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ORIGINAL ARTICLE

Assessing the Efficacy of Lund University Cardiac Assist System (LUCAS) Mechanical Chest Compression Systems Versus Manual Compression in Cardiac Arrest: A Comprehensive Systematic Review and Meta-Analysis

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Background

Mechanical chest compression devices have gained interest in resuscitation science because they have the capability to continuously provide high-quality CPR and improve outcomes. However, evidence has shown mixed results on their effectiveness. Therefore, the current review was constructed to determine whether the introduction of the Lund University Cardiac Assist System (LUCAS) as a subtype of mechanical CPR can improve the outcomes of out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) compared with manual CPR.

Methods

An extended search for studies relevant to our study was performed on five electronic databases (PubMed, Scopus, ScienceDirect, Medline, and Google Scholar). Quality appraisal of eligible randomized studies was performed using Cochrane's risk of bias tool, while the Newcastle Ottawa scale was used for the evaluation of observational studies. Moreover, the RevMan software (version.5.4.1) was used to perform all meta-analyses.

Results

Our extensive search yielded 2409 articles, of which only 18 (7 Randomized controlled trials (RCTs) and 11 observational studies) were eligible for inclusion and analysis. Both RCTs and observational studies have shown that in non-traumatic OHCA patients, pre-hospital CPR with LUCAS was not superior to manual CPR in terms of return to spontaneous circulation (ROSC), survival to hospital admission (SHA), survival to hospital discharge (SHD), and discharge with good neurological outcome. Similarly, in patients with OHCA or IHCA, in-hospital LUCAS mechanical CPR did not demonstrate superiority over manual chest compression, as shown by the ROSC and SHD outcomes. In addition, LUCAS did not improve ROSC and SHD endpoints in patients exhibiting non-shockable rhythms. Furthermore, a subgroup analysis for CPR-related injuries showed that LUCAS mechanical CPR did not pose a significant risk for rib fractures, hemothorax, or pneumothorax compared to manual compression. However, it was associated with an increased risk for sternal injuries as indicated by outcomes in three observational studies.

Conclusions In patients with IHCA or OHCA, LUCAS is not more effective than manual compression. Moreover, observational studies suggest that LUCAS might be associated with more sternal fractures. As a result, we are unable to endorse or contradict the adoption LUCAS as first-line intervention for cardiac arrest patients.

Keywords Cardiac arrest, In-hospital cardiac arrest, Lund University Cardiac Assist System, Manual compression, Mechanical chest compression devices, Out-of-hospital cardiac arrest, Systematic Review and Meta-Analysis.

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INTRODUCTION

Cardiac arrest is characterized by the termination of normal mechanical cardiac activity. Research shows that out-of-hospital cardiac arrest (OHCA) transpires in about 424000 individuals in the United States of America and 275000 in Europe every year [1,2]. Moreover, the most current annual statistics from the United Kingdom NCAA have estimated the incident rate of in-hospital cardiac arrest (IHCA) to range from 1 to 1.6 per 1000 hospital admissions [3]. Extrapolated data from the GWTG-R register also suggest that IHCA prevalence in the USA is about 9.7 per 1000 hospital admissions [3,4].

Cardiac arrest in either setting has a high mortality rate; therefore, provision of high-quality CPR is essential for survival. The current evidence on resuscitation science suggests that return of spontaneous circulation (ROSC) among patients with cardiac arrest is seemingly achieved by combining early, steady, high-quality 5.0cm chest compressions for 100–120 per minute, with a full chest recoil after every compression [5]. However, there is an increasing concern that maintaining this high-quality cardiopulmonary resuscitation (CPR), particularly before admission to hospitals, is difficult due to limited crew members, exhaustion, patient access, multiple responsibilities, and challenges associated with carrying out resuscitation during transportation [6]. Therefore, mechanical chest compression devices have been suggested as the viable remedy for improved results. One of these mechanical devices used for CPR is the Lund University Cardiac Assist System (LUCAS).

Previous research articles comparing mechanical and manual chest compressions have produced mixed results. For instance, a recent meta-analysis of pre-hospital CPR reported that mechanical CPR was more beneficial than manual CPR in the ROSC outcome, but not survival to hospital discharge (SHD), survival to hospital admission (SHA), and discharge with good neurological outcomes [7]. On the other hand, a 2018 Cochrane review found a reduced survival rate in cardiac arrest patients resuscitated using mechanical devices as opposed to those resuscitated with manual compression [8]. Another review which included IHCA cases only, reported that mechanical CPR was associated with improvement in 30-day mortality and SHD but not ROSC [9]. The mixed outcomes in these reviews might be explained by the fact that they pooled data for different mechanical devices. Therefore, we constructed this study to compare the outcomes of mechanical CPR using LUCAS with manual compression. In this sense, we included both observational and randomized controlled trials (RCTs) as we aimed to understand the effectiveness of mechanical compression with LUCAS in various clinical settings.

