Mechanical Compressions Versus Manual Compressions in Cardiac Arrest

Larissa Fritts
Pacific University

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Mechanical Compressions Versus Manual Compressions in Cardiac Arrest

Abstract

Background: More than 350,000 people suffer an out-of-hospital cardiac arrest every year. Even when medical providers have adequate training it can be difficult to carry out an effective resuscitation due to suboptimal CPR, multiple interventions needing to be done simultaneously, and many other less than ideal conditions. What if there was an alternative for compressions during emergency situations that could provide uninterrupted quality CPR and improve provider safety? Many studies have attempted to evaluate the use of mechanical compressions in these situations.

Methods: Exhaustive search of available medical literature including MEDLINE-Ovid, MEDLINE-PubMed, Web of Science, and CINAHL was performed using keywords: “mechanical compressions/LUCAS”, “manual compressions/CPR”, and “prehospital/emergency medical services/out of hospital cardiac arrest.” Studies were screened with eligibility criteria and resulting studies were then assessed for quality with GRADE.

Results: Two studies were included in this systematic review, meeting all inclusion criteria. Rubertsson et al is a RCT that looked at 4471 patients who experienced an out-of-hospital cardiac arrest. It found that mechanical compressions were equivalent to manual compressions when looking at survival rates or neurological status. Perkins et al another RCT looked at survival rates of mechanical vs. manual compressions following an OHCA. Survival rates did not significantly differ between the groups, but favorable neurological outcomes were lower in the LUCAS group when compared to manual compressions.

Conclusion: Mechanical compressions have been shown to provide consistent, effective, more technically sound compressions than manual CPR which may provide a significant advantage during specific scenarios: difficult transport, prolonged resuscitation, and during PCI. Further research in these unique situations needs to be done to establish if the variations in outcomes are due to type of compression or the overarching algorithm implemented.

Keywords: LUCAS/mechanical compressions, out of hospital cardiac arrest/prehospital, manual compressions/CPR

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Mechanical Compressions Versus Manual Compressions in Cardiac Arrest

Larissa Fritts

A Clinical Graduate Project Submitted to the Faculty of the
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Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography
Larissa Fritts born and raised in North Dakota attended Adams State College where she played soccer and double majored in Psychology and Exercise Science. After graduation, she moved to Breckenridge, CO where she worked in Outdoor Education for the mentally and physically challenged, as a critical care tech, and also as a dogsledding guide. During this time she completed the prerequisites for Physician Assistant School. Currently a student at Pacific University her present interest is in emergency medicine.
Abstract

Background: More than 350,000 people suffer an out-of-hospital cardiac arrest every year. Even when medical providers have adequate training it can be difficult to carry out an effective resuscitation due to suboptimal CPR, multiple interventions needing to be done simultaneously, and many other less than ideal conditions. What if there was an alternative for compressions during emergency situations that could provide uninterrupted quality CPR and improve provider safety? Many studies have attempted to evaluate the use of mechanical compressions in these situations.

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Keywords: LUCAS/mechanical compressions, out of hospital cardiac arrest/prehospital, manual compressions/CPR
Acknowledgements

To my husband: Thank you for helping me to achieve my goals, which ultimately you made your own. The last two years have been filled with challenges that I was able to overcome with your support. Here’s to the next chapter of our lives.

To my family: Thank you for all your support and for pushing me to set my aspirations so high. The bumps and detours along the way have definitely been worth it. I hope I’ve made you proud.

