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Outcomes of LUCAS Machine vs. Manual Compression in Cardiopulmonary Resuscitation: A Systematic Review

Omar Abutaleb Alsayed1, Hussam Abdulelah Suleiman 2, Abdullah Drwaish Alwafi1, Yousef Hudhayban Aljarrari3, Abdulraheem Saleh Alwadai4, Saleh Ali Alwadai5, Saeed Abdullah Miswak 6, Faisal Jaber Faqiri6

1Emergency Medical Services Specialist , Emergency Departmen
King Abdullah Medical Complex, Jeddah, Saudi Arabia
2Paramedic , Emergency Medical Services , King Abdullah Medical City, Makkah, Saudi Arabia
3Emergency Medical Technician, Emergency Department , Ministry Of Health, Jeddah, Saudi Arabia
4Emergency Medical Services Specialist, Ambulance Department, Southern Armed Forces Hospital, Khamis Mushait, Saudi Arabia
5Emergency Medical Services Specialist, Ambulance Department, Armed Forces Hospital In Jubail, Jubail, Saudi Arabia
6Emergency Medical Services Specialist, Medical Transportation, Ajyad Emergency Hospital, Makkah Almokrmah, Saudi Arabia

Abstract

Background: Cardiopulmonary resuscitation (CPR) is a critical intervention for cardiac arrest. Mechanical chest compression devices, such as the LUCAS machine, have emerged as an alternative to manual CPR. The comparative effectiveness of these methods on patient outcomes remains unclear.

Objective: To systematically evaluate the evidence on the effectiveness and safety of LUCAS machine-assisted CPR compared to manual CPR in improving patient outcomes.

Methods: A systematic search of electronic databases (PubMed, Web of Science, Scopus, and ScienceDirect) was conducted to identify studies comparing LUCAS machine-assisted CPR to manual CPR.

Results: Our data includes eleven articles with 3597 participants, 2146 (59.7%) of whom were males. Five studies reported that the outcomes of manual and mechanical CPR using LUCAS were comparable with no significant difference in the sustained return of spontaneous circulation (ROSC) rates. Three studies recorded that mechanical high-quality CPR delivery is preferable to human high-quality CPR delivery and it also enhances the quality of CPR during out-of-hospital cardiac arrest resuscitation by considerably lowering the no-flow fraction and by producing better chest compressions than manual CPR. Using LUCAS mechanical CPR was associated with worse survival at discharge, a higher number of pericardial injuries, greater risk of airway hemorrhage, and rib fractures than manual CPR.

Conclusion: The majority of the study's trials did not show that CPR administered via LUCAS was any more successful than CPR administered manually. Nonetheless, improvements in clinical research and technology, along with a deeper comprehension of the organizational consequences of their application, are continuously enhancing the efficacy of these tools.

Keywords: *LUCAS machine, manual CPR, cardiopulmonary resuscitation, cardiac arrest, systematic review.*

Introduction

CPR is a critical life-saving intervention for individuals experiencing cardiac arrest. The cornerstone of CPR is chest compressions, which aim to circulate blood and oxygen to vital organs until advanced medical care can be administered [1]. Traditionally, chest compressions have been

performed manually by rescuers. However, in recent years, the advent of mechanical chest compression devices, such as the LUCAS machine, has offered a potential alternative to manual CPR [2].

The efficacy and safety of mechanical chest compression devices compared to manual CPR have been the subject of extensive research and debate. While these devices promise to deliver consistent, high-quality compressions, mitigating human fatigue and error, their impact on patient outcomes remains a subject of investigation. This research aims to comprehensively evaluate the available evidence on the outcomes of LUCAS machine-assisted CPR compared to traditional manual CPR [3].

By conducting a thorough review of existing literature, including randomized controlled trials, observational studies, and meta-analyses, this study will examine the comparative effectiveness of these two CPR methods in terms of key outcome measures [4]. These outcomes may include survival rates, neurological outcomes, ROSC, and other relevant clinical endpoints. Furthermore, the study will explore potential factors influencing the effectiveness of these methods, such as patient characteristics, arrest etiology, and time to intervention [5].

Understanding the comparative benefits and limitations of LUCAS machine-assisted CPR and manual CPR is crucial for optimizing resuscitation practices and improving patient survival rates [6]. The findings of this research will contribute to evidence-based guidelines for CPR and inform decision-making among healthcare providers and emergency responders.

Study Significance

Cardiopulmonary resuscitation (CPR) is a critical intervention for individuals experiencing cardiac arrest. The quality of chest compressions is a crucial determinant of survival and neurological outcome. Mechanical chest compression devices,such as the LUCAS machine, have emerged as a potential alternative to manual CPR. Understanding the comparative effectiveness of these two methods is essential for improving resuscitation practices and patient outcomes.