METHODS

Eligibility Criteria

One reviewer separately utilized the PICOST approach to develop research questions to include papers in the present review. The proposed approach was; Participants (P): patients aged 18 or older experiencing IHCA or OHCA. Intervention (I): LUCAS or SCAS during cardiopulmonary resuscitation (CPR). Comparison (C): Manual chest compression during CPR. Outcomes (O): ROSC, SHD, SHA, survival with favorable neurological outcome, and CPR-related complications. Study design (S): Human randomized trials (RCTs) and observational/cohort studies. Time frame (T): All scientific research articles published by May 2023.

Literature search

Two reviewers separately searched PubMed, Scopus, ScienceDirect, Medline, and Google Scholar databases for papers relevant to our research. To retrieve potential studies, the investigators applied search phrases such as: (Lund University Cardiopulmonary Assist System OR LUCAS OR Mechanical) AND (manual OR standard) AND (cardiopulmonary resuscitation OR CPR OR chest compression) AND (Cardiac Arrest OR sudden cardiac arrest OR Heart attack). Moreover, they excluded any close or identical studies and grey literature that would have compromised the scientific goal of this study.

Data Extraction and Definitions

Two separate reviewers gathered the data required to perform statistical analyses and documented them in identical tables. The data gathered from each research were as follows: Author ID (First author's surname and publication year), Study design, Country of the study, context of the cardiac arrest, and outcomes examined. The outcomes were classified as primary (i.e., ROSC, SHA, SHD, and survival with favorable neurological results) and secondary (i.e., CPR-related complications). In the case of conflicts in the obtained data, the two reviewers participated in constructive talks or contacted a third reviewer to assist resolve the differences.

Good neurological outcome was determined using three separate medical measures. The most commonly used scale was the Cerebral Performance Category (CPC) scale [10], of which scores of 1or 2 were deemed as good neurological outcome. The other scale used was the modified Rankin Scale (mRS) [11], of which score of ≤3 was regarded as good neurological outcome. Finally, the Glasgow Coma Scale [12] was used in one study, of which scores of ≥13 were regarded as favorable neurological function.

Quality Appraisal

The present review comprised RCTs and observational studies; consequently, the quality assessment was undertaken using two distinct techniques (i.e., Cochrane risk of bias (RoB) and Newcastle Ottawa scales (NOS). The RoB tool was employed to appraise RCTs, while the NOS was utilized to examine observational/cohort studies. The overall methodological quality was also examined by converting the ratings from the two evaluation instruments to the Agency of Healthcare Research Quality Standards (AHRQ).

Data Analysis:

The Review Manager software was utilized to carry out all meta-analyses. The DerSimonian & Laird random effects model was used to pool the Risk Ratio (RR) of all outcomes. This model was adopted because we intended to mitigate the projected heterogeneity across studies and offer a cautious estimate of pooled effect size. Moreover, the clinical heterogeneity between studies was quantified using the I2 statistics, of which percentages larger than 50% signified considerable heterogeneity. We also carried out subgroup analyses using various PICO questions to to examine the impact of LUCAS mechanical CPR in various cardiac arrest situations. Additionally, whenever possible (i.e., more than two studies), a subgroup analysis depending on the study design was carried out.

RESULTS

Study selection

The database search using the aforementioned mesh terms yielded 2409 articles. 882 of these were eliminated after being deemed either exact or close duplicates. Another 549 with irrelevant titles and abstracts were also eliminated. Of the 978 remaining articles, 861 were excluded because they did not meet the criteria for study design. Finally, we included 18 articles for review, and excluded the other 99 as follows: 17 studies included Mankins or animals, 6 were non-English papers, and 29 evaluated LUCAS without comparing with manual compression, and 47 used Autopulse for mechanical CPR. The entire selection criteria can be viewed in the PRISMA flow chart below (Figure 1).

