Guidelines for chest drain insertion may not prevent damage to abdominal viscera

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ABSTRACT

Objectives Guidelines to improve the ease and safety of chest drain insertion recommend using the fifth intercostal space, around the midaxillary line (MAL). This study aimed to assess whether compliance with published guidelines reliably ensured such placement and avoided the potentially serious complications of subdiaphragmatic insertion and peripheral nerve injury.

Methods Three international guidelines were assessed by identifying the intercostal space for chest drain insertion using 16 cadavers (32 sides) at a point 1 cm anterior to MAL. The European Trauma Course method was compared with the British Thoracic Society's 'safe triangle' and the ATLS course technique.

Results The level most commonly found was the sixth intercostal space (43%; 41 of 96 sides). Overall the sixth space or below was found in 83% of insertions (80 of 96 sides). In the fifth intercostal space, the long thoracic nerve ran posterior to the marker placed in all cases and the lateral cutaneous branches of intercostal nerves arose anteriorly to the marker in all but one case.

Conclusions The results suggest these guidelines may result in insertion of chest drains below the fifth intercostal space, potentially risking injury to subdiaphragmatic structures. Peripheral nerves of the lateral thoracic wall appear safe from incisions 1 cm anterior to MAL.

Key messages

What is already known on this subject

- Currently, insertion of chest drains targets the fifth intercostal space.
- Guidelines exist to find this space, but little evidence exists to validate their accuracy.
- Inserting chest drains through a lower intercostal space increases the risk of iatrogenic intra-abdominal visceral injury.

What this study adds

- The first known study assessing anatomical validity of guidelines for chest drain insertion.
- Recommends caution when using current guidelines and advocates further analysis.

INTRODUCTION

Chest drain insertion is a common procedure carried out by a variety of specialties.[1] Consequently, several guidelines exist to ensure a safe technique irrespective of the circumstance.[1–5] Commonest in the UK are the British Thoracic Society (BTS) safe triangle[1 2 4] and the ATLS methods.[3] These have been adopted by many life support courses, for example, a variation of the ATLS guidelines is used on the European Trauma Course (ETC).[5]

Despite these recommendations, insertion still carries a risk of morbidity and mortality ranging from minor complications in over one-third of cases (eg, pain at insertion site) to around a 5% incidence of more serious events.[6–9] Though the exact rates on diaphragmatic perforation and damage to abdominal viscera are difficult to quantify, it is recognised that a drain inserted too low increases the possibility of abdominal placement.[10] In 2008, the UK's National Patient Safety Agency highlighted 27 cases of serious harm and death out of 2152 patient safety incidents involving chest drains over the preceding three years. Both categories included laceration of the liver due to subdiaphragmatic insertion.[11] The fifth intercostal space, on or around the midaxillary line (MAL), is a recommended site to avoid these complications.[1–5 11–14] Counting ribs down from the manubriosternal angle is often taught;[13] however, body habitus and injury can make palpation of ribs difficult. As a result, the guidelines mentioned above do not use this method.[1–5]

A less commonly recognised complication is damage to significant peripheral nerves of the lateral chest wall, that is, the long thoracic nerve[15] and the lateral cutaneous branches of the intercostal nerves (LCBs). These structures are not mentioned in the guidelines described.

The aim of this study was to determine whether compliance with the stated guidelines ensured placement of chest drain markers avoided damage to internal structures and peripheral nerves of the chest wall.

MATERIALS AND METHODS

The Licensed Teacher of Anatomy, School of Medicine, University of St Andrews, granted approval for the use of cadavers in this investigation.

Subject demographics

This study used both sides of 16 supine cadavers. All were Caucasian, 11 men and 5 women, with a mean age of 84 years (range 69–92 years). Fifteen were embalmed using formaldehyde and one using the Genelyn technique.[16] Seven had thoracic pathology or medical intervention that had the potential to alter thorax shape or structure. These included chronic obstructive pulmonary disease, ankylosing spondylitis, lung cancer, bronchiectasis, pulmonary fibrosis, a left superior lobe pneumonectomy and coronary artery bypass graft.

