

A Chest Compression Quality Evaluation Using Mechanical Chest Compressions under Different Working Situations in the Ambulance

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Received 15 January 2015; accepted 3 August 2015; published 6 August 2015

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Abstract

Objectives: The aim of this study was to analyze the quality of chest compressions in different working situations pertaining to ambulance crews using either standard chest compressions (S-CC) or LUCAS mechanical chest compressions (L-CC) in a manikin setting. **Participants and Methods:** Cardiopulmonary resuscitation (CPR) was performed using a compression to ventilation ratio of 30:2 with both S-CC and L-CC. Quality parameters were collected using a modified manikin enabling impedance measurements. The evaluation was performed in two manikin scenarios: Scenario 1 evaluated ten minutes of CPR on the ground and Scenario 2 assessed six minutes of CPR in different settings relevant to work in the ambulance. Quality parameters compared were: time to apply LUCAS, hands-off fraction, number of correct chest compressions and the rate of compressions. **Results:** In Scenario 1 the hands-off fraction was higher when S-CC was performed (S-CC group 29% vs. L-CC 16%, $P = 0.003$). We found a higher number of chest compressions (S-CC = 913 vs. L-CC = 831, $P = 0.0049$) and a higher rate of chest compressions (S-CC = 118 vs. L-CC = 99, $P < 0.0001$) in the S-CC group. In Scenario 2 we noted a higher hands-off fraction for S-CC (39% vs. L-CC = 19%, $P = 0.003$), but a higher number of compressions given during S-CC ($n = 504$) vs. L-CC ($n = 396$) $P = 0.0002$. **Conclusion:** Mechanical chest compression with the LUCAS 2™ device enables ambulance personnel to provide high quality chest compression even while transporting the patient.

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Keywords

Cardiac Arrest, Mechanical Chest Compression, External Chest Compressions, LUCAS CPR, Resuscitation

1. Introduction

In recent cardiopulmonary resuscitation (CPR) guidelines, there has been increased focus on the quality and continuity of chest compression [1] [2]. But ambulance personnel must perform cardiopulmonary resuscitation (CPR) in many different situations that may influence both the quality and continuity. Earlier experimental work [3] has shown that pauses in chest compression have a negative impact on coronary and cerebral flow and thus may decrease the likelihood of both return of spontaneous circulation (ROSC) and survival [4]. One possible way of improving chest compressions quality in the ambulance setting may be the implementation of mechanical chest compressions devices (L-CC). Previous experimental and human studies have shown that these devices improve coronary and cerebral flow parameters compared to standard chest compressions (S-CC) [5]-[7]. When evaluating quality parameters from those studies, it is evident that attaining S-CC quality in the ambulance setting is difficult [8]-[10]. Even with repeated training, high quality S-CC is hard to achieve [11]-[14]. One of the major reasons is personnel fatigue, which impairs quality during S-CC [15]. Study results are sometimes inconsistent in that some studies report quality impairment after a few minutes while other studies show adequate quality S-CC for 10 minutes [13]-[16]. This may be due to the inherent variability of the S-CC technique. Previous studies have shown the usefulness of the information obtained from impedance measurements, when evaluating the quality of standard S-CC and L-CC [17]-[20]. Impedance measurements make it possible to evaluate chest compression pauses, frequency, ventilation, defibrillation pauses and, depending on the equipment used, even depth and recoil [20]. The aim of our current study was to evaluate the effects on chest compression quality between L-CC and S-CC when CPR is performed by ambulance personnel in a manikin setting using a chest compression and ventilation ratio of 30 compressions with a pause for two ventilations (30:2). This ratio is chosen because, over time, endotracheal intubation has become less frequent in the ambulance service [21].

2. Material and Methods

2.1. Study Design

This study complies with current Swedish laws for clinical research and was performed at the ambulance organization at the Emergency Department, Värnamo County Hospital, Sweden. To enroll participants for this study, the investigator (Pär Lindblad) recruited participants in a randomized manner from those who had been trained to use the LUCAS device (Physio-Control Sweden/Jolife AB, Lund, Sweden). The majority of ambulance personnel volunteered outside of working hours and they were neither paid nor given any financial incentive to participate in the study. Participants had received advanced life support (ALS) training within three months of starting the study. The LUCAS 2™ device training was done six months prior to the study according to company recommendations. All participants were allowed to test the manikin to make sure that they could reach the expected depth. The CPR quality parameters were collected using CODE-STAT 8.0 from Life Pack 12 defibrillators (Physio-Control Inc., Redmond, USA).