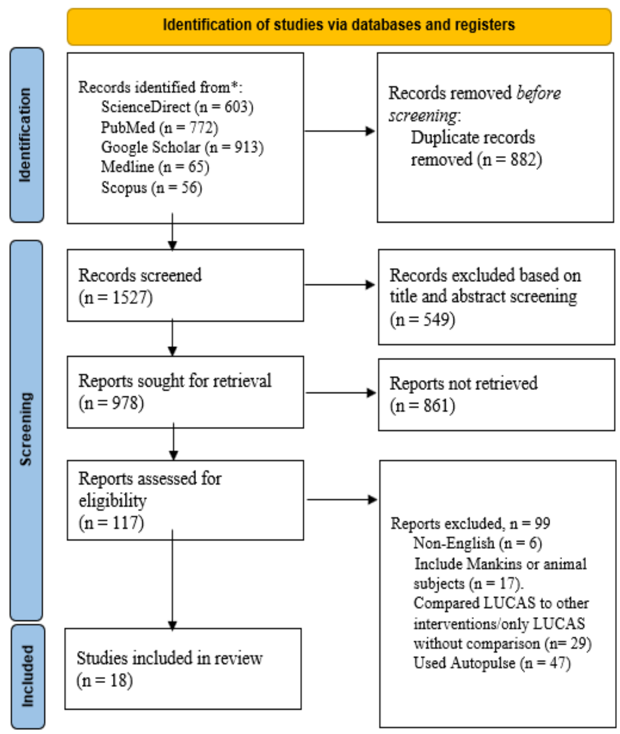

Figure 1: PRISMA flow diagram.

Summary of study characteristics

Table (1) summarizes the characteristics and outcomes of the included studies. Overall, 19 studies involving 17,809 patients with cardiac arrest were evaluated. Most studies were conducted in out-of-hospital cardiac arrest (OHCA) settings, with a few including in-hospital cardiac arrest (IHCA) or both. Most patients were adults, although age data were not consistently reported across studies. Eleven studies were randomized controlled trials, while the remaining were observational or retrospective designs. Eight studies evaluated rib and sternal injuries, with mechanical CPR (LUCAS) generally associated with a higher rate of chest wall trauma compared to manual CPR. Rates of return of spontaneous circulation (ROSC), survival to hospital admission (SHA), and survival to hospital discharge (SHD) were broadly comparable between LUCAS and manual CPR across most studies. The overall quality of the studies ranged from poor to good, with the majority rated as fair.

Table 1: Summary of Study characteristics:

Author ID	Study Design	Country	Participants' characteristics			Setting of cardiac arrest	Outcomes	Quality of the study
			Sample, n	M/F	Age			
Anantharaman *et al.*, 2017 [13]	Prospective, multicenter RCT	Singapore	1191	792/399	NR	OHCA	The rate of ROSC after LUCAS CPR was comparable to that of manual CPR (31.1% vs. 29.2%; *p*=0.537). The rate of SHD after LUCAS CPR was comparable to that of manual CPR (4.3% vs. 3.6%; *p*=0.579).	Poor
Smekal *et al.*, 2011 [14]	Prospective RCT	Sweden	148	100/48	NR	OHCA	The rate of SHD after LUCAS CPR was comparable to that of manual CPR (8.1% vs. 9.7%; *p*=0.78). The proportion of participants admitted alive did not vary between the LUCAS and manual compression cohorts (18 vs. 15; *p*=0.69). The rate of ROSC after LUCAS CPR was comparable to that of manual CPR (41% vs. 32%; *p*=0.30).	Fair
Rubertsson *et al.*, 2014 [15]	Multicenter RCT	Sweden, the Netherlands and the United Kingdom	2589	1726/863	69.1(15–99)	OHCA	The rate of ROSC after mechanical CPR was comparable to that of manual CPR (35.4% vs. 34.6%; *p*=0.68). The rate of patients surviving to discharge with good neurological outcomes after mechanical CPR was comparable to that of manual CPR (8.3% vs. 7.8%; *p*=0.25). The rate of SHA and SHD was comparable among the groups (*p*=0.83 and *p*=0.89, respectively).	Fair
Perkins *et al.*, 2015 [16]	Pragmatic, cluster RCT	The United Kingdom	4471	2813/1658	NR	OHCA	The rate of ROSC after LUCAS CPR was comparable to that of manual CPR (32% vs. 31%, respectively). The rate of patients surviving to hospital admission after LUCAS CPR was comparable to that of manual CPR (23% vs. 23%). The proportion of patients released with sufficient neurological outcomes following LUCAS CPR was equivalent to that of manual (5% vs. 6%, respectively).	Fair
Koster *et al.*, 2017 [17]	Prospective RCT	The Netherlands	374	244/130	NR	IHCA and OHCA	Rib fracture rates after LUCAS CPR were comparable to that of manual CPR (39.8% vs. 41.3%, respectively). More Sternum fractures were recorded after using LUCAS as opposed to manual compression (6.5% vs. 4.0%, respectively).	Fair
Axelsson *et al.*, 2006 [18]	Descriptive non-randomized controlled study	Sweden	328	255/73	71±13	OHCA	The rate of ROSC, SHA, and SHD after LUCAS CPR were comparable to that of manual CPR	Poor
Şener *et al.*, 2022 [19]	Retrospective observational study	Turkey	303	159/144	NR	IHCA	The rate of ROSC after manual CPR was comparable to that of LUCAS CPR (59 vs. 73; *p*=0.184). 30-day survival/SHD rate after LUCAS CPR was comparable to that of manual CPR (9 vs. 19; *p*=0.420).	Fair
Ujvárosy *et al.*, 2018 [20]	Retrospective randomized study	Hungary	520	357/163	NR	OHCA	Of the 55 cases where mechanical compression was performed, 26 had ROSC, while ROSC was observed in 83 patients in the manual compression group.	Fair
Saleem *et al.*, 2022 [21]	Retrospective study	Israel	107	71/36	NR	OHCA	The incidences of rib and sternal fractures following LUCAS CPR were equivalent to those of manual (*p*=0.41 and *p*=0.38, respectively).	Poor
Newberry *et al.*, 2017 [22]	Retrospective study	The United States	2999	1783/1216	64 ± 17	OHCA	The ROSC, SHA, and SHD rates after mechanical CPR were comparable those of standard CPR (*p*=0.3214, *p*=0.4418, and *p*=0.1312, respectively). Manual CPR improved the rate of patients discharged with good neurological than mechanical CPR (6% vs. 4%; *p*=0.036).	Fair
Chen *et al.*, 2021 [23]	Retrospective cohort study	Taiwan	552	306/246	NR	OHCA	The rate of ROSC was considerably higher after using LUCAS CPR as opposed to manual CPR (28.67% vs. 21.25%; *p*=0.044). The proportion of individuals surviving to discharge with satisfactory neurological results did not vary between the LUCAS and manual CPR cohorts (5.38% vs. 4.40%; *p*=0.593).	Good

