Regular article

Comparison of quality of chest compression in different postures using a female patient manikin

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Abstract

Early cardiopulmonary resuscitation (CPR) intervention is critical for saving individuals experiencing sudden cardiac arrest. Manikins are considered useful for CPR training, but their level of realism is low, given the visible structural differences in the chests of biological men and women. However, to our knowledge, no study has examined whether a patient's sex has an impact on the performance of chest compression. Therefore, this study aimed to investigate the quality of chest compressions in female patients, in relation to the rescuers' posture. This single-center cross-sectional study was conducted from July to October 2023 on 34 healthcare professional university students. Two postures for chest compression were analyzed: 1) kneeling beside the patient's chest (conventional compression) and 2) straddling the patient (straddle compression). The mean age of the 34 participants (18 men and 16 women) was 21.2±0.6 years. Significant differences were found in mean compression depth (p = 0.005) and appropriate compression ratio (p = 0.013) between the conventional and straddle compression but not in other parameters. In conclusion, the rescuers' posture during chest compression in female patients affects the compression depth and depth ratio. The straddle compression may facilitate the provision of well-balanced compressions of appropriate depth and depth ratio. These findings can be applied to CPR training and provide guidance for

administering chest compressions to female patients.

Keywords: Chest compression, Straddle compression, Manikin, Female patient, Silicone

女性患者マネキンを用いた胸骨圧迫の姿勢による質の比較

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要旨：突然の心停止に対して、早期の心肺蘇生介入が重要である。訓練用マネキンは教育上有用であると考えられているが、リアルさのレベルが低い。その理由には、生物学的な男女の胸部の人体構造の違いが挙げられる。しかし、我々の知る限り、患者の性別が胸骨圧迫の質に影響を与えるという推測を支持または反証する研究はない。そこで、本研究では女性患者マネキンに対する胸骨圧迫の質について、胸骨圧迫の姿勢に着目して検討した。本研究は単一施設横断研究であり、2023 年 7 月から 10 月にかけて 34 名の医療専門職大学生を対象に実施した。胸部圧迫の姿勢として、1）患者の胸の横に膝をついた姿勢（従来圧迫法）、2）患者をまたいだ姿勢（またぎ圧迫法）の 2 つを分析した。対象者 34 名（男性 18 名、女性 16 名）の平均年齢は 21.2±0.6 歳であった。平均圧迫深度（$p = 0.005$）および圧迫深度適正率（$p = 0.013$）において、従来圧迫法とまたぎ圧迫法の間に有意差が認められたが、その他のパラメーターには有意差は認められなかった。またぎ圧迫法は、適正な圧迫深度と深度適正率のバランスのとれた圧迫を提供することを容易にする可能性がある。これらの知見は CPR トレーニングに応用でき、女性患者への胸骨圧迫のエビデンスとなり得ることが示唆された。

Introduction

Sudden cardiac death is a potentially fatal event that can occur at any time. Early high-quality cardiopulmonary resuscitation (CPR) intervention is critical for saving the lives of individuals experiencing sudden cardiac arrest. Chest compression-only CPR has been associated with increased survival and favorable neurological outcomes after out-of-hospital cardiac arrest[1]. Therefore, in emergency situations, bystanders should promptly perform chest compression as a first aid measure.

Traditionally, CPR training is performed with manikins[2,3]. However, although manikins are considered useful for training because they are "realistic representations of actual human patients"[4], some argue that their level of realism is low, given the differences in the anatomical structure of the chest between biological men and women. In a study that used digital photographs of men's and women's chests to identify the correct hand placement for chest compression, laypersons tended to identify areas farther away from the recommended position they were instructed; further, the range of misplacement was found to be greater in the digital photographs of women[5].

However, to our knowledge, no study has examined whether a patient's sex has an impact on the performance of chest compression. The only study that utilized a female patient manikin reported that rescuers tend to place their hands improperly when

performing chest compression on a female simulated patient, because they try to avoid touching the nipples[6]. The change in hand placement when performing chest compression on female patients may indicate that the rescuer is consciously or unconsciously trying to avoid touching the female's breasts as much as possible. Therefore, in such cases, well-balanced chest compressions cannot be delivered, and the hand placement and posture during chest compression in female patients should be reconsidered.

Chest compressions performed in the straddle posture (i.e., sitting on the pelvis of the patient) have been found to be qualitatively equivalent to those performed in the conventional posture (i.e., kneeling beside the patient)[7,8]. Moreover, in the straddle chest compression techniques (straddle compression), the hand placement is aligned with the sternum during compression, thus allowing the first-aid provider to avoid touching the breasts. However, since no previous study has focused on chest compression quality in female patients, this assumption is not corroborated by scientific data. Therefore, this study aimed to investigate the quality of chest compressions in female patients, in relation to the rescuers' posture.

