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Basic Life Support providers' assessment of centre of the chest and inter-nipple line for hand position and their underlying anatomical structures

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ABSTRACT

INTRODUCTION

Effective chest compression is an integral part of good quality cardiopulmonary resuscitation. There remains uncertainty over the optimal method for identifying the correct hand position for chest compression. The aim of this study was to identify the relationship between basic life support (BLS) providers assessment of the inter-nipple line (INL) versus the centre of the chest (CoC) and to identify the anatomical structures underneath these land marks.

METHOD

Thirty consecutive patients having elective CT scans of the thorax were recruited and photographs of the patient fully clothed were taken in the supine position. 30 healthcare students trained in BLS were asked to mark the 'point between the nipples' and the 'centre of the chest' on each photograph in a random sequence. Corresponding points were marked on the CT images and the underlying anatomical structures were identified.

RESULTS

Hand positions using CoC landmark were significantly higher and were more variable than INL landmark (Measurement represented as ratio of sternal length: mean CoC 0.709, 95% CI 0.677, 0.740 vs mean INL 0.803 95% CI 0.772, 0.835; $p<0.0001$). Structures underneath CoC and INL hand positions were significantly different; CoC compressing predominantly the aortic arch and ascending aorta and INL compressing the left ventricle and left ventricular outflow ($p<0.001$). Hand positions were not significantly affected by gender of patients.

CONCLUSION

Both the centre of the chest landmark and inter-nipple line identify positions on the lower third of the sternum. The centre of the chest technique identifies a point that is consistently higher and more variable than the inter-nipple line. Structures compressed under both landmarks were different although the implications of this are unknown.

1. Background

Effective cardio-pulmonary resuscitation is a key link in the chain of survival.[1,2] There remains uncertainty over the optimal method for identifying the position on the chest where hands should be placed in order to perform external chest compression.[3, 4] The ideal position to place hands for chest compression needs to take account of (i) physiological response to chest compression at that position (ii) ease with which that position can be identified by CPR providers (iii) the risk of injury from chest compression at that position and (iv) CPR providers preference.

There is little scientific evidence regarding the optimum hand position for chest compressions and currently the International Liaison Committee on Resuscitation (ILCOR) has concluded that there is 'insufficient evidence for and against a specific hand position for chest compressions during CPR in adults'[3]. The paucity of evidence supporting one method over another has led to disparity between international guidelines with the AHA advocating that the rescuer should compress 'the lower half of the victim's sternum in the middle of the chest between the nipples'[3], referred to as the inter-nipple line (INL), whereas the ERC guidelines taught BLS providers to 'place the heel of one hand in the centre of the victim's chest' for chest compressions[4].

The aim of this study is to identify and compare BLS providers' assessment of the 'inter-nipple line' (INL) and 'centre of the chest' (CoC), and the relationship between these positions and underlying anatomical structures. BLS providers preferences of what technique compared to the other were also examined.

2. Method

2.1. Approval and Consent

Ethical approval was obtained from the Coventry Research Ethics Committee (09/H1210/5). Written consent was gained from the patients and the BLS providers respectively for their participation.

2.2. Participants

Thirty consecutive patients who attended Birmingham Heartlands Hospital for an elective computed tomography (CT) scan of the chest between February and May 2009 were recruited for this study. Patients under the age of 18 or had previous mastectomy were excluded from the study. Background data of age and sex were collected.

2.3. CT procedure and Photographs

The patients underwent a routine non-contrast high resolution CT scan of the chest. Toshiba Aquilion 16 slice CT scanner was used for the scans and images were archived and analysed using Picture archiving and communication system (PACS) Vitrea 2 Version 4.0 Vital Images (Plymouth, Minnesota, USA).