Study Rationale

While manual CPR has been the standard of care for decades, it is subject to human variability in compression depth, rate,and fatigue. Mechanical chest compression devices offer the potential for consistent, high-quality compressions.However, the evidence on their impact on patient outcomes is still evolving. A systematic review is necessary to synthesize the available evidence and inform clinical practice.

Problem Statement

There is a lack of definitive evidence comparing the outcomes of LUCAS machine-assisted CPR to traditional manual CPR.Existing studies have produced conflicting results, and the optimal approach for managing cardiac arrest remains unclear.

Study Questions

- Does LUCAS machine-assisted CPR improve survival rates compared to manual CPR?
- What is the impact of LUCAS machine-assisted CPR on neurological outcomes?
- How does the quality of chest compressions differ between LUCAS machine-assisted CPR and manual CPR?
- Are there specific patient populations for which LUCAS machine-assisted CPR may be particularly beneficial or detrimental?

Study Aim

To systematically evaluate the evidence on the effectiveness and safety of LUCAS machine-assisted CPR compared to manual CPR in improving patient outcomes.

Study Objectives

- To identify and appraise relevant studies comparing LUCAS machine-assisted CPR to manual CPR.
- To assess the impact of LUCAS machine-assisted CPR on survival

rates, neurological outcomes, and ROCS circulation.
- To compare the quality of chest compressions between LUCAS machine-assisted CPR and manual CPR.
- To explore potential moderators and mediators of the effects of LUCAS machine-assisted CPR.
- To assess the cost-effectiveness of LUCAS machine-assisted CPR compared to manual CPR.

Methods

We conducted this systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [7] criteria. A computerized search was conducted on databases such as PubMed, Web of Science, SCOPUS, and Science Direct to discover English-language research on LUCAS machine-assisted CPR to traditional manual CPR. Relevant keywords were used in the search method in these scenarios: "Machine," "LUCAS," "Manual," "Standard," "Cardiopulmonary resuscitation," and "CPR.". Two reviewers separately searched through the search outcomes, chose relevant papers, collected data, and utilized the appropriate assessment procedures to establish how strong the included study was. Data extraction from the included studies was conducted rigorously, with particular attention to patient demographics, intervention details, and key outcome measures such as survival rates, neurological outcomes, and ROSC. The methodological quality of each included study was critically appraised using validated assessment tools to minimize the risk of bias in the review findings.

Eligibility Criteria

Inclusion Criteria

- **Study Design:** Randomized controlled trials (RCTs) comparing LUCAS machine-assisted CPR to manual CPR in adult patients experiencing out-of-hospital cardiac arrest.
- **Population:** Adult patients (age 18 years or older) experiencing out-of-hospital cardiac arrest of presumed cardiac origin.
- **Intervention:** Use of the LUCAS machine for chest compressions compared to standard manual CPR.
- **Outcomes:** Reported outcomes include survival to hospital discharge, neurological outcomes (e.g., Cerebral Performance Category [CPC] score), ROSC, and quality of chest compressions (e.g., compression depth, rate, and fraction of compressions with adequate depth).
- **Duration:** Studies conducted within the last 10 years (2014-2024).
- **Language:** Studies published in English.

Exclusion Criteria

- **Study Design:** Studies with other designs (e.g., observational studies, case series, case reports).
- **Population:** Studies including pediatric patients, in-hospital cardiac arrests, or patients with other primary causes of arrest (e.g., trauma, drowning).
- **Intervention:** Studies comparing LUCAS machines to other mechanical chest compression devices or combined interventions.
- **Outcomes:** Studies without reporting relevant outcome measures.
- **Other:** Studies with insufficient data for analysis or with an unclear description of the intervention or outcomes.

Data Extraction

Rayyan (QCRI) was utilized to check the search results and ensure accuracy [8]. Initially, titles and abstracts were screened by two independent reviewers to assess their relevance based on the established inclusion and exclusion criteria. Studies deemed potentially eligible underwent a full-text review by the same reviewers to confirm their inclusion in the systematic review. Inter-rater reliability was calculated to assess agreement between reviewers, and any discrepancies were resolved through consensus or arbitration by a third reviewer. A standardized data extraction form was developed to systematically collect pertinent study characteristics, including author(s), publication year, study setting, sample size, patient demographics (age and sex), machine type, and

outcome measures. A validated risk of bias assessment tool was employed to critically appraise the methodological quality of included studies and assess the potential risk of bias.