Şener *et al.*, 2021 [24]	Retrospective case-control study	Turkey	214	145/69	NR	OHCA	Patients who underwent manual resuscitation achieved ROSC more than those resuscitated with LUCAS (33.1% vs. 11.1%, p<0.001). The proportion of SHD was identical across the manual and mechanical CPR cohorts (6.8% vs. 3.7%, respectively).	Fair
Couper *et al.*, 2020 [25]	Multicenter parallel group feasibility RCT	The United Kingdom	127	76/51	72(69.9–74.9)	IHCA	The rate of ROSC, SHD, and survival with good neurological outcomes after LUCAS CPR were comparable to those of manual CPR (28.3% vs. 25%, 4% vs. 3.6%, and 4% vs. 3.6%, respectively).	Poor
Tantarattanapong *et al.*, 2022 [26]	Retrospective study	Thailand	227	144/83	NR	OHCA and IHCA	The rate of sustained ROSC was improved by the use of manual CPR as opposed to mechanical CPR (30.1% vs. 9.4%; p=0.029). The rate of SHA, SHD, and SHD after LUCAS CPR were comparable to that of manual CPR (p=0.052, p=0.127, and p=1.0, respectively).	Fair
Halhalli *et al.*, 2020 [27]	Retrospective analytical study	Turkey	818	481/337	70(60–80)	OHCA	The percentage of ROSC and participants being discharged with satisfactory neurological outcomes following LUCAS CPR were equivalent to that of manual CPR (p=0.244 and p=0.501, respectively).	Fair
Smekal *et al.*, 2014 [28]	Prospective multicenter RCT	Sweden	222	152/70	NR	OHCA	Individuals undergoing manual CPR had considerably fewer injuries than individuals undergoing mechanical CPR (75.9% vs. 91.4%; p=0.002). More rib fractures were recorded after using mechanical CPR as opposed to manual CPR (78.8% vs. 64.6%; p=0.021). The rate of sternal fractures after manual CPR was comparable to that of mechanical CPR (54.2% vs. 58.3%; p=0.555).	Poor
Friberg *et al.*, 2019 [29]	Prospective Study	Sweden	414	284/130	NR	OHCA	Higher rates of rib and sternal fracture were recorded when mechanical CPR was used as opposed to manual CPR (p<0.001).	Poor
Milling *et al.*, 2019 [30]	Retrospective study	Denmark	437	322/115	NR	OHCA	Mechanical CPR was associated with increased rib and sternal fractures than manual CPR (p<0.001 and p=0.005, respectively).	Fair

RCT: Randomized controlled trial; NR: Not Reported; IHCA: In-hospital cardiac arrest; OHCA: Out-of-hospital cardiac arrest; CPR: Cardiopulmonary resuscitation; ROSC: Return of Spontaneous Circulation; SHA: Survival to hospital admission; SHD: Survival to hospital discharge; LUCAS: Lund University Cardiac Assist System.