One ALS Skillmaster 4000 (Laerdal, Stavanger, Norway) was modified with two cords placed at a depth of 4.5 cm inside the manikin, which is the average depth according to the resuscitation guidelines of 2005. This allowed impedance recordings to be taken when the compression exceeded this depth. These cords were connected to the electrodes on the manikin and then connected to the defibrillator pad cable which registered impedance wave forms (Figure 1). The manikin was adjusted to avoid deflection of the back since this has been shown to affect the accuracy of depth measurements [22].

In Scenario 1, the manikin was stationary on the floor, where 10 minutes of CPR was performed. In Scenario 2, the participants started with two minutes of CPR on the floor, then moved the manikin over to the stretcher (AllfaFernoNorden AB, Trollhättan, Sweden) with a fixed height of 70 cm) and performed an additional four

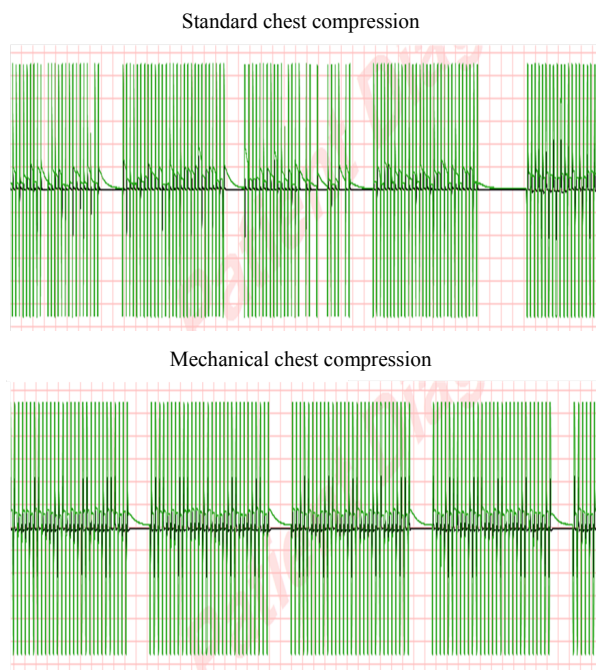


Figure 1. The figure shows a typical example of the impedance measurements using the two chest compression techniques performed in the manikin evaluation.

minutes of CPR, two minutes outside and two minutes inside the ambulance, to simulate a situation where the patient was being transported. The ambulance did not move during Scenario 2. Ambulance personnel worked in pairs in both scenarios (**Figure 2**), this being the routine in the ambulance organization and therefore used for this study. In the S-CC group, participants followed the recommendation to change chest compression provider every two minutes. In both groups, pauses in chest compressions were made when loading the manikin onto the stretcher and into the ambulance; otherwise, instructions were given to keep the pauses to a minimum. Both scenarios were performed using CPR in the 30:2 ratio and complying with recommendations regarding depth and frequency from the resuscitation guidelines of 2005, since these were being used clinically during the study period. The following quality parameters were evaluated in both scenarios:

- 1) Time interval to apply LUCAS (seconds);
- 2) Hands-off fraction (% of time);
- 3) Number of correct compressions (n);
- 4) Chest compression rate (compressions/minute).

2.2. Statistics

All data are presented as median (min-max). The Mann-Whitney U-test was used for statistical comparison and a P-value < 0.05 was considered significant.

3. Results

3.1. Scenario 1

The CPR quality parameters were evaluated for 10 pairs of randomly selected ambulance personnel. The time interval to apply LUCAS was 23 seconds (12 - 32). The total hands-off fraction was higher when S-CC was performed: 29% (17% - 32%) vs. L-CC 16% (16% - 44%), $P = 0.0003$ (**Figure 3**). The total number of compressions exceeding 4.5 cm was higher in the S-CC group (S-CC = 913 (779 - 963) vs. L-CC = 831 (794 - 846), $P < 0.0001$). The compression rate was higher when S-CC 118 (97 - 125) was performed compared to L-CC 99 (99 - 100), $P < 0.0001$.

