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Chest Wall Thickness and Decompression Failure: A Systematic Review and Meta-analysis Comparing Anatomic Locations in Needle Thoracostomy

Dr. Danuel V. Laan, MD, Ms. Trang Diem N. Vu, Dr. Cornelius A. Thiels, DO, Dr. T. K. Pandian, MD, Dr. Henry J. Schiller, MD, Dr. M. Hassan Murad, MD^a, and Dr. Johnathon M. Aho, MD^a

Department of General Surgery (Drs Laan, Thiels, Pandian, and Aho), Division of Trauma, Critical Care, and General Surgery (Dr Schiller), Division of Preventive, Occupational, and Aerospace Medicine (Dr Murad), and Department of Physiology and Biomedical Engineering (Dr Aho), Mayo Clinic, Rochester, Minnesota. Ms Vu is a student, Mayo Medical School, Mayo Clinic College of Medicine, Rochester Minnesota

Danuel V. Laan: Laan.Danuel@mayo.edu; Trang Diem N. Vu: Vu.TrangNDiem@mayo.edu; Cornelius A. Thiels: Thiels.Cornelius@mayo.edu; T. K. Pandian: pandian.twinkle@mayo.edu; Henry J. Schiller: Schiller.Henry@mayo.edu; M. Hassan Murad: Murad.Mohammad@mayo.edu; Johnathon M. Aho: aho.johnathon@mayo.edu

Abstract

Introduction—Current Advanced Trauma Life Support guidelines recommend decompression for thoracic tension physiology using a 5-cm angiocatheter at the second intercostal space (ICS) on the midclavicular line (MCL). High failure rates occur. Through systematic review and meta-analysis, we aimed to determine the chest wall thickness (CWT) of the 2nd ICS-MCL, the 4th/5th ICS at the anterior axillary line (AAL), the 4th/5th ICS mid axillary line (MAL) and needle thoracostomy failure rates using the currently recommended 5-cm angiocatheter.

Methods—A comprehensive search of several databases from their inception to July 24, 2014 was conducted. The search was limited to the English language, and all study populations were included. Studies were appraised by two independent reviewers according to a priori defined PRISMA inclusion and exclusion criteria. Continuous outcomes (CWT) were evaluated using weighted mean difference and binary outcomes (failure with 5-cm needle) were assessed using incidence rate. Outcomes were pooled using the random-effects model.

Corresponding and Reprints: Johnathon M. E. Aho, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (aho.johnathon@mayo.edu). Ph. 507-255-3812.

^aAuthors contributed equally.

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Results—The search resulted in 34,652 studies of which 15 were included for CWT analysis, 13 for NT effectiveness. Mean CWT was 42.79 mm (95% CI, 38.78–46.81) at 2nd ICS-MCL, 39.85 mm (95% CI, 28.70–51.00) at MAL, and 34.33 mm (95% CI, 28.20–40.47) at AAL (P=0.08). Mean failure rate was 38% (95% CI, 24–54) at 2nd ICS-MCL, 31% (95% CI, 10–64) at MAL, and 13% (95% CI, 8–22) at AAL (P=0.01).

Conclusion—Evidence from observational studies suggests that the 4th/5th ICS-AAL has the lowest predicted failure rate of needle decompression in multiple populations.

Keywords

needle decompression; needle decompression location; needle thoracostomy; optimal positioning; tension pneumothorax

Introduction

Tension pneumothorax is an immediate threat to a person's life. Current Advanced Trauma Life Support (ATLS) guidelines recommend initial treatment with needle thoracostomy (NT) decompression using a 5-cm angiocatheter at the second intercostal space (ICS2) on the midclavicular line (MCL) (ICS2-MCL) [1]. The past several decades have witnessed increasing evidence that a 5-cm angiocatheter may be inadequate to reach the pleural space, and ICS2-MCL [2] may not be the ideal location for needle decompression [2–13].