To everyone else: You all know who you are. Thank you for always believing in my abilities. The support, inspiration, and life lessons will never be forgotten. So many of you have shaped the person into whom I am still evolving.
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List of Abbreviations

ACLS…………………………………………………………………………….Advanced cardiac life support
AED…………………………………………………………………………….Automatic External Defibrillator
CACE…………………………………………………………………………..complier average causal effect
CDC……………………………………………………………………………center for disease control
CPC……………………………………………………………………………..cerebral performance category scores
CPR…………………………………………………………………………….cardiopulmonary resuscitation
EMS…………………………………………………………………………….emergency medical services
ETCO2………………………………………………………………………….end tidal carbon dioxide
ICU……………………………………………………………………………..intensive care unit
LUCAS…………………………………………………………………………Lund University Cardiopulmonary Assist System
OHCA……………………………………………………………………….out of hospital cardiac arrest
PCI……………………………………………………………………………percutaneous coronary intervention
PEA…………………………………………………………………………….pulseless electrical activity
ROSC……………………………………………………………………….return of spontaneous circulation
UK……………………………………………………………………………..United Kingdom
VF……………………………………………………………………………ventricular fibrillation
VT……………………………………………………………………………ventricular tachycardia
Mechanical Compressions Versus Manual Compressions in Cardiac Arrest

BACKGROUND

More than 350,000 people suffer an out-of-hospital cardiac arrest (OHCA) every year in the United States (see table I).\(^1\) Ninety-two percent of these people do not survive.\(^2\) For many years researchers have shown that the key to successful outcomes during OHCA resuscitation has been quality chest compressions.\(^1\) According to the CDC, there are five critical actions comprising the “chain of survival” that need to occur quickly during an OHCA to improve outcomes: rapid activation of EMS, rapid initiation of CPR, prompt application of AED, rapid initiation of ACLS, and early post-resuscitative care.\(^2\)

Even when responders have knowledge of the “chain of survival” there are challenges to effectively carrying it out. Not all OHCA are witnessed so there may be delays to activating EMS. Bystanders often don’t start resuscitative efforts, or they don’t know how to perform them.\(^2\) Suboptimal chest compressions due to fatigue and the need to provide multiple interventions upon arrival at the scene can also contribute to poor outcomes during OHCA resuscitation.\(^3\) Once the patient is ready to transport, effective CPR can be even more challenging. A bumpy ride in the back of an ambulance or a cramped space in a helicopter can make doing compressions dangerous for the provider and ineffective for the patient.\(^4\)

What if there was an alternative for adequate compressions during emergency situations that could not only provide uninterrupted quality CPR, but also improve provider safety? The answer may lie with mechanical compressions. In 2002, a device called LUCAS was introduced in Sweden by Physio-Control as a new method of providing mechanical compressions.\(^4\) LUCAS is a piston device in which compressed air drives the piston up and down resulting in optimal frequency and depth of compressions that allow for full chest recoil and minimal interruptions. LUCAS chest compression system can assist EMS by eliminating the fatigue factor, reducing interruptions in CPR, and allowing for focus on other life-saving interventions.\(^5\)

Multiple experimental studies have been done in an attempt to evaluate automated compression systems. These studies have evaluated return of spontaneous circulation (ROSC), survival rates, neurological outcome, cerebral blood flow, end tidal CO2 (ETCO2), compression
depth and rate, and adverse effects of mechanical vs. manual compressions. Mechanical compressions have also been looked at for use during PCI, prolonged resuscitation, and helicopter transportation.

Regardless of whether mechanical compressions improve survival, more and more evidence is coming forward suggesting that there are situations in which mechanical compressions may play an important role. The question remains can mechanical compressions during an OHCA actually improve survival rates?

**METHODS**

An exhaustive literature search using the following search engines: MEDLINE Ovid, MEDLINE PubMed, CINAHL, Web of Science, and Google scholar was conducted. The following search terms were used: “mechanical compressions/LUCAS,” “manual compressions/CPR,” and “prehospital/emergency medical services/out of hospital cardiac arrest.” Multiple bibliographies from relevant articles were screened for related articles.

Inclusion criteria included out of hospital cardiac arrest, LUCAS, LUCAS 2 or piston driven automated compression device vs. manual compressions, and endpoint measure was survival after an OHCA. Articles included had to be published in the English language and focus on human subjects. Excluded were articles that included animals or manikin participants as well as pilot studies due to low sample size. Also excluded were another two studies evaluating load-bearing band automated compressions. GRADE analysis was done to assess bias risk.