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Guidelines

To find the fifth intercostal space, ETC candidates are taught to insert the chest drain one hand's width (ie, the distance across the second to fifth metacarpophalangeal joints) below the anterior axillary fold,[5] just anterior to MAL (figure 1). The second metacarpophalangeal joint is placed under the anterior axillary fold, palm in contact with the lateral chest wall, taking care not to apply undue force to the soft tissues that would distort the axillary floor's relationship to the underlying ribs. The patient's right hand is used for their left hemithorax and vice versa. In cases where the patient's upper limb cannot be used, candidates estimate the correct level by using their own hand after comparing it with the patient's hand. This technique therefore relies on the clinician's accuracy of estimation. Both estimated and measured methods were assessed in this study.

The BTS guideline (figure 2) advocates insertion superior to the horizontal level of the fifth intercostal space, through a 'safe triangle'[1 2 4] with the following boundaries:

- an apex below the axilla/the base of the axilla superiorly
- the lateral border of pectoralis major
- the anterior border of latissimus dorsi
- a base line superior to the horizontal level of the nipple (the line of the fifth intercostal space).

The patient's upper limb is abducted, with the hand placed behind the head. With limited mobility of cadaveric limbs this was not possible, so the upper limb was abducted to 45°.

The ATLS course manual states the fifth intercostal space is 'usually at the level of the nipple'.[3] It also recommends inserting the drain just anterior to MAL.

Placement of markers

Markers were placed and assessed by two medical practitioners with experience of inserting chest drains, overseen by a former consultant in emergency medicine. The anatomical accuracy was overseen by a senior lecturer in anatomy with over 30 years of experience.

The anterior axillary line was marked on the cadaver as a vertical line, dropped inferiorly from the most prominent part of the anterior axillary fold. The posterior axillary line was marked in a similar fashion. MAL was then identified midway between these lines (figure 1).

Both estimated and measured ETC hand width measurements were taken from the anterior axillary fold and the skin was marked. Given the lack of specificity of the guidelines regarding position 'just in front of MAL', a point 1 cm anterior to MAL was chosen.

The BTS and ATLS guidelines were considered together because both use the nipple as a marker for the fifth intercostal space. A line was drawn horizontally, from the superior border of the nipple to a point 1 cm anterior to MAL (figure 1). Due to the embalming process, the soft tissues of the cadavers were relatively immobile, therefore the nipple position taken was that found in both male and female cadavers as they lay in the supine position.

At each defined point, a 0.5 cm incision was made in the skin and a channel drilled perpendicular to the surface. Markers (representing these guidelines) were then inserted to ensure the surface position was fixed in relation to underlying structures during subsequent dissection.