Two and ten minutes on the floor



Two minutes on the stretcher



Two minutes in the ambulance



Figure 2. The different manikin scenarios used in the study. These pictures show the three different scenario settings when standard chest compression is performed, the manikin and the equipment used.

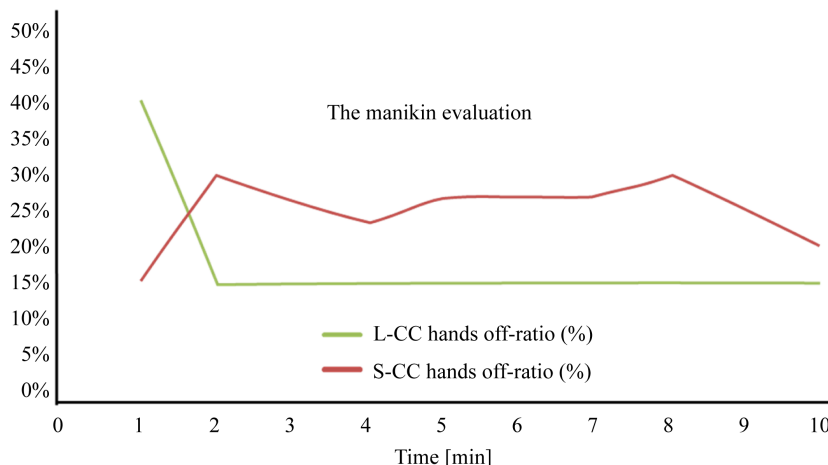


Figure 3. Median chest compressions ratio (%) during 10 minutes of standard chest compression (S-CC) and LUCAS mechanical chest compression (L-CC) in Scenario 1. This includes pauses in chest compressions for LUCAS application and ventilation.

3.2. Scenario 2

Seventeen pairs of randomly selected ambulance personnel were evaluated in this scenario. The time to apply LUCAS in this setting was 11 seconds (8 - 30). During the first two minutes on the floor, there was a higher chest compression rate noted when S-CC was performed (111 (89 - 118)) compared to L-CC (99 (99 - 99) $P < 0.0001$). During the two minutes of CPR on the stretcher, a higher hands-off fraction was noted in the S-CC group (58% vs. 21%), and a lower total number of compressions given exceeding 4.5 cm (S-CC group = 98 (0 - 164) vs. L-CC group = 156 (146 - 164), $P < 0.0001$). During the 2 minutes of chest compressions performed in the ambulance, there was a higher hands-off fraction (S-CC group = 22% (9% - 100%) vs. L-CC group 13% (11% - 13%), $P = 0.0041$), and the chest compression rate was higher (108 (91 - 132) vs. 99 (99 - 99), $P = 0.002$) in the S-CC group. When combining the three scenarios (*i.e.* six minutes of CPR) the hands-off fraction was higher when S-CC was performed (39% vs. L-CC = 19%, $P < 0.0001$). The individual variations for both techniques regarding hands-off fraction can be seen in [Figure 4](#).

4. Discussion

It was apparent that there are chest compressions quality differences between the two scenarios when using either S-CC or L-CC in working situations faced by ambulance personnel. A high chest compressions rate affected the number of pauses when S-CC was performed in 30:2 and increased the total hands-off fraction compared to when L-CC was used. It has been shown that a low proportion hands-off fraction is important if ROSC is to be achieved [23] [24]. We noted a higher chest compression rate during S-CC compared to guideline recommendations from both 2005 and 2010 [2]. Compared to recommendations in the 2010 guidelines regarding chest compressions rate, only 28% of the S-CC performed was within the recommendation of 100 - 120 compressions per minute.