Materials and methods

Study design

This study was a single-center cross-sectional study. Power analysis using the free software G*Power[9] yielded a target sample size of 34, given an effect size of 0.5, α-error of 0.05, and power of 0.8.

Participants

The study lasted from July to October 2023. Participants were recruited from among healthcare professional university students. The inclusion criteria were as follows: having attended CPR training within the past 5 years and no current disease that would interfere with measurements (e.g., orthopedic disorder of the upper limbs, neurological and cardiac diseases, etc.). Participants whose chest compression depth was <5 cm and those who were unable to maintain a compression pace of 100–120 compressions per minute (cpm) during the preliminary training were excluded. The study was approved by the Research Ethics Committee of the International University of Health and Welfare (approval number: 22-Io-16). Written informed consent was obtained after all the participants were fully informed of the research purpose. In all, 34 participants were included.

Setting up of the simulated patients

We used two Resusci Anne QCPR manikins (manufactured by Laerdal): the first was used for training, with no modifications to the manikin body, and the second was used for final measurements, following modifications to represent a female patient (Fig. 1), with the addition of silicone breasts and a bra. As regards breast size, we took the C cup size as a reference as it is fairly common among Japanese women[10], and, considering the overall age, we went down one size and used a B cup size (difference between the female patient's bust and underbust was approximately 12 cm).

Two postures for chest compression were analyzed: the first was the conventional chest compression techniques (conventional compression) of kneeling beside the patient’s chest and the second was the straddle compression (straddling the patient). The experimental protocol began with a 30-s training session using the training manikin, in which participants performed chest compression with a depth of about 5 cm (no more than 6 cm), compression pace of 100–120 cpm, and full chest recoil, followed by a 5-min interval. The order in which chest compressions were performed in the two postures by the same participant was randomized.

Parameter measurements and data were recorded using SimPad PLUS with SkillReporter (manufactured by Laerdal). Data on the following measures of chest compression quality were collected: mean compression depth (mm), appropriate

compression depth ratio (%), appropriate recoil ratio (%), mean compression tempo (cpm), and appropriate compression tempo ratio (%).

Fig. 1 Preparation of the female patient simulator (left: outerwear view; right: underwear view)

Statistical analysis

The Shapiro–Wilk test was performed to ensure the normality of data, followed by either a paired t-test or a Wilcoxon signed-rank test, with a significance level of 5%. All statistical analyses were performed using IBM SPSS Statistics 29.0 (IBM Corp., Armonk, NY, USA).

Results

The mean age of the 34 participants (18 men and 16 women) was 21.2±0.6 years. Table 1 shows each parameter based on the rescuers' posture during chest compression. The mean compression depth was significantly higher in the straddle compression than in the conventional compression (p = 0.005). The appropriate compression depth ratio was significantly higher in the straddle compression than in the conventional compression (p = 0.013). No significant differences were observed in other parameters between the

conventional and straddle compression.

Table 1. Comparison of each parameter of chest compression (n = 34)

Discussion

Several studies examining the quality of chest compressions in relation to rescuers' sex and different postures have been conducted; however, none have been performed with female patients. Thus, male examinees were reported to show a more proper compression depth and appropriate compression depth ratio in the conventional compression compared to female examinees[11], while in another study the same parameters for the straddle compression were reported to be adequate regardless of the examinees' sex[12]. However, the straddle compression study focused on chest compressions performed on a stretcher, not on the floor. Although simple comparison is difficult, it may be inferred from the above results that, because of more robust physical features such as weight and muscular strength, male examinees were able to provide higher chest compression quality regardless of posture.

In this study, all the parameters for chest compression in the female patient simulator modified with silicone breasts and a bra were compared in relation to the rescuers' posture. The results showed that the mean compression depth was 49.0 mm for the conventional

compression and 52.5 mm for the straddle compression. As per the American Heart Association guidelines 2020[13], which recommends a compression depth of about 5 cm, the above results indicate that, when performing chest compression on a female patient, the straddle compression may facilitate appropriate compression depth, closer to the recommended value. However, a study examining the relationship between chest compression depth and survival to hospital discharge rates[14] reported that the appropriate compression depth ranges from 40.3 to 55.3 mm, with the optimal depth being 45.6 mm. Considering our findings, it can be said that even in the conventional compression, the chest compression depth was not too shallow to affect the results negatively. On the other hand, the appropriate compression depth ratio between the conventional and straddle compression showed a difference of 26.5 percentage points, possibly because of specific factors related to the rescuers' posture during chest compression. In our study, silicone breasts and a bra were added to the manikin's body to mimic the anatomical structure of the female chest, giving the manikin substantial thickness and elasticity. When performing chest compression using the conventional compression, the rescuers placed their hands across the silicone breasts with the fingertips placed towards the nipples. This may have resulted in less-than-adequate adherence of the hands to the sternum, making the delivery of well-balanced compressions difficult, as the deeper the compression is,