Emerging factors encouraging reevaluation of the ATLS recommendation include chest wall thickness (CWT) greater than needle catheter length, possibility of catheter obstruction, and misidentification of patient anatomy. Multiple studies have shown significant variation in CWT between ICS2-MCL and alternative sites [3,7,14–16]. Furthermore, diagnosis of tension pneumothorax is difficult given varied patient presentation [17] and identification of ICS2-MCL has been shown to be inconsistent; many practitioners are unaware of the true location of ICS2-MCL and often identify this landmark as within the “trauma box”—a designated zone with high likelihood of major organ injury [5,11,18].

The most common alternative locations for needle decompression include the fourth (ICS4) and fifth (ICS5) intercostal spaces at both the anterior axillary line (AAL) (ICS4/5-AAL) and the midaxillary line (MAL) (ICS4/5-MAL). Studies investigating these locations tend to be small, underpowered for anatomic locations, and reflective of local patient populations, and thus their findings may not be generalizable [2–16,19]. We aimed to determine CWT at ICS2-MCL in comparison with proposed alternative anatomic locations (ICS4/5-AAL and ICS4/5-MAL) (Figure 1) and to define simulated NT failure rates with use of the recommended 5-cm angiocatheter.

Methods

Data Sources and Search Strategies

After confirming this study was exempt from the appropriate ethical committees, consistent with the Declaration of Helsinki a comprehensive search was conducted of several databases from inception to July 24, 2014, in the English language, and including any population. The

databases included Ovid Medline In-Process & Other Non-Indexed Citations, Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Central Register of Controlled Trials, Ovid Cochrane Database of Systematic Reviews, and Scopus. The search strategy was designed and conducted by an experienced librarian, with input from the study's principal investigators. Controlled vocabulary supplemented with keywords was used to search for studies of NT (Appendix 1). This review adhered to the standards of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and Meta-analysis Of Observational Studies in Epidemiology (MOOSE). The abstracts from the literature search results were screened through PRISMA guidelines, with inclusion and exclusion criteria generated a priori. Briefly, the study must have assessed chest wall thickness using either computed tomographic imaging, or directly using a cadaveric study. Studies using ultrasound were excluded based on variable compression. Needle thoracostomy failure was assessed for articles which included a 5 cm angiocatheter, and excluded if another length was used. Abstracts were reviewed by two investigators (D.V.L. and T.D.N.V.) independently in duplicate and a third investigator (J.M.A.) settled if there was a disagreement. Studies passing abstract reviews were fully reviewed similarly (Figure 2).

Measurements of CWT were abstracted from the included studies. CWT at each anatomic location and the laterality of the measurement (left or right) were included when available.

One study reported CWT for either left or right sided measurements only [10], the majority reported both measurements separately [2–6,11,12,14,16], and a few reported a single bilateral mean [7,9,13,15]. A weighted bilateral mean was derived that provided both measurements to determine the mean bilateral CWT at each anatomic location in question (ICS2-MCL, ICS4/5-AAL, and ICS4/5-MAL).

Similarly, some studies reported the CWT for only ICS4-AAL or ICS4-MAL, while others reported the CWT at ICS5-AAL or ICS5-MAL. Given the lack of statistically significant difference between ICS4 and ICS5 at each anatomic site, these data were assigned to fourth and fifth for each respective anatomic site to represent a single CWT measurement, the ICS4/5.

Statistical Analysis

Continuous outcomes (CWTs) were evaluated with weighted mean differences; binary outcomes (failures with 5-cm needle) were evaluated with incidence rate. Outcomes were pooled across the studies through the random-effects model.

Results

The search resulted in 34,652 studies. After application of inclusion and exclusion criteria (Figure 2), 15 studies were included for CWT analysis (Table 1) and 13 studies were included for NT effectiveness analysis (Appendix B). In total, 6,192 anatomic sites were measured. Comparisons between CWT and laterality and ICS4 compared with ICS5 were not significant at all locations studied ($P>.05$).

CWT Overall

Mean (95% CI) CWT was 42.79 (38.78–46.81) mm at ICS2-MCL, 39.85 (28.70–51.00) mm at ICS4/5-MAL, and 34.33 (28.20–40.47) mm at ICS4/5-AAL ($P=.08$) (Figure 3).

