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Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression–decompression techniques☆

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Abstract

Background: Complete chest wall recoil improves hemodynamics during cardiopulmonary resuscitation (CPR) by generating relatively negative intrathoracic pressure and thus draws venous blood back to the heart, providing cardiac preload prior to the next chest compression phase.

Objective: Phase I was an observational case series to evaluate the quality of chest wall recoil during CPR performed by emergency medical services (EMS) personnel on patients with an out-of-hospital cardiac arrest. Phase II was designed to assess the quality of CPR delivered by EMS personnel using an electronic test manikin. The goal was to determine if a change in CPR technique or hand position would improve complete chest wall recoil, while maintaining adequate duty cycle, compression depth, and correct hand position placement. Standard manual CPR and three alternative manual CPR approaches were assessed.

Methods and results: Phase I—The clinical observational study was performed by an independent observer noting incomplete chest wall decompression and correlating that observation with electronically measured airway pressures during CPR in adult patients with out-of-hospital cardiac arrest. Rescuers were observed to maintain some residual and continuous pressure on the chest wall during the decompression phase of CPR, preventing full chest wall recoil, at some time during resuscitative efforts in 6 (46%) of 13 consecutive adults (average ± S.D. age 63 ± 5.8 years). Airway pressures were consistently positive during the decompression phase (>0 mmHg) during those observations. Phase II: This randomized prospective trial was performed on an electronic test manikin. Thirty EMS providers (14 EMT-Basics, 5 EMT-Intermediates, and 11 EMT-Paramedics), with an average age ± S.D. of 32 ± 8 years and 6.5 ± 4.2 years of EMS experience, performed 3 min of CPR on a Laerdal Skill Reporter™ CPR manikin using the Standard Hand Position followed by 3 min of CPR (in random order) using three alternative CPR techniques: (1) Two-Finger Fulcrum Technique—lifting the heel of the hand slightly but completely off the chest during the decompression phase of CPR using the thumb and little finger as a fulcrum; (2) Five-Finger Fulcrum Technique—lifting the heel of the hand slightly but completely off the chest during the decompression phase of CPR using all five fingers as a fulcrum; and (3) Hands-Off Technique—lifting the heel and all fingers of the hand slightly but completely off the chest during the decompression phase of CPR. These EMS personnel did not know the purpose of the studies prior to or during this investigation. Adequate compression depth was poor for all hand positions tested and ranged only from 29.9 to 48.5% of all compressions. When compared with the Standard Hand Position, the Hands-Off

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Technique decreased mean compression duty cycle from 46.9 ± 6.4% to 33.3 ± 4.6%, ($P < 0.0001$) but achieved the highest rate of complete chest wall recoil (95.0% versus 16.3%, $P < 0.0001$) and was 129 times more likely to provide complete chest wall recoil (OR: 129.0; CI: 43.4–382.0). There were no significant differences in accuracy of hand placement, depth of compression, or reported increase in fatigue or discomfort with its use compared with the Standard Hand Position.

Conclusions: Incomplete chest wall decompression was observed at some time during resuscitative efforts in 6 (46%) of 13 consecutive adult out-of-hospital cardiac arrests. The Hands-Off Technique decreased compression duty cycle but was 129 times more likely to provide complete chest wall recoil (OR: 129.0; CI: 43.4–382.0) compared to the Standard Hand Position without differences in accuracy of hand placement, depth of compression, or reported increase in fatigue or discomfort with its use. All forms of manual CPR tested (including the Standard Hand Position) in professional EMS rescuers using a recording manikin produced an inadequate depth of compression more than half the time. These data support development and testing of more effective means to deliver manual as well as mechanical CPR.

Keywords: Cardiac arrest; Cardiopulmonary resuscitation (CPR); Chest compression; Emergency medical services; Out-of-hospital CPR; Paramedic

1. Introduction

Complete chest wall decompression during the performance of cardiopulmonary resuscitation (CPR) is recommended in the current American Heart Association (AHA) [1] and European Resuscitation Council [2] guidelines. Complete chest wall recoil improves hemodynamics during CPR by generating relatively negative intrathoracic pressure and thus draws venous blood back to the heart, providing cardiac preload prior to the next chest compression phase [3–5]. We hypothesized that incomplete decompression during the performance of CPR increases the frequency and duration of positive intrathoracic pressure, inhibiting venous blood return to the right heart and decreasing the hemodynamic effectiveness of CPR. The hemodynamic effects of incomplete chest wall recoil in a porcine model of cardiac arrest are the subject of a companion paper by Yannopoulos et al. in this issue of 'Resuscitation' [6].

In this report, we present a two-phased translational research initiative. Phase I was an observational case series to evaluate the quality of CPR performed by emergency medical services (EMS) providers on patients with an out-of-hospital cardiac arrest. Rescuers were observed at some point during resuscitative efforts to maintain residual and continuous pressure on the chest wall during the decompression phase of CPR, thus preventing complete chest wall recoil. This led to the generation of two important questions: (1) Would vital organ perfusion pressure increase if the chest were allowed to fully recoil during CPR?; and (2) Would a change in manual CPR technique improve the likelihood of obtaining full chest wall recoil during CPR? The companion paper by Yannopoulos addresses the first question. Phase II of this study was designed to answer the second question by: (1) assessing the quality of CPR delivered by EMS providers using an electronic recording manikin; and (2) determining if a change in CPR technique would improve complete chest wall recoil, while still maintaining adequate duty cycle, compression depth, and correct hand position placement. Standard manual CPR and three alternative manual CPR approaches were assessed.

2. Phase I

2.1. Methods—clinical observation study

This study was performed with an exception from informed consent requirements for emergency research (21 section CFR Part 50.24) following community consultation and public notification. It was part of, but unrelated to, another study of a new CPR device for which the Food and Drug Administration had approved an investigational device exemption. The Human Research Review Committee at the Medical College of Wisconsin and seven additional Institutions Research Committees representing 13 receiving hospitals in the Milwaukee area approved the study.

The clinical observation study was performed in the City of Milwaukee, where basic life support (BLS) and advanced life support (ALS) EMS personnel respond in a tiered manner. All EMS personnel were certified in BLS and completed an AHA CPR course within the previous 24 months. Care was provided according to AHA guidelines. For the study, an additional research team including a physician and paramedic was dispatched to the scene of each patient. Entry criteria for the study were: (1) adult patients (presumed or known to be ≥21 years) believed to be in cardiac arrest of presumed cardiac etiology, and (2) patients who were successfully intubated with a tracheal tube who were undergoing CPR at the time of scene arrival of the research team. A portable pressure monitor (Propaq®, Welch Allyn Protocol Inc., Beaverton, OR) was used for non-invasive electronic measurement of tracheal pressures, a surrogate for intrathoracic pressures. Following arrival at the scene and after patient intubation, the research team connected the non-invasive airway pressure sensor between the tracheal tube and the bag-valve resuscitator. Ventilations and compressions were then recorded until resuscitation attempts were discontinued or the patient was resuscitated. Research personnel at the scene of cardiac arrests observed rescuers' performance of ventilation rate, ventilation duration, and chest wall recoil (the focus of this report).