Quality Assessment Results

Using the RoB tool we noticed that of the 7 RCTs, 3 had poor quality and 4 were of fair quality (Figure 2). Only, the research by Couper *et al.,* demonstrated a considerable risk of attrition and reporting bias. According to this research, the planned number of participants was not met and the researchers had to eliminate some of the pre-planned results.

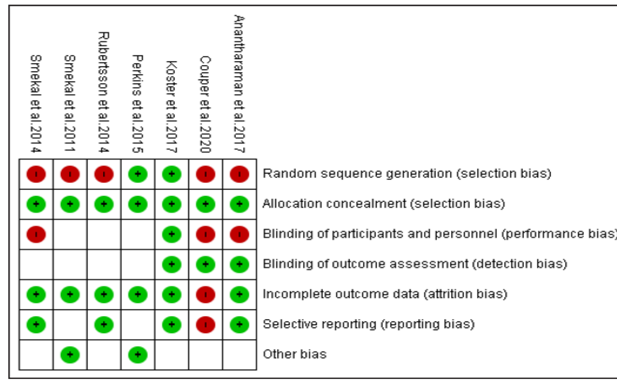

Figure 2: Risk of Bias Summary.

On the other hand, the NOS scale showed that good methodological quality was observed in only one study, while 3 studies had poor methodological quality and 7 had fair quality (Table 2). Most of the studies received a score of 2 in the selection criteria since they took place in single institutions which might not have represented a real sample of cardiac arrest patients.

Table 2: Methodological quality using Newcastle Ottawa Scale:

Study	Selection (/4)	Comparability (/2)	Outcomes (/3)
Axelsson *et al.*, 2006	3	2	1
Şener *et al.*, 2022	2	2	2
Ujvárosy *et al.*, 2018	2	2	2
Saleem *et al.*, 2022	2	2	1
Newberry *et al.*, 2017	2	2	2
Chen *et al.*, 2021	3	2	2
Şener *et al.*, 2021	2	2	2
Tantarattanapong *et al.*, 2022	2	2	2
Halhalli *et al.*, 2020	2	2	2
Friberg *et al.*, 2019	2	2	1
Milling *et al.*, 2019	2	2	2

In patients with non-traumatic OHCA, does pre-hospital mechanical compression with LUCAS compared with manual compression improve the outcomes?

In pre-hospital settings, the effect of mechanical CPR on the outcomes of patients with cardiac arrest remains controversial. Therefore, the current study analyzed data from both randomized and observational studies to determine the effect of mechanical compression with LUCAS on cardiac arrest outcomes. Our subgroup analysis has shown that the rate patients achieving ROSC does not differ significantly between the LUCAS and manual compression groups (RR: 1.02; 95% CI: 0.96–1.09; p=0.35 and RR: 1.07; 95% CI: 0.86–1.33; p=0.54, for RCTs and observational studies, respectively) (Figure 3). Similarly, our subgroup analyses did not find any significant difference in SHA (RR: 1.01; 95% CI: 0.93–1.09; p=0.87 and RR: 0.92; 95% CI: 0.69–1.23; p=0.59, for RCTs and observational studies, respectively) (Figure 4), SHD (RR: 1.00; 95% CI: 0.8–1.25; p=1.00 and RR: 0.63; 95% CI: 0.29–1.37; p=0.25, for RCTs and observational studies, respectively) (Figure 5) and discharge with good neurological outcomes (RR: 0.92; 95% CI: 0.67 – 1.25; p=0.57 and RR: 0.77; 95% CI: 0.52–1.15; p=0.20, for RCTs and observational studies, respectively) (Figure 6) between the manual compression group and the LUCAS group.

In patients with OHCA, does in-hospital mechanical compression with LUCAS improve the outcomes?