CWT of Men vs Women

Mean CWT at ICS2-MCL was 43.3 mm in women vs 35.6 mm in men ($P=.01$). At ICS4/5-MAL, mean CWT was 38.3 mm in women vs 32.6 mm in men ($P=.02$). No studies reported mean CWT of men vs women for ICS4/5-AAL.

NT Failure Rate With 5-cm Angiocatheter

Mean (95% CI) NT failure rate was 38% (24%–54%) at ICS2-MCL, 31% (10%–64%) at ICS4/5-MAL, and 13% (8%–22%) at ICS4/5-AAL ($P=.01$). The I^2 values, representing heterogeneity of the included studies, were high (Figure 4).

Discussion

Anatomic Location

Through systematic review and meta-analysis, we showed that the 5-cm catheter for decompression currently recommended by ATLS may not be sufficient at ICS2-MCL because of high failure rates. Effective needle decompression of tension physiologic characteristics may be lifesaving and restore cardiopulmonary function. To be a successful therapeutic maneuver, NT must be an appropriate length that permits access to the pleural space and stays patent long enough for tube thoracostomy to be performed. Concerns exist regarding preferred anatomic location and catheter length for safe and effective NT performance. Thus, we propose that NT should be considered at an alternative location or with increased angiocatheter length. Cadaveric, radiographic, and clinical studies report failure rates with 5-cm needles at ICS2-MCL, with failure rates ranging from 4% to 50% [4,9,11,14,20].

Because of the various study populations and methodologic factors, the present meta-analysis is characterized by a high level of heterogeneity ($I^2=98\%–99\%$). Despite this heterogeneity, in our analysis of the CWT reported at different locations, we found that the mean CWT was smallest at ICS4/5-AAL, thicker at ICS4/5-MAL, and thickest at ICS2-MCL. Despite this observed tendency, the difference in CWT was not statistically significant ($P=.08$). Data heterogeneity and the paucity of studies without significant results limited this analysis. Therefore, on the basis of these data alone, we were unable to conclude overall statistically significant differences in CWT (Figure 3).

We found the lowest failure rates of needle decompression at ICS4/5-AAL compared with ICS4/5-MAL and ICS2-MCL ($P=.01$). This information may guide physicians and emergency care providers to consider alternative sites in their practice when performing NT. The alternative decompression sites may serve as a primary site in selected patients for whom large ICS2-MCL CWT is predicted or as a secondary NT placement after a primary attempt has failed.

Excluded Studies

Two studies that passed the PRISMA criteria for review were omitted from our analysis of NT failure rates at ICS4/5-AAL. The first study, by Wax and Leibowitz [6], did show that the median CWT was smallest at ICS5-AAL but did not report theoretical failure rates at each location with a 5-cm needle. The second study, by Schroeder and colleagues [13], was the only study showing that CWT at ICS4/5-AAL was greater than at ICS2-MCL. It showed that 29% of the analyzed patients had a CWT greater than 4.5 cm at ICS2-MCL, but 45% had CWT greater than the 4.5 cm at ICS5-AAL. That study was excluded for 2 reasons. First, the study reported theoretical failure rates with use of a 4.5-cm angiocatheter rather than a 5-cm angiocatheter. Given this, we did not believe it was comparable with the other studies that reported failure rates with a 5-cm needle [2–5,11,12,20]. Second, despite claims that Schroeder and colleagues used measurements of ICS5-AAL, the respective figure in their manuscript shows measurements of ICS5-MAL. This detail explains the incongruity of their data versus our review of the literature as a whole [4–7].

Sex and Body Mass Index Effects on CWT

Many studies provided the proportion of men in their study, but only a few performed a subgroup analysis of sex and CWT [2,9,15,16]. On pooled analysis of these data, we found that women had a significantly thicker CWT at ICS2-MCL and ICS4/5-MAL than men; however, no studies evaluated the relation of CWT and sex at ICS4/5-AAL.