**RESULTS**

The initial search yielded 36 articles for review. After eliminating duplicates and screening all results for articles that met the eligibility criteria, there were 2 articles. Both articles were randomized control trials. See Table II. Another article met all criteria except that it was a pilot study with small sample size so it was used for background information. There was a recent systematic review done that looked at both LUCAS and Auto-Pulse devices. Differences between the varying devices may account for inconsistent results therefore any
studies that evaluated an automated compression device other than LUCAS was excluded from this review. Results mentioned in this review were consistent across trials and implied no advantage to mechanical chest compression devices over manual compressions in survival rates OR 0.95; 95% CI 0.85, 1.07 or neurological outcome OR 0.90; 95% CI 0.59, 1.39.3

**LINC study**

This randomized clinical trial6 looked at patients from January 2008 to August 2012 throughout Sweden, the Netherlands, and the United Kingdom. The authors wanted to explore the effectiveness and safety of LUCAS compared to manual compressions. The primary outcome of this study was 4-hour survival after successful ROSC. Multiple secondary outcomes included ROSC, survival with good neurological outcome (cerebral performance category (CPC) score 1 or 2) at ICU discharge, hospital discharge, 1 month post discharge, and 6 months post discharge.6

There were 2593 participants who were randomized to receive mechanical or manual compressions during OHCA. Four patients withdrew consent and were not included resulting in 2589 patients included in the intention-to-treat population. Upon arrival on the scene, EMS opened the envelope and those randomized to the mechanical compression group received manual CPR until the system was in place while those in the manual compression group were treated according to 2005 European Resuscitation Council guidelines. Blinding was not possible as the providers had to know which intervention to perform.6

When analyzing the outcomes they used Wald 95% confidence interval to account for difference in proportions and they used a two-sided Fisher exact test. Missing values were entered as worst possible outcome. The study found no significant difference in 4-hour survival between the mechanical and manual compression groups 307/1300 and 305/1289, respectively; 95% CI -3.3 to 3.2, P>0.99. There were no significant differences between groups in any of the secondary outcomes either (see Table III). Neurological outcome was measured using CPC scores and were not significantly different between the two groups. Post resuscitation care was similar between the groups with ROSC patients receiving hypothermia and PCI when indicated, which supports the validity of the study. Background variables and demographics were similar with the most notable difference between groups being the number of defibrillations delivered by the EMS crew and the time to first defibrillation which was delivered 1.5 minutes later in the mechanical CPR group.6
The differences that were recognized may have been a possible result of the variations in treatment algorithm between the two groups (see Figure I). The mechanical compression group received manual compressions until the device was in place and then received defibrillation 90 seconds into 3 minutes of compressions according to resuscitations guidelines without pausing to check rhythm. Heart rhythm was then checked every 3-minute cycle and shock was delivered if advised. The manual group received 2-minute cycles of compression and did not defibrillate until a rhythm check was done. The committee designing the study agreed that the benefit of this possibly unnecessary shock in the mechanical compression group outweighed the risk. Both groups received ventilation and pharmacological intervention according to recommendations.²

PARAMEDIC study

Little evidence existed for the effectiveness of mechanical compressions, but their use has been on the rise. The authors of this study¹⁴ wanted to evaluate if using LUCAS-2 mechanical CPR in EMS response vehicles would improve survival during an OHCA. This study was a pragmatic cluster randomized open label trial involving non-traumatic, adult, out of hospital cardiac arrest in the UK. Clusters were ambulance service vehicles that were randomly assigned to LUCAS-2 or manual CPR. The primary outcome was survival at 30 days following an OHCA. Secondary outcomes were ROSC, survival to 3 months, survival to 12 months, and survival with CPC score of 1 or 2 at three months.¹⁴

