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Brief Report

LUCAS compared to manual cardiopulmonary resuscitation is more effective during helicopter rescue—a prospective, randomized, cross-over manikin study☆

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Abstract
Objective: High-quality chest-compressions are of paramount importance for survival and good neurological outcome after cardiac arrest. However, even healthcare professionals have difficulty performing effective chest-compressions, and quality may be further reduced during transport. We compared a mechanical chest-compression device (Lund University Cardiac Assist System [LUCAS]; Jolife, Lund, Sweden) and manual chest-compressions in a simulated cardiopulmonary resuscitation scenario during helicopter rescue.
Methods: Twenty-five advanced life support–certified paramedics were enrolled for this prospective, randomized, crossover study. A modified Resusci Anne manikin was employed. Thirty minutes of training was allotted to both LUCAS and manual cardiopulmonary resuscitation (CPR). Thereafter, every candidate performed the same scenario twice, once with LUCAS and once with manual CPR. The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions.
Results: LUCAS compared to manual chest-compressions were more frequently correct (99% vs 59%, $P < .001$) and were more often performed correctly regarding depth (99% vs 79%, $P < .001$), pressure point (100% vs 79%, $P < .001$) and pressure release (100% vs 97%, $P = .001$). Hands-off time was shorter in the LUCAS than in the manual group (46 vs 130 seconds, $P < .001$). Time until first defibrillation was longer in the LUCAS group (112 vs 49 seconds, $P < .001$).
Conclusions: During this simulated cardiac arrest scenario in helicopter rescue LUCAS compared to manual chest-compressions increased CPR quality and reduced hands-off time, but prolonged the time interval to the first defibrillation. Further clinical trials are warranted to confirm potential benefits of LUCAS CPR in helicopter rescue.

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1. Introduction

1.1. Background

After cardiac arrest, high-quality chest-compressions are of paramount importance for survival and good neurological outcome. Unfortunately, even healthcare professionals have difficulty performing effective cardiopulmonary resuscitation (CPR). Chest-compressions often are too shallow; hands-off time is too long [1], and CPR performance deteriorates over time [2]. During helicopter transport, chest-compression effectiveness may be further reduced due to movements of the vehicle, confined space and prevailing safety regulations [3]. Such limiting factors could be the cause of low survival rates reported in helicopter transported cardiac arrest patients [4].

1.2. Importance

Mechanical chest-compression devices deliver uninterrupted chest-compressions of a predefined depth and rate. Thus, chest-compression devices may play an important role in maintaining good quality CPR in specific circumstances where CPR is difficult to perform, for example, helicopter transport, or when CPR has to be performed over a long period, for example, during hypothermic cardiac arrest [5,6]. However, data supporting this assumption are limited [7]. We hypothesized that the Lund University Cardiac Assist System (LUCAS; Jolife, Lund, Sweden) could improve chest-compression quality during helicopter transport compared to manual CPR. LUCAS is an electrically powered piston device providing 4 to 5 cm deep chest-compressions and active decompressions back to the neutral position with a frequency of 100 min^{-1} and a duty cycle of 50%.

1.3. Goal of this investigation

The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions with LUCAS compared to manual CPR [8,9]. Secondary outcome measures were compression depth, pressure point, complete pressure release, and compression rate as well as hands-off time and time until first defibrillation.

2. Methods

2.1. Study design and setting

The ethics committee of the Ludwig Maximilian University Munich, Germany, waived the requirement for a committee approval of this manikin study and authorized commencement of the study. This prospective, randomized, cross-over, manikin study was conducted at the simulation centre of the Bavarian Mountain Rescue Service in Bad Toelz, Germany, in February 2011 (www.bergwacht-bayern.de).

2.2. Participants

Twenty-five healthy advanced life support (ALS)–certified paramedics with no previous experience using LUCAS were enrolled (Supplemental Figure 1). All candidates signed informed consent and participated voluntarily. Before starting the test, the candidates were instructed by ALS-certified instructors on LUCAS and conventional manual CPR according to the American Heart Association (AHA) 2010 guidelines [10] for 30 minutes, respectively. Each candidate performed the identical scenario in a randomized order (www.randomizer.org), once with LUCAS and once with manual chest-compressions.