After the CT scans, two photographs were taken with each patient lying in a supine position fully clothed and with arms by their side. Two photographs were taken from a standard distance of 1 m using a Nikon D70s D-SLR 10 megapixel camera with field adjusted so the patient's face was excluded and no patient identifiable information was included. After taking one plain photograph, another photograph was taken with anatomical reference markers placed on the sternal notch and the xiphisternum for reference purposes. The plain photographs were printed on A4 paper to allow assessment of the centre of the chest and inter nipple lines. Reference photographs were only available to research team for measurement purposes.

2.4 Assessment of CoC and INL by BLS providers

Thirty first and second year healthcare students trained in European Resuscitation Council basic life support at the College of Medical and Dental Sciences, University of Birmingham, United Kingdom, were invited to take part in the study. Students were asked to mark with a cross where they think the 'centre of the chest' (CoC) is located and where they think 'a point midline between the nipples' (INL) in random sequence on separate photo images of the 30 patients. Photographs were randomised and students were asked to mark where they would place their hands for chest compressions using INL and CoC landmarks in random order, each position on a separate photograph. No grid or ruler was available to students.

The photographs with the reference markers were printed on A4 acetates and compared with the students' responses. The following measurements are calculated for both CoC and INL from the photographs: (Figure 1)

- Total sternal length – is sum of distance A (measured from the sternal notch to the estimate X) and distance B (measured from the estimate, X, to the xiphisternum).
- Estimates, X, for CoC and INL was calculated as a ratio of the length of the sternum (X_{COC} or X_{INL} = A/(A+B)).

CT scans were performed with the patients' arms up behind their head to reduce artefact for the chest scan. The position of the arms will affect surface anatomy but not intra-thoracic structures. Raising the arms can potentially raise the patients' nipple cephalad by an average of 2.2cm for males and 1.3cm for females.[5] In order to eliminate this effect, measurements from CoC and INL were calculated as ratios of sternum (e.g. 0.85 of total sternal length) from photographs. Anatomical positions of the estimates were then calculated by multiplying ratios by actual sternal length on CT scans (e.g. 0.85 x 131.8mm = 112.2mm).

2.5 Anatomical structures underneath COC and INL

In order to identify the anatomical structures under the estimates, the length of the sternum on the archived CT scans of the patients were measured for each patient *(Figure 2).* The anatomical structures were identified as either 'top of arch of aorta', 'top of ascending aorta', 'left ventricular outflow tract', 'root of aorta' and 'bottom of ventricles'. The distance from sterna notch to each structure was measured for each patient. The quality of one patient's CT scan was too poor to identify structures and was excluded from analysis. Structures underneath all 1740 estimates of CoC and INL were then identified from CT scans.

2.6 Attitudes towards locating hand positions

A short questionnaire was distributed to BLS providers to explore which technique they find the easiest to use and whether they would expose a patient's chest to locate hand position prior to commencing CPR.

2.7 Statistical Methods

The students' estimates of INL versus CoC were compared using repeated measure ANOVA. INL and CoC were inputted as between subject factors and the thirty patients as within subject factors. Greenhouse Geisser was used to correct for sphericity. Assessment of INL and CoC were compared with Bonferonni correction. The equality of variance between INL and CoC was compared using Levene's test. Corresponding underlying structures of both landmarks were analysed using Pearson chi square test. All analyses were conducted using SPSS PASW 17.

3. RESULTS

Thirty patients were recruited for this study. This group consisted of 20 males (70%) and 10 females (30%), with an average age of 60.5±15.0 and 50.0±14.8 respectively.

3.1 Assessment of COC and INL by BLS providers

BLS providers on average estimated the INL to lie more caudally along the sternum than the CoC. CoC (mean CoC 0.709, 95% CI 0.677, 0.740 vs mean INL 0.803 95% CI 0.772, 0.835) (Figure 3). Greater variability was found for CoC estimates than for INL (Levene's test $P < 0.001$). There were no differences in hand position estimates using both landmarks in male and female patients (CoC $p= 0.42$, INL $p= 0.073$).