There were 4471 eligible patients who were included in the study; 1652 were assigned to the LUCAS group while 2819 were assigned to control group between April 2010 and June 2013 with 12 months of follow up. There were 418 emergency vehicles that were randomly assigned to either utilize LUCAS or manual compressions. The arrests that received resuscitation did not differ between groups: 1737of 4192 for LUCAS and 2953 of 6980 for manual. Only 60% of the patients in LUCAS group received mechanical compressions due to trial related causes n=272, not possible n=256 or unknown causes n=110. There were not any significant differences between group characteristics.¹⁴

For the primary outcome, survival at 1 month was similar between LUCAS 104 (6%) and manual compression 193 (7%). The adjusted OR was 0.86 (95%CI 0.64-1.15). Secondary outcomes including ROSC and survival at 3 months were also similar between the two groups.
Favorable neurological outcome (a CPC of 1 or 2) was lower in the LUCAS group than manual compression group in both CACE analyses (see Table III).\textsuperscript{14}

Primary analysis was by intention-to-treat and the study used two different CACE analyses to estimate the effect in cardiac arrest where protocol was followed. The CACE analyses allowed the authors to retain the advantages of randomization and avoided introducing bias. This sensitivity analysis did not make a substantial difference to the general results. This pragmatic, cluster randomized trial did not demonstrate any improvement in primary outcome of 30 day survival with the use of mechanical compressions when compared to the use of manual compressions.

**DISCUSSION**

The most reassuring result of these studies\textsuperscript{6,14} is that performing manual compressions is equally efficient when compared to mechanical compressions in promoting survival during resuscitation of an OHCA. Unfortunately, that also means that there does not appear to be any improved benefit to using mechanical compressions during cardiac resuscitation, as there is no improvement in survival rates.\textsuperscript{6,14} The PARAMEDIC study\textsuperscript{14} further found worse neurological outcomes when compared to manual compressions \( I^2=69\% \).\textsuperscript{14} However there is inconsistency between the LINC and PARAMEDIC studies\textsuperscript{6,14} in regards to neurological outcomes.\textsuperscript{6,14}

There is evidence that mechanical compressions are more technically sound.\textsuperscript{5} Automated mechanical compression systems have been shown to provide more consistent and adequate depth and rate of compression with complete recoil of the chest wall when compared to manual compressions.\textsuperscript{12} Another benefit of mechanical compressions is increased initial and minimum value of ETCO2, which results in higher cardiac output than manual compressions.\textsuperscript{9} Higher cardiac output during resuscitation should result in increased cerebral blood flow, which should result in better neurological outcomes after an OHCA. In a 2005 study, LUCAS’s ability to adequately perfuse the brain was evaluated using porcine subjects.\textsuperscript{7} The LUCAS system was able to maintain a cortical cerebral blood flow of 65\% baseline throughout the duration of CPR; manual compressions were only able to maintain approximately 40\% baseline.\textsuperscript{7} One might extrapolate that because mechanical compressions provide consistent efficient compressions with improved cerebral blood flow and increased ETCO2 that using mechanical compressions will
also improve survival during resuscitation of an OHCA. This is not the case, after synthesis of the results from this systematic review yielded no significant difference in survival rates after an OHCA when comparing mechanical and manual chest compressions. There may be limitations in applying results from efficacy trials to real life practice. LUCAS is not the only automated chest compression system on the market. Load distributing bands such as the Auto-Pulse work in a slightly different manner than the piston based LUCAS system. Auto-Pulse consists of a wide band that fits around the chest; it is then adjusted and provides rhythmic chest compressions. This systematic review looked strictly at the benefit of LUCAS in pre hospital cardiac arrest as different devices operate in different ways and therefore could have different treatment effects. In analyzing additional articles the results appear to differ between LUCAS and Auto-Pulse trials.