In most studies evaluating OHCA cases, mechanical CPR was started at the scene or during transport to hospitals. However, two observational studies have reported that since mechanical compression device (LUCAS) was not available in the pre-hospital setting, manual CPR was performed until mechanical CPR was available in the emergency department (ED). Data pooled from these studies showed insignificant differences in ROSC and SHD outcomes between the LUCAS and manual compression group (RR: 0.58; 95% CI: 0.21–1.58; p=0.29 and RR: 0.98; 95% CI: 0.57–1.69; p=0.95, respectively) (Figure 7,8).

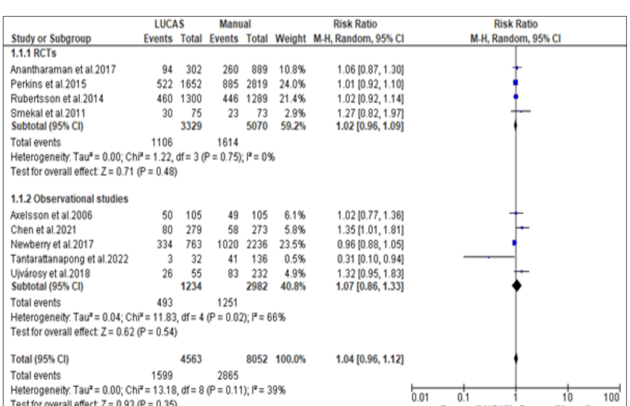

Figure 3: The effect of pre-hospital LUCAS compared with manual compression on the rate of ROSC.

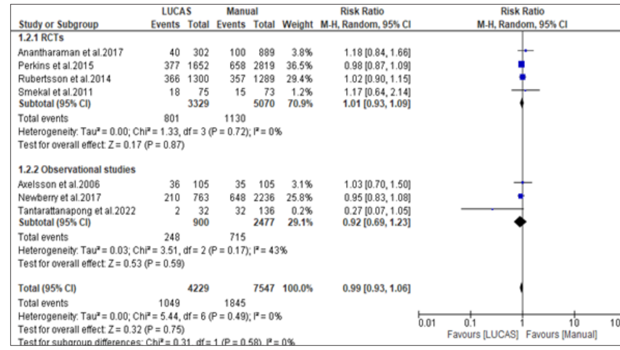

Figure 4: The effect of pre-hospital LUCAS compared with manual compression on the rate of SHA.

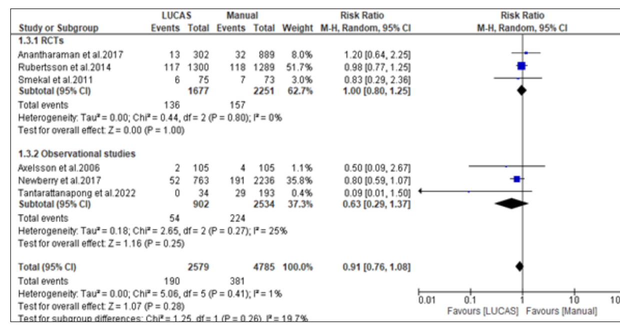

Figure 5: The effect of pre-hospital LUCAS compared with manual compression on the rate of SHD.

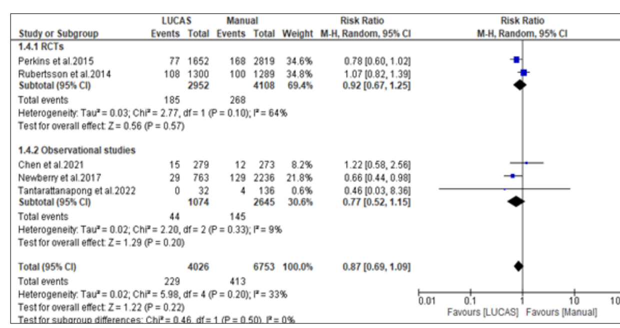

Figure 6: The effect of pre-hospital LUCAS compared with manual compression on the rate of survival with good neurological outcome.

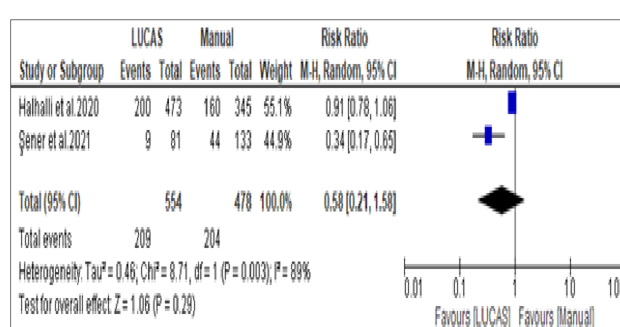

Figure 7: The effect of in-hospital LUCAS in OHCA patients compared with manual compression on the rate of ROSC.