3.2 Anatomical structures underneath COC and INL

Anatomical structures corresponding to each hand position using CoC and INL estimates were identified using the CT scans. Using the hand positions recorded, the majority of chest compressions would have taken place over the ascending aorta, with 48% of CoC and 38.6% of INL estimates. CoC estimates were distributed more cephalad with significantly more estimates landing above aorta, aortic arch and ascending aorta ($P<0.001$). INL estimates were more caudad with more estimates on left ventricular outflow tract and left ventricle ($p<0.001$) (Figure 4).

3.3 BLS providers' preference in hand position and exposure of patient's chest

24 (80%) of the BLS providers would not expose the victim's chest prior to commencing CPR. Eighteen (60%) preferred using the COC as landmark for hand position. We note with interest that 9 (75%) of the 12 providers who preferred using

the INL method of landmark identification, would not expose patient's chest before commencing CPR even though the location of nipples would be harder to determine when patient is fully clothed.

4. DISCUSSION

To our knowledge, there has been no previous research comparing the interpretation of the two landmarks for hand positions by BLS providers and their anatomical relations. Whilst manikin is often of standard shape and sizes, patients may have a wide variation in their thoracic shape and anatomical relations. [6] The main finding of this study was that the use of both INL and CoC techniques identify locations in the lower third of the sternum. The CoC approach identifies a point that is more cephalad and more variable in location than the INL. The two different landmark positions also correspond to different anatomical structures.

External chest compression, also known as external or closed-chest cardiac massage was first illustrated in humans by Kouwenhoven in 1960. Chest compression was described as placing 'heel of one hand with the other on top…on the sternum just cephalad to the xiphoid' and applying 'firm pressure vertically downwards'.[7] Reports of injury to intra-thoracic and intra-abdominal injuries from chest compressions led to re-examination of the hand position. [8-10] In 2002, Handley *et al* argued that the traditional method of identifying rib margins and xiphisternum with 2 fingers and sliding hand into centre of lower half of sternum was complex and involved too many psychomotor steps. By instructing rescuers to simply 'place hands in the 'centre of the chest' enhanced skill acquisition, performance and retention.[11] Their study led to the development of simplified hand positions of both the ERC 'centre of the chest' position and AHA 'between the nipples' approach.

Shin study evaluated the anatomical relations of the internipple line from CT scans of 189 adult patients and found that in 80% of cases, structures other than left ventricle was located under the internipple line.[5] Kusunoki investigated the safety of using the internipple line and argued that the landmark could lead to the xiphoid process being compressed in nearly half of the patients, potentially leading to the epigastrium being compressed especially in elderly female patients or patients with short stature.[12] Our study revealed that despite both approaches targeting the 'centre of the chest', both in fact identify a position in the lower third of the sternum, with the centre of the chest approach in a slightly higher location. The physiological consequences of these differences in position are likely to be small. The exact mechanism and haemodynamic effects behind chest compressions remain to be elucidated. The cardiac pump theory[7] of CPR suggests that compression directly over the ventricles is important to generate blood flow[13, 14] whilst in the thoracic pump theory where changes in intrathoracic pressures are at play, the actual structures compressed during cardiopulmonary resuscitation would appear less crucial with left ventricle acting more as a conduit.[15] In the present study the INL would result in significantly higher proportion of estimates compressing left ventricle (INL 19.1%, CoC 11.6%, $P<0.0001$). This finding is consistent with Shin group study which found that left ventricle would be under the inter-nipple line in 20.6% of cases.[5]

There is limited human data linking hand position to physiological effectiveness of chest compressions. Orlowski *et al* conducted a randomised controlled cross over trial in ten children who sustained a cardiac arrest whilst being monitored in the cardiac intensive care unit. Chest compressions at the lower one-third of the sternum (1.5 to 2 cm above the xiphoid) in children corresponded to the position of the ventricles on CT scan and were associated with higher systolic and mean arterial blood pressure than inter-nipple line[16]. Whether these observations would translate into a similar model in adults is unknown as is the precise impact of the 10% difference in sternal position seen in this study with the two different approaches.

