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Coronary perfusion pressure and compression quality in maternal cardiopulmonary resuscitation in supine and left-lateral tilt positions: A prospective, crossover study using mannequins and swine models

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ABSTRACT

Objective: The risk of maternal and fetal mortality is high if cardiopulmonary arrest occurs during pregnancy. To assess the best position for maternal cardiopulmonary resuscitation (CPR), a prospective randomized crossover study was undertaken, involving basic life support mannequin-based simulation (BLS-MS) and a swine model of pulseless electrical activity (an unstable cardiac state) incorporating a fetal mannequin (PEA-FM).

Study design: The BLS-MS (performed by certified rescuers) served to evaluate the quality of chest compressions in 30° left lateral tilt (LLT) and supine positions. Based on a 5-point scale, each rescuer subjectively graded their experience. The PEA-FM model was used to compare coronary perfusion pressure readings during CPR in supine, supine with left uterine displacement, 30° LLT, and 30° right lateral tilt positions. Compression rate and correctness of hand position, compression depth, and recoil were measures of compression quality (BLS-MS).

Results: Compared with LLT position, supine position enabled correct hand position (rate: 0.99 vs 0.88; $p < 0.05$) and compression depth (rate: 0.76 vs 0.36; $p < 0.001$) significantly more often. Moreover, BLS-MS rescuers found chest compressions significantly easier to perform with the mannequin in supine (vs LLT) position (difficulty score: 1.75 vs 3.95; $p < 0.001$). In the PEA-FM study arm, supine position with left uterine displacement and right lateral tilt positions had the highest and lowest recorded coronary perfusion pressure readings, respectively.

Conclusion: Supine position with left uterine displacement is optimal for maternal CPR.

Introduction

Cardiopulmonary arrest in pregnant women carries a high risk of maternal and fetal mortality [1,2], placing the survival of both in jeopardy. First responders have approximately 4 min to initiate cardiopulmonary resuscitation (CPR) for maternal cardiac arrest, thereafter calling for emergency caesarian section [3]. Because of the toll already exacted on cardiac, respiratory, gastrointestinal, and reproductive systems in pregnant women, reduced chest compliance and residual capacity, as well as diminished cardiac output (owing to uterine compression of the inferior vena cava) constitute important challenges for resuscitative efforts during pregnancy [1,4].

Other studies of pregnant women have indicated that left lateral tilt position (LLT) improves maternal hemodynamic parameters; however, adopting a full lateral position for maternal CPR may substantially decrease the effectiveness of chest compressions and affect the feasibility of caesarean delivery [5–7]. Soar et al. have reported that the ability to provide effective chest compressions declines as the angle of LLT increases, with mannequins tending to roll at angles >30° [8]. However, upon investigating the hemodynamic effects of right lateral tilt (RLT) and LLT (5° and 10°) in pregnant women, Ellington et al. discovered no significant difference in maternal blood flow [9]. Matorras et al. also saw no obvious benefit for LLT in instances of emergency caesarean delivery, finding maternal parameters (blood pressure, heart rate) similar for partial left lateralization and supine position [10]. Finally, a more recent mannequin study by Butcher et al. has

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shown comparable effectiveness of chest compressions in both supine/uterine displacement and lateral tilt positions, suggesting that either method may be suitable for maternal CPR [11]. These studies demonstrate the lack of a definitive protocol for CPR in an obstetric setting. Because related clinical trials involve ethical and practical concerns, development of suitable preclinical models of maternal cardiac arrest and resuscitation is essential for instituting effective CPR interventions in pregnant women.

The present study entailed use of a basic life support mannequin simulation (BLS-MS) to evaluate CPR effectiveness, comparing 30° LLT tilt and supine positions. A 5-point questionnaire then served to score the ease of performing CPR. Position-dependent changes in coronary perfusion pressure (CPP), a major indicator of CPR effectiveness [12], were also assessed. For this purpose, a novel swine model of maternal CPR was devised, incorporating pulseless electrical activity (PEA) cardiac arrest and a fetal mannequin (PEA-FM).

Materials and methods

Study design

This prospective randomized crossover study was conducted at Yokohama Advanced Cardiovascular Life Support (BLS-MS arm) and Kobe Medical Device Development Center (PEA-FM arm) between 2008 and 2012. To measure CPR parameters such as compression rate and hand position, certified rescuers performed chest compressions on a mannequin placed in either supine or 30° LLT position, using an adjustable bed (comparable to an operating room table) as platform. The degree of tilt was protractor-verified in each instance. Participants provided their own assessments of the difficulty encountered during each procedure. The medical ethical review board of Kanazawa University approved the study protocol.

