Original Article

Do mannequin chests provide an accurate representation of a human chest for simulated decompression of tension pneumothoraxes?

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BACKGROUND: Tension pneumothorax (TPX) is an uncommon but life-threatening condition. It is important that this uncommon presentation, managed by needle decompression, is practised by paramedics using a range of educationally sound and realistic mannequins. The objective of this study is to identify if the chest wall thickness (CWT) of training mannequins used for chest decompression is an anatomically accurate representation of a human chest.

METHODS: This is a two-part study. A review of the literature was conducted to identify chest wall thickness in humans and measurement of chest wall thickness on two commonly used mannequins. The literature search was conducted using the Cochrane Central Register of Controlled Trials, MEDLINE, CINAHL, and EMBASE databases from their beginning until the end of May 2012. Key words included chest wall thickness, tension pneumothorax, pneumothorax, thoracostomy, needle thoracostomy, decompression, and needle test. Studies were included if they reported chest wall thickness.

RESULTS: For the literature review, 4 461 articles were located with 9 meeting the inclusion criteria. Chest wall thickness in adults varied between 1.3 cm and 9.3 cm at the area of the second intercostal space mid clavicular line. The Laerdal® manikin in the area of the second intercostal space mid clavicular line, right side of the chest was 1.1 cm thick with the left 1.5 cm. The MPL manikin in the same area or on the right side of the chest was 1.4 cm thick but on the left 1.0 cm.

CONCLUSION: Mannequin chests are not an accurate representation of the human chest when used for decompressing a tension pneumothorax and therefore may not provide a realistic experience.

KEY WORDS: Chest wall thickness; Tension pneumothorax; Chest decompression; Mannequin anatomical accuracy; Emergency medical technicians

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INTRODUCTION

Tension pneumothorax (TPX) is an uncommon but life-threatening condition, which is most commonly associated with major trauma.^[1] Specifically, TPX is highly correlated with chest trauma resulting in rib fractures, with a great number of rib fractures being associated with a higher probability of developing a TPX.^[2] The treatment for TPX involves emergency chest decompression via needle,^[3] which is often performed in the prehospital, emergency room, or ICU environment.^[1]

In 2002, the Victorian ambulance service attended

1 319 cases that involved either penetrating or blunt injury to the thorax, which accounted for only 2.5% of all trauma cases.^[4] The incidence of TPX varies across populations and has not been well established because it is in part due to figures often reporting suspected TPX, rather than an actual diagnosis.^[1] The incidence rate of TPX has been reported internationally as between 0.7% to 30% of major trauma patients.^[5–8] The incidence rate of prehospital TPX in Australian studies varies between 14.5% and 35%.^[6,9,10] These international and Australian studies have only included data from patients

presenting to a specific trauma center or by a specific mode of transport (helicopter), and hence may be an over representation of the true state incident rate.

The procedure for prehospital chest decompression undertaken by most paramedics is to locate the 2nd intercostal space, at the mid clavicular line, and to insert a 45 mm cannula at right angles to the chest, with the needle tip pointing towards the spine.^[11] Air escaping the cannula is indicative of TPX, however, absence of air escaping does not exclude TPX. When considering this method, a study by Barton et al^[12] reported that the most common complications were a failure to adequately penetrate the chest wall, and difficulty in inserting the cannula into the pleural space. In addition to the potential for the cannula to fail to reach the pleural space, there is also a danger inherent in advancing a needle deep to the pleural space, where it can cause damage to the underlying tissue, particularly lung tissue.

Because of the infrequent occurrence of TPX and its importance as a life-saving procedure, it is essential that practitioners are taught chest decompression utilizing a mannequin with a realistic CWT. Two commonly used mannequins are manufactured by Laerdal® and Medical Plastics Corporation (MPL). In order for these mannequins to be authentic and practical for use in training, they should exhibit a high degree of anatomical accuracy, which includes both the presence of anatomical landmarks and an appropriate chest wall thickness (CWT). The objective of this study was to identify if the chest wall thickness of training mannequins used for chest decompression is an anatomically accurate representation of a human chest.