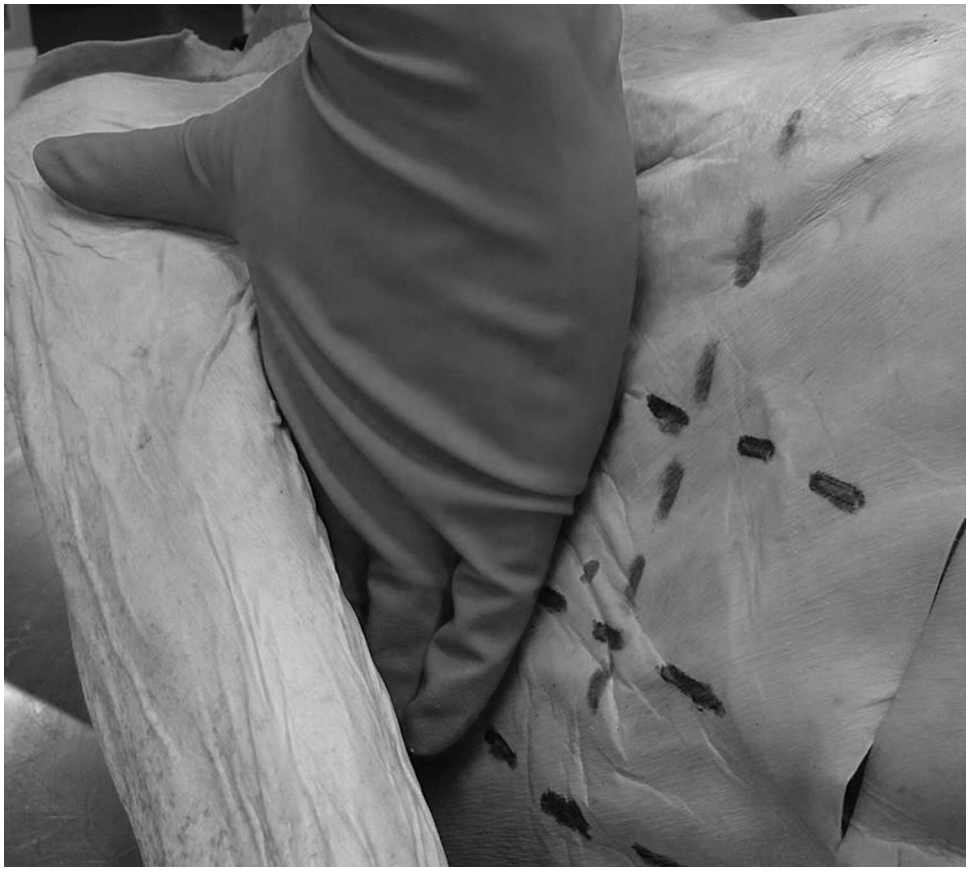

Figure 1 The European Trauma Course (ETC) hand width technique and data collection. (The anterior and posterior hashed vertical (anatomically) lines represent the anterior and posterior axillary lines, respectively, with the midaxillary line between them. The horizontal (anatomically) hashed line represented the level of the nipple. The hand and dot represent an example of the measured and estimated ETC hand width method.)

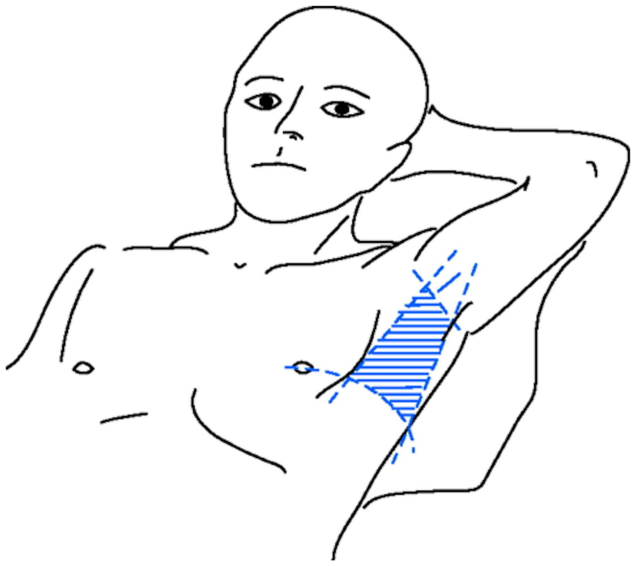

Figure 2 The British Thoracic Society safe triangle.[4]

Identification of intercostal spaces

The location of each marker was subsequently determined by dissection of the chest wall. Ribs 1–6 were removed from the anterior end to the anterior axillary line to enable access to the ribs and intercostal spaces without damaging the area of study.

The fifth intercostal space was identified by counting down, on the internal surface, from the first rib. The space through which the marker passed was then determined and verified by a second investigator who was blind to the initial verdict. In cases of disagreement, both original investigators recounted alongside a third investigator in order to ensure accuracy of reassessment.

If a marker was placed through a rib, the intercostal space above was recorded. This is consistent with clinical practice to ensure instrumentation is in the lower part of the space and avoids the main intercostal neurovascular bundle running in the subcostal groove.[4 12 13 17 18]

Identification of the long thoracic nerve and the lateral cutaneous branches of the intercostal nerves

After the skin of the chest wall was removed, both long thoracic nerve and LCBs were identified on the lateral thoracic wall and their positions judged relative to MAL at the level of the fifth intercostal space. The actions were again verified by a second investigator. As before, in cases of disagreement both investigators reassessed in the presence of a third investigator.