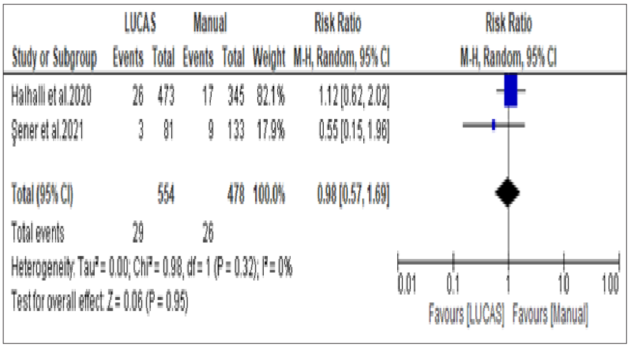

Figure 8: The effect of in-hospital LUCAS in OHCA patients compared with manual compression on the rate of SHD.

In patients with IHCA, does in-hospital mechanical compression with LUCAS improve the outcomes?

Although most of the focus has been on OHCA, mechanical chest compression can also be performed in IHCA cases. Data pooled from two studies has shown no significant difference in ROSC rate between the LUCAS compression group and the manual compression group (RR: 0.85; 95% CI: 0.68–1.08; *p*=0.19) (Figure 9). Similarly, our analysis demonstrated no significant difference in SHD rate between the LUCAS and manual compression groups (RR: 1.40; 95% CI: 0.69–2.87; *p*=0.35) (Figure 10). Moreover, the statistical analyses showed no heterogeneity between the studies (I2= 0%).

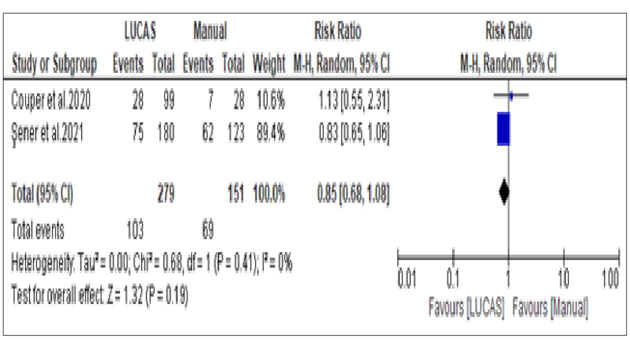

Figure 9: The effect of in-hospital LUCAS in IHCA patients compared with manual compression on the rate of ROSC.

In Cardiac Arrest patients with non-shockable rhythms (Pulseless Electrical Activity (PEA) and asystole), does resuscitation with LUCAS compared with manual compression improve the outcomes?

PEA and asystole rhythms are not amenable to shock; therefore, performing high-quality CPR in cardiac arrest patients with these rhythms is essential for resuscitation. Only two RCTs included in this review evaluated the effect of LUCAS on the outcomes of patients with non-shockable rhythms. Data pooled from these studies showed that the rate of ROSC did not differ between the LUCAS and manual compression groups (RR: 1.12; 95% CI: 0.90–1.40; *p*=0.29) (Figure 11). Similarly, our analysis found no considerable difference in SHD rate between the LUCAS and Manual compression groups (RR: 2.13; 95% CI: 0.76–6.00; *p*=0.15) (Figure 12).

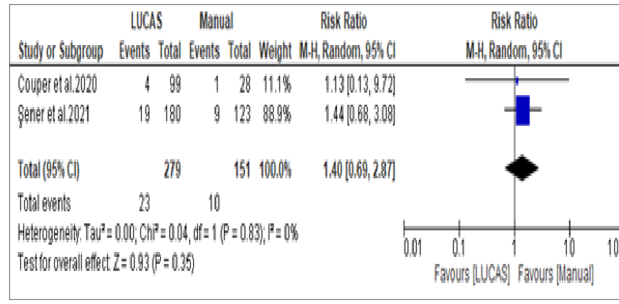

Figure 10: The effect of in-hospital LUCAS in IHCA patients compared with manual compression on the rate of SHD.

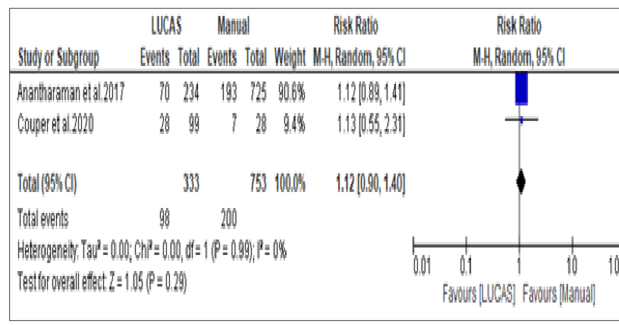

Figure 11: The effect of in-hospital LUCAS in cardiac arrest patients exhibiting non-shockable rhythms compared with manual compression on the rate of ROSC.