METHODS

Design

This study was undertaken in two parts. Part 1

consisted of a review of the literature to identify CWT in humans. Part 2 consisted of the measurement of the chest wall thickness for two mannequins commonly used in prehospital education.

Procedures

In part 1, the search was conducted using the Cochrane Central Register of Controlled Trials, MEDLINE, CINAHL, and EMBASE databases from their beginning until the end of May 2012. Key words included chest wall thickness, tension pneumothorax, pneumothorax, thoracostomy, needle thoracostomy, decompression, and needle test. Studies were included if they reported chest wall thickness and excluded if they were non-English. The references of included articles were also reviewed to avoid missing relevant studies.

In part 2, a set of outside spring callipers were used to determine the chest wall thickness of a Laerdal® and an mannequin, in the area of the 2nd intercostal space, mid clavicular line. The callipers were closed until the chest wall at the second intercostal space, mid clavicular line, just moved between the calliper ends. The callipers were then placed on an engineering steel rule and the gap between the two calliper ends were measured.

RESULTS

Part 1

In total, 4 461 articles were retrieved through the literature search, and a total of 9 studies met the inclusion criteria.^[13–21] In the 9 studies, there were a total of 1 504 participants. The reported CWT for adults at the 2nd intercostal space, mid clavicular line varied between 1.3 cm and 9.3 cm. The mean CWT reported by the studies varied between 2.1 cm and 5.36 cm. Table 1 summarises the findings from these 9 studies.

Table 1. Basic vital signs and disease score before and after CRRT treatment

Leading author	Method of measurement	Total subjects (male)	Mean CWT (95%CI)	Mean age (range)
Britten, 1996 ^[13]	Ultrasound	54 (29)	3.2 cm (range 1.3–5.2 cm)	NR (18–55)
Marinero, 2003 ^[17]	CT scans	30 (30)	4.6 cm (NR)	NR
Givens, 2004 ^[14]	CT scans	110 (79)	4.24 cm (3.9–4.52 cm)	NR
Harccke, 2007 ^[15]	CT scans	101 (101)	5.36 cm (range 3.07–9.35 cm)	25.7 (19–48)
Stevens, 2009 ^[19]	CT scans	108 (82)	Male: 4.04 cm (NR) Female: 5.14 cm (NR)	43.5 (18–85)
Zengerink, 2009 ^[21]	CT scans	774 (604)	Left: 3.50 cm (NR) Right: 3.51 cm (NR)	40 (25–53)
Yamagiwa, 2010 ^[20]	CT scans	256 (192)	Right: 3.10 cm (NR) Left: 3.01 cm (NR) Total: 3.02 cm (NR)	48 (18–95)
McLean, 2010 ^[18]	Ultrasound	51 (33)	Male: 2.1 cm (1.9–2.3 cm) Female: 2.3 cm (1.7–2.7 cm)	35 (19–59)
Inaba, 2011 ^[16]	Manual measurement in cadavers	20 (14)	Left: 4.4 cm (2.8–6.1cm) Right: 4.5 cm (3.1–6.2 cm)	NR

NR: not reported.

Part 2

At the point of the 2nd intercostal space, mid clavicular line, the Laerdal® mannequin had a right sided CWT of 1.1 cm and a left sided CWT of 1.5 cm. The MPL mannequin had a right sided CWT of 1.4 cm and a left sided CWT of 1.0 cm.

DISCUSSION

The results of this study indicate that both Laerdal® and MPL mannequins do not provide an accurate representation of a human chest in relation to chest wall thickness. The Laerdal mannequin was, on average, between 0.8 cm and 3.3 cm thinner than the average CWT reported in the 9 studies. The MPL mannequin was, on average, between 0.9 cm and 3.4 cm thinner.