Outcome measures

The primary outcome assessed in this cadaveric study was whether compliance with the ETC measured guideline, ETC estimated guideline or the ATLS method/BTS safe triangle (level of the nipple) successfully ensure insertion at, or above, the fifth intercostal space. This was defined as insertion through the third, fourth or fifth intercostal spaces as these space are above the diaphragm and not known to compromise other anatomical structures.

The secondary outcome assessed was whether placement of a chest drain marker at 1 cm anterior to MAL, as recommended by the ETC guideline and ATLS method, avoids the nerves of the lateral thoracic wall that lie more anteriorly or posteriorly in the BTS safe triangle.

Data handling

The cadaveric data were collected in an electronic format (Microsoft Excel spreadsheet) for analysis.

A pragmatic approach of descriptive analysis of the data, rather than a statistical analysis, has been used in comparing a relatively small study population. The subgroups described above are compared with each other and the potential impact of the results discussed.

RESULTS

Summary of results

The most common intercostal space found by all methods was the sixth (41 of 96 sides, 43%) with a range varying from the third to eighth spaces. The fifth intercostal space or above was found in 16 of 96 sides (17%; table 1).

European trauma course

ETC estimated hand width

The most common insertion level was the sixth intercostal space (14 of 32 sides, 44%), with a range from the fourth to seventh. In total, 9 of the 32 markers (28%) located the fifth intercostal space, or above.

ETC measured hand width

The most common insertion level was the seventh intercostal space (15 of 32 sides, 47%) with a range from the fifth to eighth. Only 3 of 32 markers (9%) found the fifth intercostal space, or above.

Right versus left and men versus women

The fifth intercostal space or above was found in 5 of 32 sides (16%) on the right using the ETC methods compared with 7 of 32 sides (22%) on the left. In male cadavers, the fifth intercostal space or above was found in 6 of 44 sides (14%) compared with 6 of 20 sides (30%) in women.

BTS safe triangle inferior boundary and ATLS

The sixth intercostal space was most commonly found using the level of the superior border of the nipple (15 of 32 sides, 47%), with a range from the third to the eighth. The fifth intercostal space, or above, was only found in 4 of 32 sides (13%).

The fifth intercostal space, or above, was found in 1 of 16 sides (6%) on the right compared with 3 of 16 sides (19%, difference to right due to rounding) on the left. In male cadavers, the fifth intercostal space or above was found in 2 of 22 sides (9%) compared with 2 of 10 sides (20%) in women.

Table 1 Intercostal spaces (ICS) identified using the European Trauma Course (ETC) hand width techniques and the inferior boundary of the British Thoracic Society (BTS) safe triangle/ATLS technique

	ETC measured		ETC estimated		BTS/ATLS	
ICS	Left	Right	Left	Right	Left	Right
3rd					1	
4th				1		1
5th	1	2	6	2	2	
6th	7	5	5	9	8	7
7th	7	8	5	4	5	7
8th	1	1				1

Peripheral nerves

Long thoracic nerve

The long thoracic nerve reached the fifth intercostal space in 16 of 32 sides (50%; table 2). In other cases, it penetrated the muscle, supplying it, or ended in a series of branches that subsequently penetrated the muscle between the third and sixth intercostal space. When present in the fifth intercostal space it was always located on, or posterior to, MAL. It was therefore consistently found posterior to the inserted markers, which were located 1 cm anterior to MAL.

Lateral cutaneous branches of intercostal nerves (LCBs)

LCBs were identified in the fifth intercostal space in 25 of 32 sides (78%). At this level, they were found anterior to the inserted markers (ie, 1 cm anterior to MAL) in all but one case (table 3). In this exception, they were found in line with the marker.

DISCUSSION

Currently, ETC is taught in 21 countries, predominantly in mainland Europe.[5] The BTS safe triangle has been widely adopted in the UK and abroad,[1 4 10 12–14 18–23] and ATLS protocols, including chest drain insertion, have been taught to over one million doctors in >50 countries.[3]

This cadaveric examination of these guidelines found overall that they identified the fifth intercostal space, or above, in only 16 of 96 cases (17%), and in less than one-third of cases for each guideline. More positively, compliance with the ETC and ATLS recommendations avoided the long thoracic nerve in all cases and LCBs in 96% in the fifth intercostal space. In contrast, the anterior and posterior aspects of the BTS safe triangle put these nerves at risk. Consequently, these data suggest that current guidelines may involve areas that risk subdiaphragmatic insertion and nerve injury.