Similarly, most of the studies reported median or mean body mass index (BMI) (without SD) of their respective cohorts. However, only 3 studies performed a subgroup analysis to highlight correlation between CWT and BMI [4,11,13]. Inaba et al [4] showed a stepwise increase in CWT across all BMI quartiles at each location of measurement (ICS2-MCL and ICS5-AAL). Likewise, Powers et al [11] found that as BMI increases, it correlates to an increasing CWT. However, their study evaluated CWT only at ICS2-MCL.

Variance by Geographic Location

The studies we identified varied by geographic region (nationality) and patient population. We assumed that each study's participants originated from the region in which the study was performed (Appendix 1). For instance, average CWT at ICS2-MCL for patients studied in rural Ohio was 45.9 mm (average BMI, 30.25) [20], whereas the average CWT at ICS2-MCL for patients studied in Japan was 33.5 mm (mean BMI of the Japanese population by census data, 21.9) [15,21]. Given the correlation between BMI and CWT observed by Inaba et al [4] and Powers et al [11], the regional variability in CWT studies may be partially explained by differences in BMI. Thus, in the United States and other Western countries where BMI has increased substantially, a change may be necessary in NT performance location or catheter length, yet in other parts of the world, ICS2-MCL decompression may be more successful.

Considerations of Needle Length

Tension physiologic characteristics tend to occur in austere environments; equipment in these situations is limited despite optimal preparedness and training. A catheter of ideal length and diameter to traverse the skin, subcutaneous tissues, and muscular structures of the

chest wall may not be immediately available. Providers are also less likely to place the needle in a trajectory that lies on the shortest distance into the pleural space, particularly in patients with thoracic trauma. These off-axis needle entries, coupled with provider awareness of available sites for performance of NT, need to be considered when selecting a needle of appropriate length. A longer needle may be difficult to find in these situations, and use of the anatomic site with the shortest distance to access the chest is imperative.

Theoretical rates of decompression based on CWT measurements have been shown to be nearly 100% in patients when an 8-cm catheter is used at ICS2 [5]. Recently, the Committee for Tactical Combat Casualty Care, the Defense Health Board's Trauma and Injury Subcommittee [22], and the Prehospital Trauma Life Support: Military Edition (Seventh Edition) [23] from the United States have supported the use of an 8-cm, 14-gauge angiocatheter at both ICS2-MCL and ICS4/5-AAL for NT. Recently, Clemency et al. [24] undertook a similar investigation to our current one at the ICS2-MCL and found that a 5 cm needle is not sufficient, and to achieve decompression in 95% of patients a 6.4 cm catheter would be required. They did not however assess alternative anatomic sites which we found plays a critical role in CWT and effectiveness. An important consideration when suggesting alternative sites such as ICS4/5-AAL or ICS4/5-MAL is the ability to access these anatomic sites during transport or treatment. Tension may be diagnosed and treated during various stages of transportation and resuscitation. However, obtaining access to lateral NT sites may be problematic while the patient is in a helicopter, secured to a backboard, or undergoing transport.

Safety of ICS4/5 and Increased Angiocatheter Length

Safety of NT is poorly understood, and devastating injuries to the underlying cardiopulmonary vasculature have been reported [18,25]. To our knowledge, little clinical evidence is available to support any safety profile beyond case reports, cadaveric or radiologic data [3,5,26] for decompression of ICS2-MCL with a 5-cm angiocatheter. Chang et al [5] performed an observational, retrospective radiographic analysis of chest computed tomography images of 100 consecutive adult trauma patients at a Level I Trauma Center to evaluate NT safety with use of simulated 5-cm and 8-cm angiocatheters. This evaluation was accomplished by comparing depth to the pleural space versus depth to an underlying vital structure in each patient. They observed no injury to an underlying structure when using a 5-cm needle at the right or left ICS2-MCL. Similarly, no injury occurred in their cohort with a 5-cm needle aimed perpendicular to the chest wall at ICS4-AAL, regardless of which side (left or right) the needle was placed. They observed a 1% rate of injury with a 5-cm needle at the left ICS4-AAL when a shallow angle of entry was used vs a perpendicular angle (correct placement). In addition, Chang et al analyzed safety with 8-cm needles at both ICS2-MCL and ICS4-AAL. They found an injury rate as high as 9% with optimal placement of the 8-cm needle and a 32% rate of injury to an underlying structure with placement at a shallow angle at ICS4-AAL. These latter findings bring into question the safety of using longer catheters at alternative sites (eg, ICS4/5 MAL, ICS4/5 AAL) and, in our opinion, are an area for further investigation.