Data Synthesis Strategy

Summaries of the research outcomes and aspects were generated using information from relevant studies in order to provide a qualitative assessment. The optimum technique to ensure the use of the data from the included studies was determined upon after gathering the information for the systematic review was completed.

Risk of Bias Assessment

The study's quality was assessed using the critical assessment criteria for studies reporting prevalence data developed by the Joanna Briggs Institute (JBI) [9]. This tool contained nine questions. A one was provided for a favorable response, and a zero for a negative, ambiguous, or irrelevant response. The following scores will be classified as poor, moderate, or high quality: less than 4, between 5 and 7, and greater than 8. Researchers rated the quality of the studies separately, and disagreements were resolved through discussion.

To evaluate the risk of bias in the included randomized control trials, the Cochrane Collaboration Risk of Bias (ROB) instrument [10] was employed. The results are displayed in a table using various color schemes. Red indicates high danger, green indicates low risk, and yellow indicates an inability to assess the risk of bias because of insufficient information.

Results

Systematic search outcomes

Following the removal of 685 duplicates, a systematic search yielded 1211 study papers. After 526 studies' titles and abstracts were reviewed, 406 papers were rejected. Out of the 120 reports that needed to be obtained, just two articles were not found. 118 articles passed the full-text screening procedure; 78 were rejected owing to inaccurate study results, 22 were due to improper population type, 5 were abstracts, and 2 were editor's letters. Eleven of the research publications included in this systematic review met the eligibility criteria. **Figure 1** depicts an overview of the approach used to choose the research.

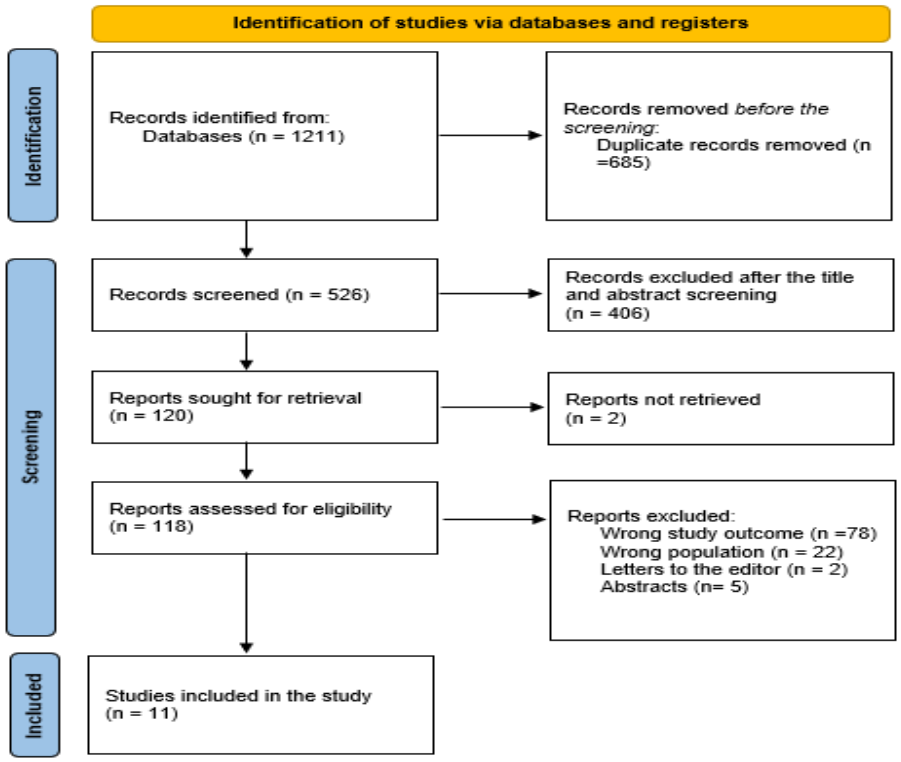

Figure 1: A PRISMA diagram is used to summarize the study decisions.

Sociodemographics of the comprised participants and studies

Table 1 displays the sociodemographic information from the research articles. Our data includes eleven articles with 3597 participants, 2146 (59.7%) of whom were males. Four studies were retrospective cohorts [11, 12, 15, 18], two were prospective RCTs [19, 21], two were prospective observational studies [17, 20], one was prospective cohort [13], one was prospective case-series [14], and one was an experimental trial [16]. Three studies were conducted in the USA [11, 13, 14], two in the Czech Republic [15, 17], one in Korea [12], one in Turkey [16], one in Australia [18], one in Singapore [19], one in Denmark [20], and one in Sweden [21].