Finding the fifth intercostal space

The intercostal level for chest drain insertion is a compromise. The fifth intercostal space, or above, is recommended to prevent potentially life-threatening abdominal visceral laceration.[11 17 22]

However, insertion through higher intercostal spaces can become technically challenging and be less comfortable for the patient. Damage to the sympathetic trunk has also been associated with chest drain placement near the apex of the lung, discouraging insertion through the upper intercostal spaces.[10] Therefore, insertion through the fourth or fifth intercostal space is typically advised, hence the focus of this study. However, our analysis also considered insertion through the third intercostal space a success due to the lack of deleterious effects recorded when this space is used.

The traditional method of finding the fifth intercostal space by palpating and counting ribs, as taught in medical schools, is summarised by Ellis.[13] In practice, this can be difficult in obese and muscular patients, or in those with chest trauma. Therefore, an accurate and rapid guideline will still be required.

The BTS and ATLS guidelines use a soft tissue landmark, the nipple, to identify a space between two bones. Some quote the level of the nipple as being, for example, in the fourth[24] or fifth intercostal space.[3 23] However, this is variable within and between individuals depending on gender, body position, adiposity and age.

The fifth intercostal space was found in a greater proportion in women than men for the ETC methods (30% vs 14%) and BTS/ATLS level (20% vs 9%). However, the authors feel that, with the variables involved that cannot be account for in this study (eg, soft tissue mobility), such a difference in a small study population must be viewed with caution and a more extensive study conducted before conclusions can be drawn.

Table 2 Intercostal spaces (ICS) at which the long thoracic nerve finished

ICS	Left	Right
3rd	3	
4th	5	8
5th	8	5
6th		3

Table 3 Position of lateral cutaneous branches of the intercostal nerves in the fifth intercostal space

Left		Right	
Anterior axillary line	8 of 16 (50%)	Anterior axillary line	5 of 16 (31%)
Between anterior and midaxillary line (MAL)	5 of 16 (31%)*	Between anterior and MAL	7 of 16 (44%)
Not seen	3 of 16 (19%)	Not seen	4 of 16 (25%)

All lateral cutaneous branches lay anterior to a point 1 cm anterior to MAL unless stated by *, in which the nerve laid in line with marker on one side.

Peripheral nerves

In addition to ensuring that the chest drain lies above the diaphragm, clinicians must also avoid the peripheral nerves of the chest wall. The long thoracic nerve runs vertically downwards on serratus anterior, posterior to MAL.[25] LCBs, cutaneous sensory branches of intercostal nerves, pierce muscles of the chest wall in MAL,[25] before supplying the skin (figure 3).

In support of published literature, the long thoracic nerve was always found on, or posterior to, MAL. It was therefore posterior to the chest wall markers in this study, which were 1 cm anterior to MAL. In contrast, LCBs were almost always found anterior to the markers.

Therefore, our findings support insertion just anterior to MAL (eg, 1 cm as used in this study), which would generally avoid the significant peripheral nerves of the lateral thoracic wall. As such, these data are consistent with instructions given by ETC and ATLS. However, the anterior and posterior extremes of the BTS safe triangle would put these nerves at risk.

Study limitations

Limitations of this study are acknowledged. The study was restricted by the number of cadavers available within the host medical school at the time. No statistical analysis has been presented on this data as the results would be effected by sample size and therefore potentially misleading. Thus, 32 sides in an elderly mainly Caucasian population requires that these results be viewed with caution when transferring the findings to clinical practice.