Complications of chest compressions can be divided into skeletal injuries such as rib and sternal fractures; and damage to internal organs such as liver, spleen, lungs and heart[17, 18]. Skeletal injuries are inevitable when effective chest compressions are carried out, a correct hand position may help to reduce the incidence of adverse injuries. Some avoidable fractures are fractures to first and second rib including those at the sternochondral junction caused by too high hand position; and fractures of rib 6 through to 11 at the sternochondral junction by too low hand position[19]. The reported incidence of chest wall injuries varies from 3.5-89% for rib fractures and 2-31% for sternal fractures[17, 19, 20] but the true prevalence remains hard to determine as conventional chest radiographs on survivors provide only limited views[8, 21] and data from autopsy of cardiac arrest victims are limited to non-survivors. Serious abdominal organ injury caused by incorrect hand position such as splenic and liver rupture has a reported incidence of 0.3 to 30.8%[20]. In the present study there were minimal differences in the proportion of compressions below the ventricles (CoC 2% versus INL 2.9%) which suggests there would be unlikely to be any difference in injury patterns.

The 2005 guidelines from both the AHA and the ERC sought to simplify the approach to finding the correct hand location for chest compressions, with the aim of making it easier for volunteers to better understand and retain the techniques. Our results suggest that centre of the chest is the preferred method for rescuers with 60% of volunteers preferred the method for hand placement for chest compressions. 80% of volunteers would not remove the patient's clothing to aid in finding the anatomical landmarks such as the nipples, which included 75% of the few volunteers who preferred the method of 'a point between the nipples', arguably making the inter-nipple line an unreliable method. This preference may be unique to our study sample but we are not aware of any other study which has explored rescuers' preference of hand placement in CPR.

5. LIMITATIONS

As our study set out to assess whether using 'centre of the chest' or 'midpoint between the nipples' would lead to different hand positions, participants were asked to mark where their hands would be placed using the two landmark techniques. The investigators have tried to limit any effect of suggesting two separate locations by asking participants to mark each point in random order and on separate photographs. However, the effect of suggesting the possibility of different hand positions could not be precluded.

In this study, gender did not significantly affect hand positions. However, there were fewer female patients in our sample. Demographically, the proportion of males to females in this study matched the ratio for cardiac arrests in people aged under 65.[22] However, the majority of cardiac arrests happen in those older than 65 years old and as the age of those having a cardiac arrest rises, so does the proportion of women.

The present study used photographs of patients as opposed to actual patients. The BLS providers' interpretation of the landmarks could be hampered by the 2D nature of the images and the fact that the patients were photographed whilst clothed. Contrary to wide held perceptions, the removal of clothing does not improve hand placement and is associated with delays in the initiation of CPR. Moreover in the present study 80% of BLS providers stated that they would not remove outer clothes during CPR. A recent study by Mortensen found that undressing a manikin by laypeople before starting chest compressions could lead to a mean delay of 23 seconds (95% CI 19, 27) but no difference in quality of CPR performed (chest compression depth, p=0.16; correct chest compressions, p=0.15)[23]. Their results suggest that undressing the victim will only delay initiation of chest compressions with no added benefit.

6. CONCLUSION

Both the centre of the chest landmark and inter-nipple line identify positions on the lower third of the sternum. The centre of the chest technique identifies a point that is consistently higher than the inter-nipple line but at the same time centre of chest estimates are more variable. Structures compressed under both landmarks were different although the implications of this are unknown

Conflict of Interest

None declared.

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Legend for Figures and Tables

Figure 1 A schematic diagram showing the measurements taken

Figure 2 An illustration of how measurements were taken from CT scans of thorax. A represents top of aortic arch, B is top of ascending aorta, C is left ventricular outflow tract, D is root of aorta, E is bottom of ventricle.

Figure 3 Figure illustrating the location of hand position estimates using the two landmark techniques

Figure 4 Graph showing structures compressed under estimates of the two landmark techniques