indicated that pneumothorax may be overlooked on chest X-rays. Consequently, alternative diagnostic methods, such as ultrasound and CT scans, may be employed to address this potential oversight (6). The clinical utilization of ultrasound for the diagnosis of pneumothorax was initially documented by Wemecke et al. in 1987 (7). In 1992, Targhetta and colleagues reported two cases of pneumothorax that they had identified using ultrasound (8).

Recent studies have indicated that the use of standard cannulas for needle decompression has been unsuccessful in a subset of patients (9). A study on patients with multiple trauma revealed a 65% failure rate when a 3.2-centimeter needle was utilized, while a 4% failure rate was observed with the use of a 4.5-centimeter needle (10). A multicenter study conducted in Turkey has indicated that when a 5-cm catheter fails to reach the pleura and needle thoracostomy is necessary, selecting the fifth intercostal space along the anterior axillary line is a more reliable approach. This is attributed to the thinner chest wall thickness in this area. In a study by Yamagiwa et al., the distance between the skin and the pleura was measured at 3.06 ± 1.02 cm. This finding indicates that 94% of Japanese trauma patients could be treated with a 5-cm

catheter (11). In a study conducted by Melissa and her colleagues, the mean distance between the skin and the pleura was calculated to be 4.90 centimeters for women and 4.16 centimeters for men. Furthermore, the distance between the skin and the pleura was found to be greater than 5 centimeters in 25% of patients (12). In the study conducted by Inaba et al., the distance between the skin and the pleura was calculated to be 3.5 ± 0.9 cm at the fifth intercostal space and 4.5 ± 1.1 cm at the second intercostal space. The study demonstrated a 58% success rate when accessing the target area via the second intercostal space along the midclavicular line. However, when the approach was modified to utilize the fifth intercostal space, the success rate increased to 100% (13).

The findings of the present study demonstrate that gender exerts a substantial influence on the distribution of skin-pleural distances exceeding 50 mm. This threshold is widely accepted as the clinical failure criterion for needle decompression in cases of tension pneumothorax. This finding aligns with the literature on the subject, which has demonstrated that the inability to achieve this distance in female patients results in a significantly higher rate of potential procedural failure. The failure rate in female patients was 31.7% for right-side measurements and 33.3% for left-side measurements. In contrast, the failure rate was only 2.3% for both sides in male patients. The underlying cause of this substantial discrepancy is the marked increase in the distance between the skin and the pleura that is observed when measurements are obtained from the

midclavicular line at the second intercostal space. This finding underscores the necessity to acknowledge gender as a pivotal risk factor when devising needle decompression protocols in emergency departments.

Notwithstanding the absence of prior reports in the extant literature, the present study sought to examine the correlation between measurements of 50 mm or greater and age categories. Despite the absence of a statistically significant discrepancy between the groups, a trend was observed, indicating that the distance between the skin and the pleura was greater in the younger age group compared to the older patient group. This finding was hypothesized to be attributable to the greater amount of muscle tissue present in younger individuals. Given that the majority of patients included in the study were oncology patients, it was interpreted that muscle tissue loss (sarcopenia) associated with the disease and chemotherapy in the older patient group was also a significant factor in the reduction of this distance.

The present study examined the relationship between patients' VKE values and potential failure in a clinical setting. Consistent with the general trend in the literature, it was observed that the failure rate increased as VKE increased. This finding indicates a direct correlation between body fat and the skin-pleural distance. However, the fact that the patients included in our study consisted solely of normal-weight and overweight individuals, with no patients in the underweight or obese/morbidly obese categories, constitutes a significant limitation in comparing these results across the full spectrum of VKE. This

phenomenon has hindered the establishment of more definitive interpretations regarding the skin-pleural distance in specific subgroups of obesity.

Limitations

The present study is subject to several key limitations. Firstly, the study's single-center, retrospective design may limit the generalizability of the findings to the general population. Secondly, the restriction of the sample size to 150 patients has the potential to compromise statistical power, particularly in the context of subgroup analyses. A third and significant limitation of the study is that the study group consisted predominantly of oncology patients. This may have led to the skin-pleural distance being measured as thinner than it actually is due to sarcopenia (muscle loss) in elderly patients. Furthermore, the sample is not homogeneous in terms of Body Mass Index (BMI) distribution, as all patients included in the study fall into the normal or overweight categories. The exclusion of patients with underweight, obese, or morbidly obese BMI values from the sample precluded a comprehensive analysis of changes in the skin-pleural distance at extreme BMI values. The fact that measurements were taken on stable patients limits the reflection of dynamic pathophysiological changes—such as chest wall expansion caused by tension pneumothorax—in the measurements.

Conclusion

In summary, the implementation of a uniform cannula length for needle decompression introduces a substantial clinical risk, particularly in female patients,

younger patients, and those with high VKE. In light of these findings, the adoption of patient-specific treatment approaches in emergency medicine is imperative for enhancing procedural success and reducing patient mortality.


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