Clinical outcomes

Table (3) presents the clinical findings. Five studies reported that the outcomes of manual and mechanical CPR using LUCAS were comparable with no significant difference in the sustained ROSC rates [11, 14, 15, 17, 19]. Three studies recorded that mechanical high-quality CPR delivery is preferable to human high-quality CPR delivery [13, 16] and it also enhances the quality of CPR during out-of-hospital cardiac arrest resuscitation by considerably lowering the no-flow fraction and by producing better chest compressions than manual CPR [20]. The advantage of employing a mechanical CPR apparatus would lie more in its ability to lessen the team's mental and physical strain, freeing them up to focus on other resuscitation procedures [11]. Only one study found a low sustained ROSC rates was substantially correlated with both cardiac origin arrest and the use of LUCASTM in the investigation comparing mechanical CPR using the device to manual CPR [12].

Using LUCAS mechanical CPR was associated with worse survival at discharge [12, 17], higher number of pericardial injuries [15], greater risk of airway hemorrhage [18], and rib fractures [21] than manual CPR.

Table 1: Sociodemographic parameters of the involved populations.

Study	Study design	Country	Participants	Mean age	Males (%)
Mastenbrook et al., 2022 [11]	Retrospective cohort	USA	Manual CPR only (n=110), LUCAS only (n=80), and both manual and LUCAS (n=92)	NM	69 (62.73%)
Kim et al., 2022 [12]	Retrospective cohort	Korea	Manual CPR (N = 149) and LUCAS TM CPR (N = 149)	56-79	197 (66.1%)
Manoukian et al., 2022 [13]	Prospective cohort	USA	15	32.5-48	14 (93%)
Frascone et al., 2022 [14]	Prospective case-series	USA	Manual CPR (n = 39) and LUCAS (n = 54)	64	36 (38.7%)
Karasek et al., 2021 [15]	Retrospective cohort	Czech Republic	Manual CPR (n = 559) and LUCAS (n = 64)	49-75	449 (72%)
Şan et al., 2021 [16]	Experimental trial	Turkey	20	24-30	10 (50%)

Karasek et al., 2020 [17]	Prospective observational study	Czech Republic	Non-LUCAS (n=134) and LUCAS (n=144)	54.5-77	186 (64.8%)
Asha et al., 2020 [18]	Retrospective cohort	Australia	LUCAS CPR (n=54) and manual CPR (n=215)	52-79	103 (38.2%)
Anantharaman et al., 2017 [19]	Prospective RCT	Singapore	Manual CPR (n = 923) and LUCAS (n = 255)	67.1 ± 15.9	782 (66.4%)
Tranberg et al., 2015 [20]	Prospective observational study	Denmark	Manual CPR (n = 155) and LUCAS (n = 155)	66 ± 15	230 (74.2%)
Smekal et al., 2014 [21]	Prospective RCT	Sweden	Manual CPR (n = 139) and LUCAS (n = 83)	21-100	70 (31.5%)

Table (2): Management strategies of the comprised participants.

Study ID	LUCAS type	Efficacy	Complications	JBI
Mastenbrook et al., 2022 [11]	LUCAS-2	When compared to manual chest compressions, the LUCAS-2 mechanical CPR device did not appear to have an impact on the sustained ROSC rates. The advantage of employing a mechanical CPR apparatus would lie more in its ability to lessen the team's mental and physical strain, freeing them up to focus on other resuscitation procedures.	NM	Moderate
Kim et al., 2022 [12]	LUCAS™	Low sustained ROSC rates was substantially correlated with both cardiac origin arrest and the use of LUCAS™ in the investigation comparing mechanical CPR using the device to manual CPR.	Since it was eliminated from the final regression model, the use of the LUCAS™ as a mechanical CPR device did not substantially correlate with survival at discharge.	High
Manoukian et al., 2022 [13]	LUCAS-3	In both steady and dynamic riverine navigation, mechanical high-quality CPR delivery is preferable to human high-quality CPR delivery.	Mechanical high-quality CPR delivery was not impacted by drive style, whereas manual high-quality CPR delivery performed worse in dynamic transportation situations than in stable transport conditions.	Moderate
Frascone et al., 2022 [14]	LUCAS-2	Between the two compression techniques, there was no difference in the recovery of spontaneous circulation upon ED admission.	NM	Moderate