While mechanical compressions do not appear to have a significant advantage over manual compressions in survival rates there does appear to be a place for mechanical compression systems in healthcare. In a prospective randomized cross over manikin study LUCAS was used during helicopter rescue scenarios to evaluate effectiveness of the compressions. LUCAS compressions compared to manual chest compressions were more frequently correct before, during, and after flight. The inferiority of manual compressions was most evident during the helicopter flight with only 41% of compressions being done correctly. Patients with OHCA who do not respond to paramedic resuscitation are not routinely transported to hospital because it is hazardous for paramedics to undertake rapid transport whilst administering chest compressions. Prolonged resuscitation efforts take a toll on medical providers delivering CPR; the providers often become fatigued and compression quality begins to decline. Mechanical compression devices may allow for prolonged resuscitation during transport while reducing risk to the medical providers and improving survival rates at the same time.

Another utilization for mechanical compression systems may be in the catheterization lab. A case study of a 53-year-old male reported great neurological recovery after a 115-minute resuscitation 90 minutes of which was performed using mechanical compressions. Due to the extreme difficulty of performing effective chest compressions during percutaneous coronary intervention, mechanical compressions may play an important role of maintaining perfusion until the procedure can be finished. During cardiac arrest LUCAS has been shown to sustain both
coronary and cerebral circulation and since the compression device is mostly translucent it can be used concomitantly during a PCI.\textsuperscript{7,10}

Limitations are evident after completion of the systematic review. Both studies\textsuperscript{2,13} demonstrated a low risk of bias. Even though the manufacturer of the LUCAS system sponsored the LINC trial it didn’t appear to be a reason to downgrade GRADE. Blinding of the medical providers was not possible, but it would be unlikely to affect the outcome in either group. The intervention in the LINC study\textsuperscript{6} involved an entire treatment algorithm versus the Paramedic study\textsuperscript{14}, which simply replaced manual compressions with mechanical compressions.\textsuperscript{14} Another concern in interpreting the results from these studies is the nonuse of automated compression devices in participants that were allocated to the mechanical compression group.\textsuperscript{14} There was a proportion (15\%) of non-use due to difficulties implementing the device and training and quality issues, which need to be addressed as research move forward.\textsuperscript{14} One must also consider the number of cardiac arrests that are encountered by providers, as the infrequency of using the device and limited annual training would make it difficult for any provider to become an expert in deploying the automated device.\textsuperscript{14} When evaluating the efficacy of automated compression devices one has to take into consideration how the European CPR guidelines differ from US guidelines: does their training differ, and does that influence the outcomes? Do additional treatment interventions play a larger role and therefore influence outcomes? Post resuscitative care differed between the two studies; LINC participants were treated with hypothermia and PCI\textsuperscript{6} as necessary, whereas PARAMEDIC participants were treated per individual hospital protocol.\textsuperscript{14}

Ultimately CPR using a mechanical compression device can be done with minimal complications, but it does not actually improve survival rate when compared to manual compressions. There are instances where the automated compression device can be better for the patient’s survival. This study suggests that differences between algorithms needs to be evaluated separately from the type of compression to determine if it is strictly the compression type that makes a difference or if the different algorithm is responsible for differences between the two groups. An in-depth look at the training that providers received in both operating the mechanical compression device and performing manual compressions is needed.

There is additional research that needs to be done evaluating mechanical compression systems. While LUCAS is one of the most researched alternatives to manual CPR during pre-
hospital cardiac arrest and ambulance transfer, there is little research on the feasibility of its use in emergency helicopter transport. Research is currently being done on implementing LUCAS-2 in helicopter rescue.\textsuperscript{17} There is also new research being conducted on the newest version of mechanical compressions LUCAS-2AD that is going to evaluate the hemodynamics of the intervention.\textsuperscript{18} Additional research that evaluates multiple facets of quality CPR in various settings will be able to guide future management of cardiac arrest.\textsuperscript{18,19}

CONCLUSION

At this time evidence does not support mechanical compressions resulting in superior survival outcomes as compared to manual compressions. Using LUCAS during an OHCA does not demonstrate any benefit over manual compressions when evaluating survival rates. Mechanical compression systems should not be looked at as a replacement for manual compressions, but rather as a supplemental adjunctive treatment option for treating OHCA. The ultimate benefit of using LUCAS is most evident in situations where there is confined space or unfavorable scenarios where delivering uninterrupted, efficient, and adequate chest compressions can be difficult.