2.3. Intervention

Immediately after the training, a standardized simulated cardiac arrest scenario was presented to the candidates: “You are part of a helicopter crew called to a hypothermic cardiac arrest patient. Neither pulse nor breathing is detectable and bystander CPR is being performed. Core body temperature is 28°C (82.4°F). Please take care of this patient.”

A modified Resusci Anne manikin (Laerdal, Stavanger, Norway) was employed. For better CPR error, analysis the scenario was divided into three parts: *before, during, and after helicopter flight*. The *before flight* part started with a short emergency assessment performed by an emergency physician (BP). In the manual group the candidates performed manual chest-compressions in rotation with the physician every 2 minutes. In the LUCAS group candidates performed manual chest-compressions until LUCAS placement. At this point mechanical chest-compressions commenced until termination of the test. Candidates were not corrected during placement or conduction of LUCAS or manual chest-compressions. After applying the defibrillation pads on the manikin the electrocardiogram showed ventricular fibrillation. Three defibrillations at intervals of 2 minutes were given without reversing ventricular fibrillation. The manikin was intubated, ventilated with a bag-valve device (Ambu, Bad Nauheim, Germany), and after the third defibrillation, fastened on a stretcher and transported to the helicopter to conclude the *before flight* part (~6 minutes).

The *during flight* part consisted of a simulated eight minute flight (average transport time of medical helicopters in the Eastern European Alps). The manikin was loaded into the helicopter (BK117dummy, MBB, Ottobrunn, Germany) and connected to an Oxylog ventilator (Dräger, Lübeck, Germany). In the manual group, the candidates continued chest-compressions while kneeling beside the manikin`s chest and the physician was positioned behind the head. After landing, the manikin was loaded on a trolley.

In the *after flight* part, CPR continued on the manikin, which was placed on a trolley for the simulated two minute transport to the trauma department. Manual chest-compressions were delivered in a straddling position [11].

2.4. Outcome measures

The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions. The percentage, and not the absolute number, of correct chest-compressions was used to rule out the influence of too high or low compression rates. Secondary outcome measures were depth, pressure point, complete pressure release and rate of chest-compressions, hands-off time, and time to first defibrillation.

The LUCAS default setting for chest-compressions depth was 38 to 51 mm in alignment with the 2005 AHA guidelines [12]. Because the candidates were already trained according to 2010 guidelines, we considered all compressions with a depth of 40 to 60 mm as correct to combine the LUCAS default setting with the 2010 AHA guidelines [10]. The pressure point was counted as correct when performed in the lower half of the sternum and pressure release was correct when complete release between chest-compressions was recorded by the Laerdal Skill Reporting System (Laerdal, Stavanger, Norway). Correct pressure rate was defined as 100 to 120 chest-compressions per minute. Data were analyzed with Microsoft Excel (Microsoft, Redmond, WA) and SPSS (Version 18; IBM, Armonk, NY).

2.5. Statistical analysis

In a pilot LUCAS vs manual CPR study, the mean of correct chest-compressions was 80% vs 60% and SD was 15%. Based on these data and considering $\alpha = .01$ and $\beta = 90\%$, 15 participants were necessary to allow for significant results. To allow for possible dropouts 25 participants were included in this study. The outcome measure values are presented as mean ± SD and 95% confidence interval (95% CI). The Kolmogorov-Smirnov test was used to test for normality. Student t test was used for paired samples with normal distribution, and Wilcoxon test for samples with non-normal distribution. All reported P values were 2 sided, and a type I error level of 5% was considered. The statistical power varies between 90% and 99% depending on the group comparisons.

3. Results

Two candidates were excluded from the analysis because of incomplete data recording during the scenario due to wire dislocation between the manikin and the data-recording laptop. The remaining 23 candidates (6 female) had a mean age of 29 ± 11 years, mean height of 178 ± 10 cm, and mean weight of 75 ± 14 kg.

