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Research article

Identifying a safe site for intercostal catheter insertion using the mid-arm point (MAP)

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ABSTRACT

Background: Over 85% of chest injuries requiring surgical intervention can be managed with tube thoracostomy/intercostal catheter (ICC) insertion alone. However, complication rates of ICC insertion have been reported in the literature to be as high as 37%. Insertional complications, including the incorrect identification of the safe zone chest wall location for ICC placement, are common issues, with up to 41% of insertions occurring outside of this safe area. A new biometric approach using the patient's proportional skeletal upper limb anatomy to allow correct identification of the chest wall skin site for ICC insertion may reduce complications.
Aim: The aim of this study was to examine the performance of the mid-arm point (MAP) method in identifying the safe zone for ICC insertion.
Methods: Thirty healthy volunteers were recruited from The Alfred Hospital, a Level I Adult Trauma Centre in Melbourne, Australia. Blinded investigators used the MAP to measure the mid-point of the adducted arm of each volunteer bilaterally. A skin marking was placed on the anterior axillary line of the adjacent chest wall, and with the arm then abducted to 90 degrees, the underlying intercostal space was identified.
Results: Using the MAP method, all of the 120 measurements fell within the 'safe zone' of the fourth to sixth intercostal spaces bilaterally. The median intercostal space identified was the fifth space, with investigators finding this in 86% of measurements independent of age, sex, height, weight or side.
Conclusion: A simple technique using the MAP is a reliable marker for the identification of the safe zone for ICC insertion in healthy volunteers. The clinical utility for patients undergoing pleural decompression and drainage needs prospective evaluation.

Keywords: Intercostal catheter, emergency medicine, pleural decompression, pneumothorax

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INTRODUCTION

Injury is the leading cause of mortality, morbidity and disability in those under the age of 45 years, and contributes significantly to total life years lost.[1] In the severely injured, thoracic trauma is a common presentation, directly resulting in 25% of all deaths due to trauma, as well as partially contributing to a further 25–50%.[2] Of those patients with severe thoracic injury requiring a surgical procedure, 85% can be managed with large-bore tube thoracostomy or intercostal catheter (ICC) insertion alone.[3] The technique of ICC insertion for pleural decompression is a core skill in trauma resuscitation. However, ICC-related complications have been reported to be as high as 37%,[4] with the majority of these complications associated with incorrect insertion sites and poor tube positioning.

Incorrect identification of the chest wall skin site for insertion of an ICC is a commonly recognised issue. ICCs are safely inserted in the fourth, fifth, or sixth intercostal space in the mid-axillary line.[5,6] ICC placements lower than this increase the risk of iatrogenic diaphragmatic injury, intra-abdominal placement and potentially life-threatening visceral injury. More cephalad sites result in greater technical difficulty during insertion, an increased risk of bleeding from the pectoralis muscle, neural damage or damage to the breast in women.[7,8] The fifth intercostal space in the anterior axillary line is most commonly quoted as the 'ideal' location for ICC insertion in the literature.[9]

Poorly inserted ICCs can lead to tube malposition, which is an issue with a prevalence as high as 30%.[10] Malpositioned tubes are significantly more likely to give rise to more complicated and longer hospital admissions, increased infection rates and higher numbers of undrained haemo- or pneumothoraces.[11,12]

Despite the implementation of various guidelines, such as the Advanced Trauma Life Support program, the British Thoracic Society's triangle of safety, and the European Trauma Course, complications resulting from incorrect ICC insertions continue, with up to 56% of junior doctors being unable to identify the safe zone for insertion.[13,14] The majority of errors in the selection site are related to sites that are too low and are indicative of the difficulty in identifying this safe zone, even on a healthy individual. A recent study demonstrated this high incidence of iatrogenic injuries that result from improper ICC insertion, with almost 1% of all insertions within the hospital resulting in a visceral injury, and overall complication rates of pleural decompression reported at 22%.[15] In 2014, up to 41% of ICC insertions in a high volume institution were reportedly placed outside the safe zone.[16]

Few biometric approaches to assist in identifying the correct site for ICC insertion have been considered previously. Whilst the nipple has been proposed to correlate with the fifth intercostal space, the inherent variability of the nipple location on the chest wall, particularly between males and females, renders this an unreliable marker.