We also noted various degrees of difficulty when performing chest compressions at a depth of over 4.5 cm for different ambulance personnel in Scenario 2, *i.e.* on the stretcher and in the ambulance, when chest compressions were done by S-CC, as shown in a previous study [8]. One reason for lack of chest compression depth when S-CC is performed might be that the participants were poorly trained [25], even though training followed the local recommendations. Another explanation might be that the training environments are seldom relevant to the clinical setting [26]. Yet another explanation could be the individual provider's physical size. In earlier studies, the difference in individual CPR providers' physical size has been shown to affect the ability to perform high quality chest compressions even in children and young adults [27]. In Scenario 2 ([Figure 4](#)) we noted a large variation between the teams when they started to move the patient, which is consistent with findings from a previous study [10]. The contribution of psychological stress factors that occur in real clinical cardiac arrest situations [28] is less likely since the participants were informed about the evaluation. There is a risk/benefit

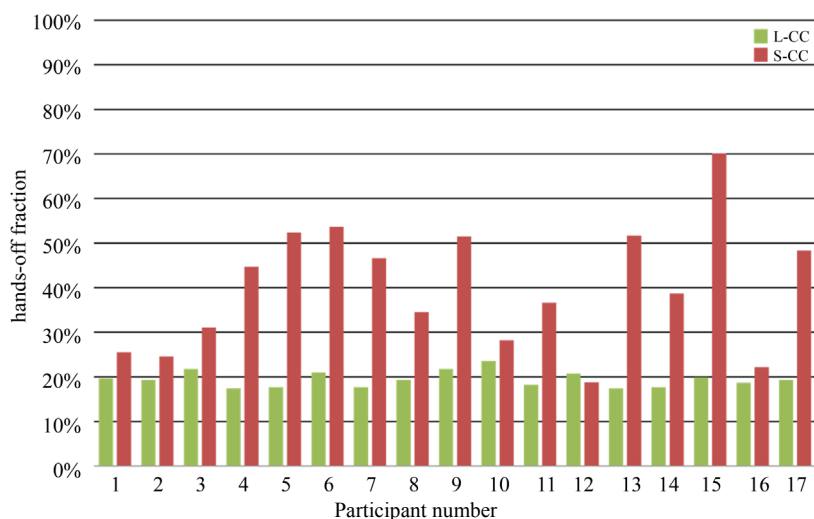


Figure 4. Individual hands-off fraction (%) during three CPR situations relevant to the clinical ambulance service. The median individual hands-off fraction (%) during six minutes of CPR using standard chest compression (S-CC) and LUCAS mechanical chest compression (L-CC). This includes pauses in chest compressions for LUCAS application, ventilation, loading onto the stretcher and into the ambulance, as well as incorrect depth (*i.e.* <4.5 cm).

consideration when conducting S-CC in the ambulance. Patients may need transportation yet ongoing S-CC is unsafe for the ambulance crew. In this situation it seems reasonable to use L-CC, as a report from Asia and US have suggested [29]. However, it is important to provide high quality S-CC, and having a mechanical chest compression device does not diminish the attention of this required of the personnel. Moreover, individual differences have been seen regarding the application time of the L-CC. Therefore S-CC as the initial treatment before the first defibrillation of VF seems to be the most appropriate strategy [30]. The application time of the L-CC device should be an important consideration when using a L-CC device, because the perceived time taken for the transition between S-CC and L-CC might not reflect the measured time [20]. It is also a matter of training and, if this process is monitored and measured, it is possible to shorten the application time and therefore reduce the hands-off fraction [31]. Chest compressions quality might be the most important factor for the group of patients that do not initially respond to defibrillation and/or do not achieve ROSC [18]. It is not enough simply to go along with current standards, saying, “push hard and push faster” because this will not assure quality CPR [32]. We found that an increased chest compressions rate also increases the number and length of pauses and therefore the total hands-off fraction, which could reduce the chances of achieving ROSC [23]. To perform high quality chest compressions requires a combination of depth, rate and duty cycle, to allow for full recoil and short hands-off fractions [33] [34] and this was best provided by L-CC in the present study.

Limitations

ALS manikins are made for education and training purposes, not for precise CPR depth measurements. According to the manufacturer, it measures CPR depth with an accuracy of $\pm 15\%$. The surface beneath the manikin’s back has also been shown to affect the reliability of depth measurements [22]. To minimize this effect, the space beneath the manikin’s back was filled to minimize deflection from the back of the manikin. We were not able to measure chest recoil in this setting, which also is an important factor for high quality CPR [35]. The number of years of training and the situations in which training is performed varies between different personnel and this could affect the results seen. The use of a metronome would be one way to control the compression rate but this was not used in this study [36].

5. Conclusion

Mechanical chest compression with the LUCAS 2™ device enables ambulance personnel to provide high quali-

ty chest compression even while transporting the patient.

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