3.1. Primary outcome

LUCAS compared to manual chest-compressions were more frequently correct, both *before* (97% vs 61%, $P < .001$), *during* (100% vs 41%, $P < .001$) and *after flight* (100% vs 76%, $P < .001$), as well as in the overall scenario (99 vs 59%, $P < .001$; Table 1 and Fig. 1A).

3.2. Secondary outcome

LUCAS compared to manual chest-compressions were more often performed correctly regarding depth (99% vs 79%, $P < .001$), pressure point (100 vs. 79%, $P < .001$) and pressure release (100% vs. 97%, $P = .001$; Table 1 and Fig. 1B-D). In the LUCAS compared to the manual group, mean compression rate was less (100 vs.113min^{-1}, $P < .001$), hands-off time was shorter (46 vs 130 seconds, $P < .001$), and time to first defibrillation was longer (112 vs 49 seconds, $P < .001$). The mean compression depth did not differ between groups (49 vs 47 mm, $P < .309$; Table 2).

The *before flight* part in the LUCAS compared with the manual group lasted on average 393 (95% CI 383-403) vs 350 seconds (95% CI 336-364), the *during flight* part 491 (95% CI 484-499) vs 488 seconds (95% CI 482-493), the *after flight* part 169 (95% CI 165-172) vs 170 seconds (95% CI 166-175), and the overall scenario 1053 (95% CI 1039-1067) vs 1008 seconds (95% CI 990-1025).

4. Discussion

In this study of simulated CPR during helicopter rescue, LUCAS chest-compressions were more often correct than manual chest-compressions. Also, total hands-off-time was shorter in the LUCAS group, whereas time to first defibrillation was longer.

While LUCAS delivered uninterrupted high-quality chest-compressions, the quality of manual chest-compressions was consistently inferior throughout the scenario (Table 1). This was most pronounced during the helicopter flight with only 41% of correct manual chest-compressions (Fig. 1A), most likely because of the confined space and the unfavorable position of the candidates in the helicopter. This contrasts with a prior manikin study, reporting that manual chest-compressions were equally effective during helicopter flight as on the ground with ~77% correct chest-compressions by assessing chest-compressions depth and pressure point [3]. Similarly, another manikin study found a comparable chest-compressions depth during helicopter flight when compared to CPR at the scene. However, the median chest-compressions depth was only 33 mm during flight and 37 mm at the scene [13]. These two studies are

Table 1 Absolute numbers of chest compression variables in both groups presented as mean value±standard deviation and 95% CI. Before denotes performance *before flight*; during, *during flight*; after, *after flight*; and overall, *the overall scenario*

	LUCAS group	95% CI	Manual group	95% CI
Total chest compressions				
Before	588 ± 38	572-605	508 ± 58	483-533
During	814 ± 29	801-826	909 ± 44	890-928
After	279 ± 16	272-286	242 ± 20	234-251
Overall	1681 ± 53	1658-1704	1659 ± 94	1618-1700
Correct chest compressions				
Before	567 ± 34	553-582	309 ± 136	250-367
During	814 ± 29	801-826	369 ± 233	268-470
After	279 ± 16	272-286	186 ± 74	154-218
Overall	1660 ± 45	1640-1679	864 ± 381	699-1028
Correct depth of chest compressions				
Before	579 ±37	563-595	389 ± 124	335-442
During	814 ± 29	801-826	705 ± 224	608-802
After	279 ± 16	272-286	203 ± 68	173-233
Overall	1671 ± 52	1649-1694	1296 ± 380	1132-1460
Correct pressure point of chest compressions				
Before	583 ± 36	567-599	426 ± 88	389-464
During	814 ± 29	801-826	539 ± 200	453-625
After	279 ±16	272-286	228 ± 49	207-249
Overall	1675 ± 50	1654-1697	1194 ± 260	1081-1306
Correct pressure release of chest compressions				
Before	581 ± 38	565-597	476 ± 90	437-515
During	814 ± 29	801-826	894 ± 75	862-927
After	279 ± 16	272-286	238 ± 23	228-248
Overall	1673 ± 50	1652-1695	1608 ± 166	1536-1680