the more the fingers come into contact with the breast. On the contrary, in the straddle compression, the placement of hands between the silicone breasts (aligned with the sternum during compression) not only allowed the rescuer to avoid touching the breasts but also facilitated appropriate compression depth and depth ratio. The results of the study support our hypothesis that the straddle compression allows rescuers to perform higher-quality chest compressions than the conventional compression.

A limitation of this study is that it utilized a manikin, albeit one that mimicked the realistic anatomy of a female patient. Although the silicone breast form used in the study was representative of the breasts of adult women, it is not clear whether the size, shape, and sagging of breasts caused by aging affect the quality of chest compression. Women's cup sizes can vary in different countries worldwide. Generally, they are larger in North America and Europe but smaller in Asia than in the rest of the world. Therefore, considering cup size in the assessment of chest compression quality holds significance. In view of these important limitations, caution should be exercised in generalizing these results. Moreover, although the straddle compression improved the quality of chest compression, there are concerns that it may exert a compressive force on the patient's abdomen and that the act of straddling a person, even a patient who is experiencing cardiac arrest, may be socially unacceptable. For instance, a severely obese individual

may have difficulty in maintaining the correct posture during chest compression, and for a pregnant patient, the effect of straddling on the mother and fetus must also be considered. Therefore, the effectiveness of the straddle compression for female patients should be further investigated so that a public consensus can be reached. It should also be noted that rescuer's sex may also affect the quality of chest compression. However, since this study was not designed to examine sex differences, we were unable to determine sex differences in chest compression quality in relation to different postures.

In conclusion, our findings suggest that the rescuers' posture during chest compression in female patients affects the compression depth and depth ratio. The straddle compression may facilitate the provision of well-balanced compressions of appropriate depth and depth ratio. The results of this study can be applied to the current field of CPR training and provide guidance for administering chest compressions to female patients.

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Conflicts of Interest

The authors have no conflicts of interest to disclose.

Contributions

KK and YH conceptualized the study design and protocol and selected the research institution. IS, IH, KA, and IY were responsible for data collection and organization. KK, IS, IH, KA, and IY were responsible for data analysis and interpretation. KK and YH were responsible for drafting the manuscript. The manuscript submitted was critically reviewed, revised, and approved by all the authors.

Availability of data and materials

Raw data were generated at International University of Health and Welfare. Derived data supporting the findings of this study are available from the corresponding author KK on request.

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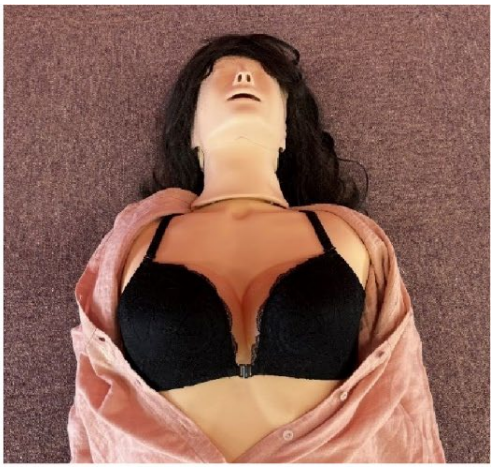

Table 1. Comparison of each parameter of chest compression (n = 34)

	Conventional	Straddle	*p*-value
Mean compression depth (mm)	49.0 (41.8–54.0)	52.5 (47.8–55.3)	0.005[a)]
Appropriate compression depth ratio (%)	56.0 (8.0–95.8)	82.5 (26.0–100.0)	0.017[a)]
Appropriate recoil ratio (%)	99.5 (67.8–100.0)	98.0 (80.8–100.0)	0.622[a)]
Mean compression tempo (cpm)	114.5 (111.8–119.0)	116.0 (111.8–118.3)	0.610[a)]
Appropriate compression tempo ratio (%)	93.0 (50.0–99.0)	90.0 (56.5–99.3)	0.302[a)]

The data are expressed as the median (25^{th}–75^{th} percentile)

[a)] Wilcoxon signed-rank test