Karasek et al., 2021 [15]	LUCAS-2	Instances of serious CPR-related injuries were comparable across manual and mechanized CPR.	Although it did not affect the overall severity of the injuries, the length of mechanical CPR (LUCAS) was much longer and led to a significantly higher number of pericardial injuries.	Moderate
Şan et al., 2021 [16]	LUCAS^{TM}	According to the chest compressions used by the medical staff during patient transfer, it was discovered that the mechanical chest compression device was superior to the guides' technique in terms of both speed and duration.	NM	
Karasek et al., 2020 [17]	LUCAS-2	The recovery of spontaneous circulation is not much different. There were noticeably greater conversions from non-shockable to shockable rhythm in the LUCAS group.	Patients with out-of-hospital cardiac arrest had a worse survival rate when the LUCAS method was used. The 30-day death rate was significantly greater in patients receiving LUCAS treatment.	
Asha et al., 2020 [18]	LUCAS-2	NM	When compared to manual CPR, the LUCAS mechanical CPR device is linked to a greater risk of airway hemorrhage.	
Anantharaman et al., 2017 [19]	LUCAS-2	The MECCA trial found no evidence of a statistically significant benefit between normal manual CPR and the LUCAS 2 mechanical CPR device.	NM	
Tranberg et al., 2015 [20]	LUCAS-2	The LUCAS device's mechanical chest compressions enhance the quality of CPR during out-of-hospital cardiac arrest resuscitation by considerably lowering the no-flow fraction and by producing better chest compressions than manual CPR.	NM	
Smekal et al., 2014 [21]	LUCAS-2	NM	Rib fractures were more common following mechanical CPR in patients with ineffective CPR following out-of-hospital cardiac arrest, although there was no difference in the incidence of sternal fractures. The pathologist determined that no injury was lethal.	

***NM=Not-mentioned**

Discussion

Resuscitation studies have historically evaluated the impact of interventions on total patient populations on survival rates in order to determine whether an intervention is better than its control. That being said, this presupposes that the same intervention would have a comparable impact on a diverse range of patients in different situations. Thus far, only a couple of conclusions have helped to resolve the clinical dilemma: whether a particular patient would benefit from mechanical chest compressions and whether the team should aim for the use of an automated mechanical CPR device at a particular time. This suggests that a review is necessary in order to close this knowledge gap. The review should concentrate on carefully selecting subgroups based on patient characteristics, locations, and scenarios.

Although automatic devices perform chest compressions with great quality, opinions differ on whether or not they enhance the effectiveness of CPR. We carried out this systematic review to compare LUCAS CPR with manual CPR in cardiac arrests.

Nearly half of the included literature reported that the outcomes of manual and mechanical CPR using

LUCAS were comparable with no significant difference in the sustained ROSC rates [11, 14, 15, 17, 19]. **Sheraton *et al.*** similarly reported that although the quality of CPR is improved, the use of mechanical devices during CPR does not enhance ROSC outcomes. However, we do advise emergency medical services personnel to have access to these devices as a backup plan in case they become fatigued, run out of manpower, or encounter other circumstances that prevent them from starting high-quality manual CPR early in the field [22]. In contrast, **Li *et al.*** compiled the results of nine investigations—three conducted in inpatient settings, three in outpatient settings, and two RCTs and observational studies. They came to the conclusion that manual compressions had a higher chance of achieving ROSC than load-distributing bands [23].

In addition to improving the quality of CPR during out-of-hospital cardiac arrest resuscitation by significantly lowering the no-flow fraction and by producing better chest compressions than manual CPR [20], three studies included in this review documented that mechanical high-quality CPR delivery is preferred over human high-quality CPR delivery [13, 16]. By reducing the team's physical and emotional stress, a mechanical CPR machine would benefit them more by allowing them to concentrate on other resuscitation techniques [11].

Using LUCAS mechanical CPR was associated with many complications including worse survival at discharge [12, 17], higher number of pericardial injuries [15], greater risk of airway hemorrhage [18], and rib fractures [21] than manual CPR. In contrast, **Remino *et al.*** reported that manual CPR prompted more prevalent anterior rib fractures, sternal fractures, and midline chest abrasions along the sternum than automated CPR [24].

Limitations

The use of observational research was the main source of limitation. The nature of our inquiry renders both types similar, despite the fact that these are thought to be less effective than RCTs. Every study had a distinct field of research. The location of the arrest, the distance to the hospital, the traffic the ambulance had to navigate, and the security of manual compressions during transit were among the logistical variations that went unaccounted for.

Conclusion

The findings of this study are inconclusive. The majority of the study's trials did not show that CPR administered via LUCAS was any more successful than CPR administered manually. Nonetheless, improvements in clinical research and technology, along with a deeper comprehension of the organizational consequences of their application, are continuously enhancing the efficacy of these tools.

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