lacking a mechanical CPR group. Our study clearly shows that LUCAS can improve CPR during a transport scenario. However, a recent manikin study showed that LUCAS chest-compressions are less efficient than manual chest-compressions [14]. According to this study, 57% of the participants did not apply the mandatory stabilization strap of LUCAS, which resulted in sliding of LUCAS on the chest during CPR. Contrary to our study, the participants did not train with LUCAS directly before the study. This may be the reason for the poor CPR quality with LUCAS and emphasizes the imperative of regular training to apply LUCAS efficiently.

The hands-off time in our study was remarkably short in both study groups. In the manual group it accounted for only 13% of the total scenario time. In real life hands-off times of up to ~50% have been reported as a result of multiple tasks during CPR [1,15]. In the LUCAS group the hands-off time accounted for only 4% of the total scenario time and was only registered before initiation of mechanical CPR and during rhythm analysis.

Chest-compression quality and shorter hands-off time directly influence survival during CPR [9]. This is particularly important for hypothermic cardiac arrest patients, as prolonged CPR may be required before return of spontaneous circulation [5,16]. Despite prolonged CPR outcome may be good and improved by high-quality CPR as provided by a mechanical chest-compression device. Therefore, recently published expert-based guidelines of the University Hospital Berne, Switzerland, recommend the initiation of mechanical chest-compressions for all hypothermic cardiac arrest patients immediately after helicopter landing until return of spontaneous circulation [17].

Time to the first defibrillation was prolonged in the LUCAS group due to time required for installation of the device before the first rhythm analysis. The time delay until first defibrillation may negatively affect clinical outcome [18]. However, a recently published cluster-randomized trial found no difference in survival or neurological outcome whether an early or delayed (ie, 2 minutes) defibrillation was performed [19]. Moreover, longer periods to check for pulse and respirations as well as a maximum of three defibrillations are recommended below a core body temperature of 30°C. Therefore, a short delay until first defibrillation in hypothermic cardiac arrest seems to be of lesser importance to normothermic cardiac arrest, provided that the time until first defibrillation is bridged with high-quality manual CPR.

5. Limitations

Firstly, CPR was simulated on a manikin and transport and flight were performed in a simulator. Thus, this setting