Following a detailed review of landmarks and options during trauma reception and resuscitation, the authors (MF and FB) proposed that the arm, with its' relationship to the thoracic wall, could be an ideal marker for ICC insertion. The hypothesised benefit is the proportional skeletal relationship to the patient's own thoracic anatomy.

The aim of this study was to determine if the ipsilateral mid-arm point (MAP) is a reliable chest wall skin marker for 'safe' ICC insertion.

METHODS

The study was conducted using a convenience sample of 30 healthy volunteers at The Alfred Hospital, a Level I Adult Trauma Centre in Melbourne, Australia. Patients were recruited using advertising flyers distributed around the hospital site. Demographic variables (age, sex, height and weight) were collected for all participants.

In order to simulate the positioning of a trauma patient during initial trauma reception and primary survey, the participant was placed in a cervical collar in a fully supine position. To perform the MAP method, the ipsilateral arm was fully adducted in the anatomical position, with the elbow flexed to 90 degrees and the forearm in mid-pronation. A length of tracheostomy tape was passed from the tip of the acromion to the tip of the olecranon and folded in half to determine the midpoint (Figure 1).

Using this midpoint as a reference point, the tape was rotated perpendicular to the arm to identify the corresponding intercostal space on the chest wall in the anterior axillary line. This interspace was marked with an erasable marker pen (Figure 2).

The arm was then abducted to 90 degrees to reproduce the 'crucifix' positioning used for ICC insertion, and clinical palpation was undertaken, counting downward from the second interspace, to determine which interspace this pen marking lays over (Figure 3).

Figure 1. **Images showing measurement of the midpoint. The patient is supine with the elbow flexed to 90 degrees. The midpoint is located as the halfway point between the olecranon and the acromion.**

The skin marking was made with the arm adducted moved superiorly with abduction. Accordingly, the examiners were instructed to only identify the underlying interspace when the arm was abducted to 90 degrees.

Four experienced consultant trauma physician investigators, each with at least 10 years of clinical experience in trauma reception and resuscitation (92 years total experience, mean 23), independently performed the localisation procedure. Each of the 30 participants underwent MAP measurement bilaterally by two investigators, yielding a total of 120 measurements. The investigators were blinded, with measurements performed in separated, screened environments, with all pen markings erased fully between the two investigators measuring the same subject.

The second intercostal space was identified bilaterally and the intercostal spaces – including that underlying the skin marking – were sequentially identified. There were no participants for which the investigators indicated that this was unable to be performed.

The primary outcome measure was to determine whether the skin site over the interspace measured with the arm in 90-degree abduction would fall between the fourth and sixth interspace and correspond to a ‘safe zone’ for ICC insertion. Investigators were fully briefed on the technique for arm measurement prior to the study commencement. Skin markings were removed from the participants before examination by the second investigator. All data were manually collected and

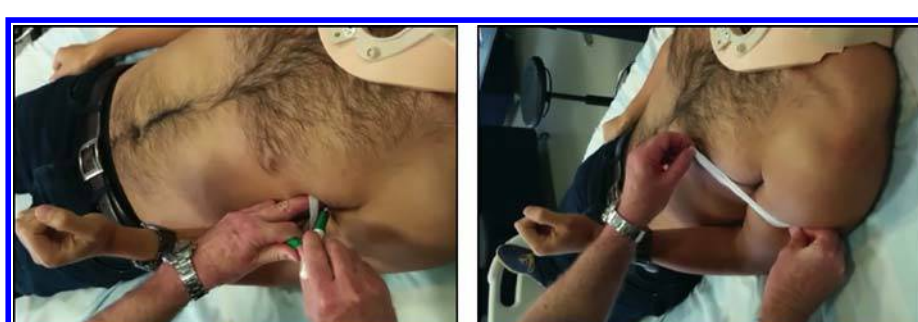

Figure 2. **Images showing marking of the intercostal space. The interspace at the level of the midpoint of the arm is identified and marked with a pen while the arm remains in adduction.**