At this time there is no evidence to support moving from a resuscitation algorithm involving manual compressions to one involving mechanical compressions. Manual compressions are a well-known and well-studied intervention that results in positive outcomes equivalent to mechanical compressions; however, if providers are working in those conditions stated above there is reason to consider implementing mechanical compression devices to aid responders in difficult resuscitation efforts.
References


Table I: Cardiac Statistics AHA

<table>
<thead>
<tr>
<th>Statistical Update</th>
<th>Out-of-Hospital Cardiac Arrest</th>
<th>In-Hospital Cardiac Arrest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incidence</td>
<td>Survival rate*</td>
</tr>
<tr>
<td></td>
<td>Bystander CPR (overall)</td>
<td>Adults</td>
</tr>
<tr>
<td></td>
<td>Survivor rate* (overall)</td>
<td>Children</td>
</tr>
<tr>
<td>2013</td>
<td>359 400</td>
<td>209 000</td>
</tr>
<tr>
<td>2012</td>
<td>382 800</td>
<td>209 000</td>
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Table II: Quality Assessment of Reviewed Articles

<table>
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<th>Downgrade Criteria</th>
<th>Upgrade Criteria</th>
<th>Quality</th>
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<tr>
<td>Roberstsson et al (LINC)</td>
<td>RCT</td>
<td>Not serious *</td>
<td>Not likely</td>
<td>High</td>
</tr>
<tr>
<td>Perkins et al (PARAMEDIC)</td>
<td>RCT</td>
<td>Not serious *</td>
<td>Not likely</td>
<td>high</td>
</tr>
</tbody>
</table>

*a Lack of blinding but risk of bias is low due to objective outcome measures

Table III: Summary of Findings

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcome</th>
<th># of Participants</th>
<th>Treatment difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roberstsson et al (LINC)</td>
<td>4 hour Survival</td>
<td>307(23.6%)</td>
<td>-0.05(-3.3 to 3.2)</td>
</tr>
<tr>
<td></td>
<td>Survival with CPC 1 or 2</td>
<td>108(8.3%)</td>
<td>0.55(-1.5 to 2.6)</td>
</tr>
<tr>
<td></td>
<td>ROSC</td>
<td>460(35.4%)</td>
<td>0.78(-2.9 to 4.5)</td>
</tr>
<tr>
<td>Perkins et al (PARAMEDIC)</td>
<td>Survival to 30 days</td>
<td>104(6%)</td>
<td>0.86(0.64 to 1.15)</td>
</tr>
<tr>
<td></td>
<td>Survived event</td>
<td>377(23%)</td>
<td>0.97(0.82 to 1.14)</td>
</tr>
<tr>
<td></td>
<td>Survival to 3 months</td>
<td>96(6%)</td>
<td>0.83(0.61 to 1.12)</td>
</tr>
<tr>
<td></td>
<td>Survival with CPC 1 or 2</td>
<td>77(5%)</td>
<td>0.72(0.52 to 0.99)</td>
</tr>
<tr>
<td></td>
<td>ROSC</td>
<td>522(32%)</td>
<td>0.99(0.86 to 1.14)</td>
</tr>
</tbody>
</table>
Figure I.
Description of Study Intervention Algorithms
Ventilation and medication were given according to guidelines16 in both groups.

Figure II: CPC scale
Cerebral Performance Category (CPC) Scale
CPC 1: Full recovery or mild disability
CPC 2: Moderate disability but independent in activities of daily living
CPC 3: Severe disability; dependent in activities of daily living
CPC 4: Persistent vegetative state
CPC 5: Dead