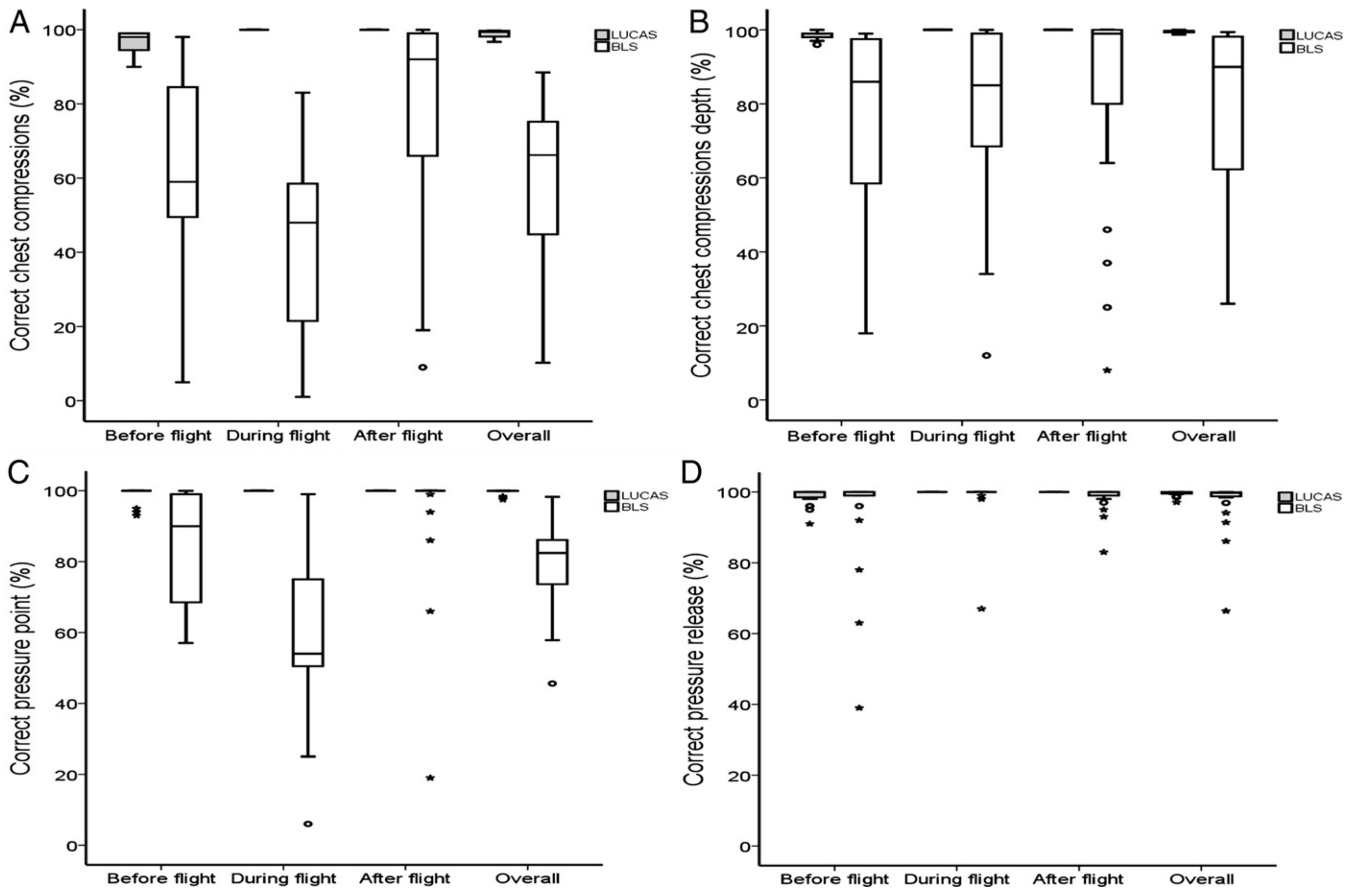

Fig. 1 Graphs display chest compression variables for the LUCAS and the manual group before, during and after flight and for the overall scenario. Outliers and extreme values are shown as circles (○) or as asterisks (*), respectively. A, Correct chest compressions (%). B, Correct chest compression depth (%). C, Correct chest compression pressure point (%). D, Correct chest compression pressure (%).

does not necessarily reflect a real CPR scenario. Secondly, improvements in CPR depicted by this study may not result in improved patient outcomes. Although there have been studies demonstrating that mechanical chest-compressions may improve clinical parameters such as blood pressure [20], coronary perfusion pressure [21], cortical cerebral blood flow [22], and end-tidal CO_2 [23], no high-quality study has been published yet which shows improved outcome in humans [24,25]. Thirdly, it was not possible to blind the candidates to the intent of the study. But they were blinded to the adequacy of chest-compressions.

6. Conclusions

During this simulated cardiac arrest scenario in helicopter rescue LUCAS compared to manual chest-compressions increased CPR quality and reduced hands-off time but prolonged the time interval to the first defibrillation. Further clinical trials are warranted to confirm potential benefits of LUCAS-CPR in helicopter rescue.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ajem.2012.07.018.

Table 2 Secondary outcome measure variables of both groups presented as mean value±standard deviation and 95% CI

	LUCAS Group	95% CI	Manual Group	95% CI
Hands-off time (s)	46 ± 5	43-48	130 ± 15	123-136
Time to first defibrillation (s)	112 ± 12	107-118	49 ± 6	47-52
Mean compression rate ($1/min^{-1}$)	100 ± 0,5	100-100	113 ± 6	110-116
Mean compression depth (mm)	49 ± 2	48-50	47 ± 6	45-50

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