Figure 3. Images showing the palpation of the intercostal space. Clinical examination was used to determine which interspace correlated with the pen marking.

transcribed into a Microsoft Excel spreadsheet. Statistical analysis was performed using Stata version 13.1 (©StataCorp LP, College Station, Texas 77845, USA). Any potential predictive relationship between the outcome and the independent variables of age, sex, height, or weight was assessed using univariate logistic regression. Two-sided values of $p < 0.05$ were considered statistically significant. Although the fourth, fifth, and sixth interspaces are all considered to be safe, the fifth intercostal space is most commonly quoted as the ideal location for ICC insertion. For statistical modelling, the fifth intercostal space was considered to be the most ideal, with each rib space away from this level sequentially carrying less weight.[9]

Ethics approval was gained from the Alfred Health Human Ethics Committee prior to commencement of the study.

RESULTS

The study involved 30 volunteers, predominantly males in their mid-20s (Table 1). The mean BMI of the participants was 23.7, ranging from underweight to obese categories. All those who volunteered were included in the study.

The median intercostal space identified using the methodology described was the fifth, with 86% of measurements within this space. All 120 measurements fell within the safe zone of fourth to sixth interspaces [fourth interspace: 2 (1.7%); fifth interspace: 103 (85.8%) and sixth interspace: 15 (12.5%)].

As all measurements fell into the safe zone, the primary outcome of localising a safe interspace was shown to be successful at 100%. For the purposes of regression analysis, the 'most ideal' location was considered to be the fifth intercostal space, with the results dichotomised accordingly. The participants' age, sex, height and weight were each examined using logistic regression, as well as left- and right-sided measurements. No statistically significant result emerged from these analyses, $p > 0.05$ (Table 2).

Table 1. Participant demographics.

Median age	**25.5 (IQR 24.0–29.8)**
Sex (male)	N 17/30 (0.57)
Mean height (cm)	173.3 (158–193, SD 10.1)
Mean weight (kg)	71.8 (50–111, SD 15.7)
Mean BMI	23.7 (18.1–30.1, SD 3.5)

Table 2. Logistic regression analysis of participant demographics.

	Left side	Right side
Height (cm)	OR = 1.07 (CI 0.97–1.18), $p = 0.20$	OR = 1.06 (CI 0.98–1.15), $p = 0.18$
Weight (kg)	OR = 1.04 (CI 0.98–1.11), $p = 0.19$	OR = 1.04 (CI 0.98–1.09), $p = 0.18$
Age	OR = 1.42 (CI 0.98–2.08), $p = 0.06$	OR = 1.02 (CI 0.93–1.13), $p = 0.64$
Sex	OR = 3.81 (CI 0.68–21.48), $p = 0.13$	OR = 2.25 (CI 0.56–9.00), $p = 0.25$

DISCUSSION

This study has investigated the use of a new anatomical marker for ICC site selection using MAP to accurately identify a safe interspace for pleural decompression and ICC insertion in healthy volunteers. Eighty-six percent of measurements were over the fifth intercostal space in the anterior axillary line, with all measurements over the 'safe' zone between the fourth and sixth interspaces.

The majority of complications associated with ICC insertion during trauma reception and resuscitation arise from iatrogenic injuries during insertion, and the subsequent location and positioning of the tube. While a small number of insertional complications occur secondary to pathological factors such as cardiomegaly[17] or pleural adhesions,[7] the majority of trauma patients are young, without chronic illness and with a low prevalence of co-morbidities. Using this new method of skin site incision localisation, it may be possible to standardise the practice of ICC insertion site selection and reduce the potential for iatrogenic insertion complications.

The evaluation of any potential confounding relationships were conducted using regression analyses (Table 2). A consideration surrounding the introduction of an anatomical marker may be its limited use in certain patient demographics, and possible effects of independent predictors, such as height or weight influencing its accuracy. However, the results of this analysis are consistent with the hypothesis grounded in the biological plausibility that an individuals' thoracic and limb anatomy are in proportion to each other. The findings from the regression analysis suggest that this clinical tool can be used as a biometric marker for safe ICC insertion – irrespective of age, sex, height or weight.