Limitations

Most studies analyzed in the present meta-analysis used radiographic assessment of NT. However, this methodology cannot account for chest wall deformation and the degree of chest wall compression that providers may generate to access the pleural space during NT or the dynamic chest wall movement that can lead to catheter obstruction. Therefore, our study may underestimate decompression rates with use of a 5-cm catheter. Conversely, subcutaneous emphysema may artificially increase CWT in the acutely injured patient, which was not well reported in the observational studies of this meta-analysis. Radiologically, it is not possible to determine degree of mobility of soft tissues such as the breast, which could be retracted in a caudad direction to decrease CWT. Various methodologies were used to determine CWT and NT failure rates; the available data were heterogeneous and highly varied, and independent measurements were not verifiable. A publication bias may be present because all of the analyzed studies showed significant differences favoring either ICS2-MCL or a lateral position of ICS4/5-MAL or ICS4/5-AAL. Studies that found no differences may have never been published.

Conclusion

NT for decompression of tension physiologic characteristics may be more effective at alternative anatomic sites, such as ICS4/5-AAL and ICS4/5-MAL, than ICS2-MCL with a 5-cm angiocatheter. Alternative sites and increased catheter length should be considered as options for NT. Providers who are likely to encounter such pathologic conditions need to be aware of the limitations of NT as currently recommended.

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Figure 1.
Anatomic Locations for Needle Thoracostomy Decompression. A denotes the currently recommended second intercostal–space midclavicular line (ICS2-MCL); B, the fourth and fifth intercostal spaces midaxillary line (ICS4/5-MAL); and C, the fourth and fifth intercostal spaces anterior axillary line (ICS4/5-AAL). (Used with permission of Mayo Foundation for Medical Education and Research.)

Figure 2.
The Preferred Reporting Items for Systematic Reviews and Meta-analyses Flow Diagram.
The diagram details the search strategy and the inclusion and exclusion criteria.

Figure 3.

Chest Wall Thickness by Recommended Anatomic Location and Alternative Anatomic Locations. Shown are the fourth and fifth intercostal spaces–anterior axillary line (ICS4/5-AAL), the fourth and fifth intercostal spaces–midaxillary line (ICS4/5-MAL), and the second intercostal space–midclavicular line (ICS2-MCL).

Figure 4.

Needle Thoracostomy Failure Rates by Anatomic Location. Mean (95% CI) for fourth and fifth intercostal spaces–anterior axillary line (ICS4/5-AAL), the fourth and fifth intercostal spaces–midaxillary line (ICS4/5-MAL), and the second intercostal space–midclavicular line (ICS2-MCL).