To measure CPP at different positions, fetal mannequins were placed within abdominal cavities of four pigs, subsequently inducing PEA cardiac arrest in these animals. The Animal Experiment Committee of the Intervention Technical Center for the use of laboratory animals in the Kobe Medical Device Development Center granted approval for this aspect of the study.

BLS-MS participants, protocol, and outcome measures

Twenty rescuers $\geq$ 18 years old and certified as competent in American Heart Association (AHA) basic life support (BLS) volunteered for this investigation. All participants provided written informed consent, and all completed the study successfully.

On a random assignment basis, each BLS rescuer performed simulated chest compressions on a mannequin (Resusci Anne Simulator; Laerdal Medical, Stavanger, Norway) placed in either supine or 30° LLT position, continuing for 2 min in the position first assigned, resting for 10 min, and then repositioning the mannequin and repeating CPR for 2 min in the second assigned position. The 2-min intervals for CPR conformed to AHA BLS guidelines of 2005 and 2010. To avoid potential bias, rescuers were blinded to the monitor screen displaying compression rate or hand position. Analysis of all collected data involved proprietary methods (PC Skill Reporting System; Laerdal Medical).

The primary outcome measure was chest compression quality (stipulated as a compression depth of 50–60 mm, hand positioned on the lower half of the sternum, and recoil to within 5 mm of baseline chest height) and rate (number of compressions executed in 1 min). As a secondary outcome, rescuers scored the ease of

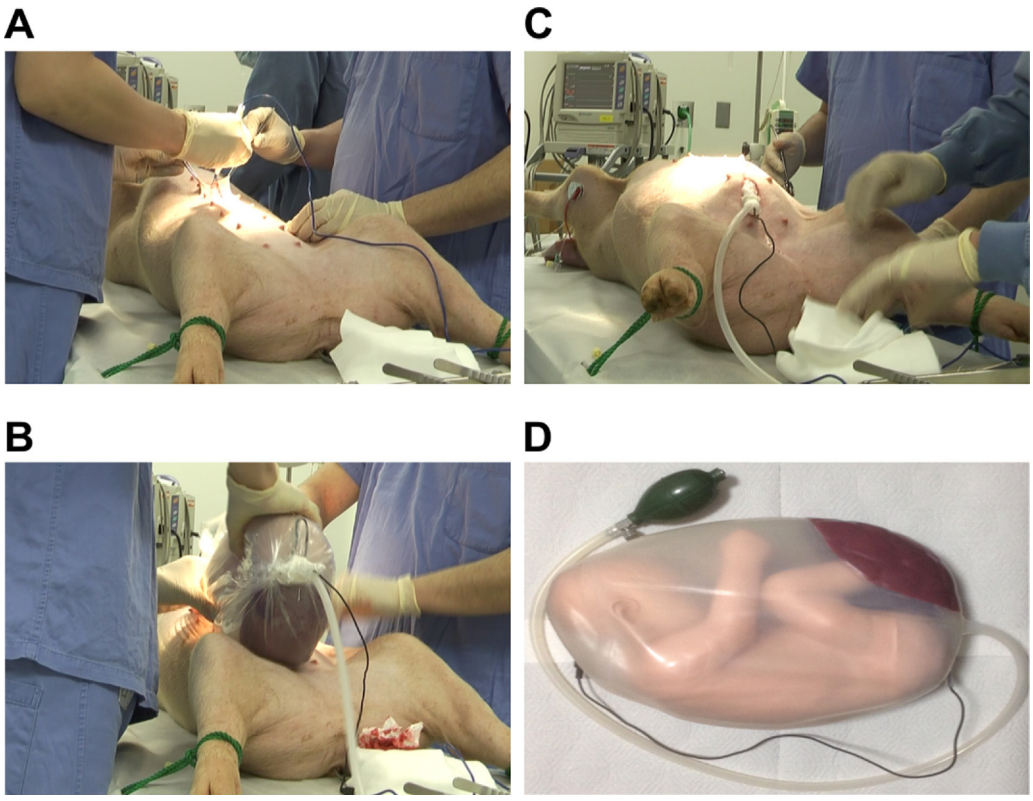

Fig. 1. Preparation of swine model for maternal CPR.
A–C: Fetal mannequin placed intra-abdominally in sedated pig and positioned against inferior vena cava, inserting a Swan-Ganz catheter to monitor arterial and central venous pressures; D: Fetal mannequin, consisting of full-body pregnancy simulation fetus with amnion (LM-105; Koken Co Ltd, Tokyo, Japan). Abbreviations: CPR, cardiopulmonary resuscitation.