The study sample was skewed towards a younger age group (median age of 25.5 years), which is representative of the major trauma population.[18] Although males were slightly over-represented within the study population, 73% of all major trauma patients and 77% of trauma patients requiring ICC insertion at The Alfred Hospital are male.[18,19] A possible caveat to the use of this approach is the potential effect of body mass index (BMI). Given the demographic of the sample population as predominantly healthy and young individuals, the mean BMI was within the healthy range at 23.7. However, two participants were considered underweight with BMIs of less than 18.5, while eleven participants were overweight, with BMIs greater than 25. One participant was recorded with a BMI greater than 30, thereby placing them in the obese category. Thus, 47% of participants were outside of the healthy BMI range, yet 100% of measurements remained within the safe site for ICC insertion. A further understanding of any potential effect of BMI upon the MAP method will be derived from a future prospective study with a larger sample size.

Although not measured in this pilot study, it is assumed that the MAP method is time-efficient and can realistically be performed in a time-critical situation. It provides the equivalent of an anatomic checklist and its simplicity lends itself to the multi-dimensional trauma environment, where several interventions may be taking place simultaneously.

Ninety percent of trauma-related deaths occur in developing countries.[20] The total death rate from injury is also 2.4 times higher in remote locations when compared to major cities.[21] The lack of trauma systems, inexperience, and limited access to resources render trauma care within these areas suboptimal. The introduction of this basic MAP tool may standardise the procedure of pleural decompression of ICC insertion for trauma patients. Furthermore, the MAP may improve pre-hospital pleural decompression. Pre-hospital needle decompression to relieve tension in the pneumothorax has been shown to be unreliable. Catheters may easily block, kink or become dislodged, allowing a tension pneumothorax to reaccumulate.[22] Needles often fail to reach the pleural space at all and are ineffective in decompressing the pleural space.[23,24] Within many Helicopter Emergency Medical Services (HEMSs), there has been a shift away from the use of needles entirely, with emergency medical crews instead employing the technique of simple finger thoracostomy in the fifth intercostal space.[25] The MAP could play a role in this practice and facilitate pre-hospital pleural decompression.

This study has limitations. The study measures a small cohort size of healthy volunteers being selected as a convenience sample. However, the participants' demographics were similar to those of the typical major trauma population.

Clinical palpation of the ribs has been argued as an inferior method of determining interspaces when compared to CT. The highest level of validity testing would have involved comparing the use of this new technique against the gold-standard of CT-imaging. However, this would have involved subjecting healthy participants to radiation in this pilot study. Also, the skin site was measured with the ipsilateral arm abducted to 90 degrees – a position not used during CT chest scanning. Having the arm overhead or adducted may yield an intercostal space that is respectively higher or lower than that identified during pleural decompression and ICC insertion.

The independent investigators selected were highly experienced emergency and trauma consultant physicians, within a high-volume Level I Trauma Centre with a low ICC complication rate of 7.6%.[19] With current best practices for this procedure usually still relying on senior physicians' judgment and clinical examination skills, the investigators' ability to palpate the intercostal spaces was deemed to be the appropriate pragmatic benchmark for this study. This measurement method may also be limited in some cases, when the ipsilateral humerus or pectoral girdle is injured and prevents the appropriate positioning of the arm in abduction. Additionally, in cases of burns or previous surgery causing scarring, the skin mobility over the chest wall may be limited, thereby affecting the accuracy of the approach. Using the contralateral arm as a guide in these circumstances will need to be prospectively validated.

This pilot study provides the foundation for future research in improving the technique of ICC insertion. The data from this research may be utilised towards formulating a prospective, CT image-guided study to confirm the value of the midpoint of the arm as a localising biometric marker for ICC insertion.

CONCLUSION

This study which investigated the use of a new anatomical marker (MAP) for ICC site selection, demonstrated that the mid-point of the ipsilateral adducted arm was able to accurately identify a safe interspace for skin incision for chest tube insertion, when the arm was abducted 90 degrees with the subject supine. The data from this study serves as a valuable first step towards advancing the procedure of pleural decompression in trauma patients.

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