Table 1

Summary of Findings of Each Study of Chest Wall Thickness

Study	Study Population, Location and Cohort	Findings
Akoglu et al (2)	Zonguldak, Turkey; 160 adult patients with CT-confirmed pneumothorax, with tube thoracostomy from November 2010 to October 2011	Comparison of CWT at ICS2-MCL and ICS5-MAL At ICS2-MCL, the pleural cavity is inaccessible in 17% of men and 48% of women when a routine 5-cm catheter was used; at ICS5-MAL, 13% and 33%, respectively, would be inaccessible Patients with trauma, subcutaneous emphysema, and multiple rib fractures had greater CWT at both sites Confirmed that a 5.0-cm catheter is unlikely to access pleural space in at least one-third of female and one-tenth of male Turkish trauma patients, regardless of puncture site. When NT is needed, ICS5-MAL is a better option for a puncture site, with less CWT
Carter et al (20)	Athens, Ohio; 91 adults (age >18 y) requiring CT, with absence of SQ air or chest wall tumor, November 1–19, 2010	Retrospective review of CWT at ICS2 bilaterally Found that 46-mm needles were successful in only 52.7% of patients vs ATLS- recommended length of 51 mm, which had success in 64.8% A 64-mm needle would have been successful in 79% of study patients
Chang et al (5)	Charlotte, North Carolina; 100 adult (age >18 y) trauma patients requiring CT from January through September 2011	Evaluation of 5 and 8-cm needles directed at ICS4-AAL in 100 consecutive trauma patients CWT at ICS4-AAL was significantly thinner than at ICS2-MCL ($P<.05$) On the basis of radiographic measurements, 8-cm catheters had a greater chance of pleural decompression (96%) vs 5-cm catheters (66%-81%) Steeper angle of entry at ICS4-AAL improved 8-cm noninjury rates to >91%
Givens et al (9)	San Antonio, Texas; convenience sample of 111 adults (age >18 y) requiring CT in 2002, with no SQ air	CWT measured at ICS2-MCL to nearest 0.1 cm Mean CWT averaged 4.24 cm, but nearly one-fourth of patients had CWT >5 cm. Catheter length of 5 cm will penetrate the pleural space of only 75% of patients Women had greater CWT than men (4.90 vs 4.16 cm; $P=.022$)
Harecke et al (10)	US military; 100 male trauma patients with no thoracic deformity underwent total body MDCT before autopsy from January through March 2006	Multidetector CT scans were used to determine CWT at right ICS2-MCL in deployed male military personnel Mean (SD) horizontal CWT was 5.36 (1.19) cm with angled (perpendicular) CWT of mean (SD) of 4.86 (1.10) cm An 8-cm angiocatheter would have reached the pleural space in 99% of these patients
Inaba et al (3)	Los Angeles, California; 20 adult cadavers with no congenital or neoplastic malformations	Evaluated placement of standard 14-gauge 5-cm needle at ICS5-MAL and ICS2-MCL in right and left chest walls of randomly selected unpreserved adult cadavers Overall, 100% of needles placed in ICS5-MAL and 57.5% in ICS2-MAL entered chest cavity On average, CWT was 1 cm less at ICS5-MAL vs ICS2-MAL, possibly contributing to the discrepancy in success rates
Inaba et al (4)	Los Angeles, California; 120 patients (age >16 y) with CT from January 2009 through January 2010	CWT on CT at ICS2-MCL compared with ICS5-AAL on right and left sides. Study patients were separated into quartiles by BMI Significant difference in CWT between ICS2-MCL and ICS5-AAL in all BMI quartiles on right and left sides ($P<.05$) Of patients, 42.5% had CWT >5-cm decompression needle at ICS2-MCL; 16.7% at ICS5-AAL CWT at ICS5-AAL was 1.3 cm thinner on average and may be a preferred location for NT decompression
Lamblin et al (7)	French military; 122 soldiers in infancy	CWT was measured at ICS2 and ICS4 bilaterally CWT >5 cm in 24.2% at ICS2 and 4.9% at ICS4 ($P<.001$) Authors concluded that a lateral approach to needle decompression at ICS4 could decrease risk of failure relative to ICS2
McLean et al (26)**	Albuquerque, New Mexico; convenience sample of 51 adult (age >18 y) medical staff and students with no surgical alteration to chest wall	Observational, cross-sectional study of persons in which CWT was correlated with BMI and national data were used to estimate percentage of patients with CWT >4.5 cm Using national BMI estimates, the authors found that <1% of the US population would be expected to have CWT >4.5 cm Authors concluded that CWT may not be the source of the high failure rate of needle decompression in tension pneumothorax
Powers et al (11)	Wilmington, North Carolina; 326 adults (age >18 y) with CT from January 2004 through September 2006	Retrospective review in which BMI was calculated for each patient and CWT measured at ICS2-MCL bilaterally to determine whether BMI predicts catheter length needed for NT Mean (SD) CWT was 6.2 (1.9) cm on right and 6.3 (1.9) cm on left. On average, patients needed catheter length of 6.0–6.5 cm to decompress tension pneumothorax successfully As BMI increased, CWT increased ($P<.0001$) in all BMI groups