The skill of decompressing a tension pneumothorax (TPX) is a vital component of a clinician's skill-set and like other invasive skills should be practised regularly, ensuring that competence is maintained in procedural and recognition skills. As such, any deviation a training mannequin which exhibits from an anatomically correct

design could contribute to a failed decompression in the field. A practitioner must practise inserting the needle far enough to penetrate the pleural space, while still superficial enough not to damage any underlying vital structures. Thus, it is undesirable for a training mannequin to exhibit a CWT which is either too thin or thick. In fact, failed decompressions due to the needle not penetrating far enough has been cited as a common cause of failed decompression.^[12] While there are numerous reasons cited for this, anatomically inaccurate training mannequins may also contribute to failed chest decompression.

In addition to CWT anomaly, both mannequins had other inaccurate skeletal representations. For example, both mannequin chests had only the required skeletal parts necessary to accurately find the 2nd intercostal space, mid clavicular line, and therefore they lead the student towards the correct decompression site (Figures 1 and 2). Alternatively, higher fidelity mannequins, which often have a broader range of uses, contain additional components within the chest cavities, which may confound chest decompression, such as tubing, cables, or inflatable lungs.

Figure 1. The MPL mannequin chest anatomy.

Figure 2. The Laerdal mannequin chest anatomy.

Figure 3. The MPL mannequin skin cross-section.

Figure 4. The Laerdal mannequin skin cross-section.

Likewise, the rubber skin used to cover the chest of the mannequins (Figures 3 and 4) and the tension air bags underneath were both easily damaged by using a 14 gauge cannula which is a standard practice for most paramedics. As the purpose of each mannequin is to be reusable over a long period, this can enable students to use thinner gauge needles (20 g or 18 g) to prevent frequent replacement of both parts. Again, this is undesirable as it is a deviation from normal practice, and may contribute to a lack of experience in clinical practice. In addition, the skin surrounding the correct insertion site quickly may be marked with needle holes, again, providing a reference point for students, which is educationally unsatisfactory. This raises a question of whether such invasive skills should be practised with animal ribs or human cadavers.

Moreover, alternatives to mannequins have been used for many decades, such as animal parts like pork ribs. However, such an approach will not always be practical, cost effective, or religiously appropriate. Another consideration is for mannequins to be manufactured with a variable CWT, to better represent the varying CWT found in the general population. This may, however, result in mannequins which are not cost effective.

In addition to the reported CWT values, certain studies raised other salient points in regards to CWT in the general population. One study sampling male American military personnel^[15] reported that as age increased, CWT increased, though the age range was limited to 19–48 years. Several studies reported thicker chest walls in females,^[14,16,19,21] and one of them noted that females exhibit a wider range of thicknesses than males.^[22] One study noted that raising the patient's arms above their head increased the thickness by 10%–20%.^[21] Should an attempt be made to produce a more anatomically accurate mannequin, such factors could be taken into account when determining the appropriate CWT.

The findings of this study suggest that there is a need to review the teaching strategies and equipment used in simulated chest decompression. This may include the use of purpose made mannequins with a higher anatomical accuracy, particularly in regards to the CWT. This would then allow further analysis to determine if training with high fidelity mannequins leads to an increase in chest decompression success in the field.

A limitation of this study is that it did not investigate whether anatomical accuracy of CWT in training mannequins is beneficial to the success rate of chest decompression in the field. Further studies may wish to examine the success rate of chest decompression in

different medical populations using different training mannequins and techniques. In this study we investigated two commonly used mannequins and the results may not be truly representative of all mannequins available.

In conclusion, the results of this study indicate that both Laerdal® and MPL mannequins do not provide an accurate representation of a human chest in relation to CWT. This may lead to unrealistic and poorer quality training in the skill of tension pneumothorax decompression. The manufacture and use of anatomically accurate mannequins may lead to an increase in the success rate for chest decompressions in the field, which would improve patient outcomes.

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