Of the seven cadavers with structural thoracic pathology, none affected the nipple, axilla, ribs or the neurovascular bundles of the lateral chest wall. There was no evidence that the pathologies in the cadavers had affected the results of the

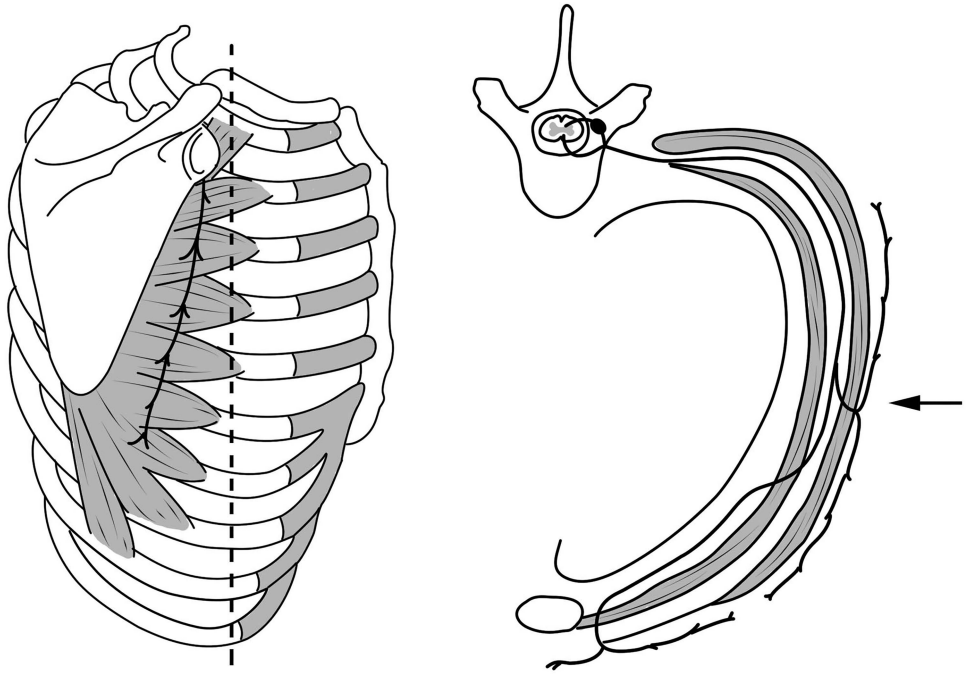

Figure 3 Position of the long thoracic nerve (left, midaxillary line (MAL) marked with hashed line) and lateral cutaneous branches of the intercostal nerves (right, MAL marked with arrow).

locating procedures used (ETC, BTS safe triangle or the ATLS guideline).

The authors accept that cadaveric anatomy, especially after fixation, does not perfectly replicate that of living patients. The skin and subcutaneous soft tissue is less pliable after the embalming process: rigidity of the axillary fold may cause the superior extent of the ETC method to start from a more inferior position. As mentioned in the 'Methods' section, the nipple position used in this study was that found in the supine, fixed cadaver. These marks therefore likely represent the highest level likely to be seen as more pliable breast tissue in living patients will potentially take a lower position. Consequently, the risk of chest drain insertion at a lower level in a clinical setting would be the same or greater.

It is acknowledged that the ribs and diaphragm adopt a position of exhalation at postmortem relaxation, and in life vary with phase of respiration. The authors do not feel that these changes would significantly influence the relationship of the lateral thoracic wall skin to underlying intercostal spaces. The question of whether the dome of the diaphragm extends above the fifth intercostal space was not the focus of this study.

Potential for error may also arise from the position of the pectoral girdle. For example, with the shoulder elevated in the 'shrugged shoulder' position, the ETC method would locate a higher intercostal space than if the shoulder was depressed. Nevertheless, care was taken during this study to replicate the procedure in the clinical setting and it currently represents the only available assessment of the ETC guideline.

As the cadaveric joints have limited mobility, the upper limb could not be fully abducted (and the hand placed behind the head) as recommended in the BTS safe triangle guidelines.[1 4] It is foreseeable that the thoracic skin will move superiorly in relation to the underlying ribs upon full abduction of the glenohumeral joint. Consequently, the effect this has on nipple position, and subsequent intercostal space found, could not be determined in this study but would merit further investigation.

CONCLUSIONS

While limitations of this study are acknowledged, these initial data suggest current guidelines risk inferior placement of chest drains, which in turn risk injury to abdominal viscera. With respect to the peripheral nerves, a site just anterior to MAL (eg, 1 cm) appears suitable.

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Competing interests PD is a member of the European Trauma Course teaching committee and is a contributor to the development of their guidelines.

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