Study	Study Population, Location and Cohort	Findings
Sanchez et al (12)	Boston, Massachusetts; 159 emergency department patients with blunt trauma and CT between June 2008 and February 2009, without SQ emphysema	Retrospective review with 6 measurements from skin surface to the pleural surface for each patient: anterior ICS2, lateral ICS4, and lateral ICS5 on left and right Distance of anterior approach was less than lateral ICSs ($P<.01$). The authors concluded that with commonly available angiocatheters, the lateral approach is less likely to be successful than the anterior approach
Schroeder et al (13)*	Washington, District of Columbia; 201 trauma patients (age 18–80 y) with CT from January through December 2011 (CWT within boundaries of image)	Retrospective review evaluating CWT at ICS2-MCL and ICS5-AAL and ISS, CWT, and BMI Of overall cohort, 29% (27 male and 32 female patients) had CWT >4.5 cm at ICS2-MCL and 45% (54 male and 36 female patients) had CWT >4.5 cm at ICS5-AAL Authors concluded no significant interaction between sex and CWT at either site, but BMI was positively associated with CWT at both sites
Stevens et al (14)	Charlotte, North Carolina; 110 adult (age >18 y) trauma patients with CT between January and March 2005	Retrospective review of CWT measurements at ICS2-MCL on CT Mean (SD) CWT on right was 4.5 (1.5) cm and on left was 4.1 (1.4) cm. Of patients, 55 had at least 1 side of chest wall measuring >4.4 cm The standard 4.4-cm angiocatheter was likely to be unsuccessful in 50% (95% CI, 40.7%–59.3%) of trauma patients on basis of body habitus
Wax and Leibowitz (6)*	New York, New York; 100 randomly selected adults (age >18 y) with CT archived and anesthesia for video-assisted thoracoscopy in 12 mo before data retrieval	CT used to measure distance from skin surface to pleura and to intrathoracic structures at the sternal angle level at MHL and at xiphoid process level at AAL and MAL and distance from sternal midline to internal mammary vessels Margin of safety was less on left than right, and MHL site was safest on both sides On basis of ranges of obtained depth-to-pleura distances, authors suggested that needle decompression of suspected tension pneumothorax be performed in the MHL at sternal angle with a needle 7 cm inserted perpendicular to the horizontal plane
Yamagiwa et al (15)	Isehara-City, Japan; 256 adult (age >18 y) trauma patients of Japanese descent with CT from January to July 2008	Study was designed to analyze CWT in Japanese trauma patients with CT and to determine percentage of patients whose pleural space would be accessible with a 5.0-cm catheter CWTs at 94.3% of sites were <5.0 cm (mean CWT at ICS2-MCL, 3.06 cm) CWT of women was significantly greater than men ($P<.05$), and patients with SQ emphysema had greater CWT than those without it Authors concluded that >94% of Japanese trauma patients can be treated with a 5.0-cm catheter
Zengerink et al (16)	Calgary, Alberta, Canada; 774 adult (age >18 y) major trauma admissions (ISS, >12) with chest CT scan, admitted from October 2001 until March 2004	Retrospective review of chest CT scans in which the mean CWT in 604 men and 170 women studied averaged 3.50 cm at left ICS2-MCL and 3.51 cm at right ICS2-MCL. Mean CWT was greater for women than men ($P<.0001$). Of men, 9.9%–19.3% had CWT >4.5 cm; of women, 24.1%–5.4% had CWT >4.5 cm Based on these findings, catheter length of 4.5 cm will not penetrate the chest wall of 9.9%–35.4% of study population, depending on age and sex

Abbreviations: AAL, anterior axillary line; ATLS, Advanced Trauma Life Support; BMI, body mass index; CT, computed tomography; CWT, chest wall thickness; ICS5, fifth intercostal space; ICS4, fourth intercostal space; ICS2, second intercostal space; ISS, Injury Severity Score; MAL, midaxillary line; MCL, midclavicular line; MHL, midhemithoracic line; NT, needle thoracostomy; SQ, subcutaneous.

** Designates study excluded from both analyses.

* Designates excluded from NT Failure Analysis but included for CWT.