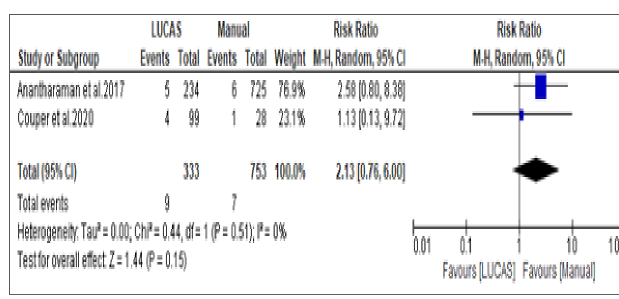

Figure 12: The effect of in-hospital LUCAS in cardiac arrest patients exhibiting non-shockable rhythms compared with manual compression on the rate of SHD.

In patients with OHCA or IHCA, is mechanical compression with LUCAS as safe as Manual compression?

To analyze whether LUCAS is safe as manual compression, we grouped CPR-related injuries into skeletal (i.e., rib and sternal fractures) and visceral injuries (i.e., hemothorax and pneumothorax). Data pooled from 2 RCTs and 3 observational studies showed no considerable difference in the rate of rib fractures between the LUCAS and manual compression groups (RR: 1.01; *p*=0.97 and RR: 1.35; *p*=0.08, respectively). Similarly, pooled analysis of 2 RCTs demonstrated no significant difference in the sternal fracture incidences (RR: 1.10; *p*=0.45). However, 3 observational studies revealed that patients resuscitated with LUCAS had higher incidences of sternal fractures than those resuscitated with manual compression (RR: 2.46; p<0.00001).

On the other hand, our subgroup analyses of visceral injuries showed a non-significant incidence of hemothorax between the LUCAS and manual compression groups (RR: 1.79; p=0.47 and RR: 1.33; p=0.84, for RCTs and observational studies, respectively). Additionally, the incidence of pneumothorax did not differ statistically between the two groups (RR: 0.84; p=0.78 and RR: 0.80; p=0.70, for RCTs and observational studies, respectively). These findings are summarized in Table (3).

Table 3: Meta-Analytic results on the incidence of CPR-related injuries between LUCAS and Manual CPR groups:

CPR-related injuries	Type of injury	Study design	No of studies	RR (95% CI)	p-value	I^2 (%)
Skeletal	Rib fractures	RCTs	2	1.01(0.68–1.49)	0.97	85
		Observational	3	1.35(0.97–1.89)	0.08	52
	Sternal fractures	RCTs	2	1.10(0.86–1.39)	0.45	0
		Observational	3	2.46(1.71–3.53)	<0.00001	13
Visceral	Hemothorax	RCTs	1	1.79(0.37–8.67)	0.47	-
		Observational	2	1.33(0.08–22.02)	0.84	58
	Pneumothorax	RCTs	2	0.84(0.26–2.75)	0.78	0
		Observational	2	0.80(0.24–2.59)	0.70	0

CPR: Cardiopulmonary resuscitation; RCTs: Randomized controlled trial; No: Number; RR: Relative risk; CI: Confidence interval.

DISCUSSION

Patients with cardiac arrest are usually subjected to CPR to restore spontaneous circulation and enhance the probability of surviving. Therefore, high-quality CPR high-quality CPR is necessary for them to survive. Currently, CPR is performed either through manual or mechanical compression with devices such as Autopulse and LUCAS. However, the impact of mechanical CPR on the consequences of cardiac arrest remains debatable. Therefore, the current meta-analysis was conducted to evaluate the effectiveness and safety of mechanical compression using LUCAS compared to manual compression. Our meta-analysis has shown that CPR with LUCAS has similar outcomes (i.e., ROSC, SHD, SHD, and discharged with good neurological outcomes) as manual CPR in non-traumatic OHCA cases addressed in pre-hospital and in-hospital settings. Similarly, when the data was limited to IHCA cases and patients with non-shockable rhythms, we found that LUCAS had similar outcomes as manual compression. Moreover, our subgroup analyses showed that mechanical CPR with LUCAS is as safe as manual compression. However, LUCAS seems to have an increased risk for sternal fractures than manual compression.

In pre-hospital settings, high-quality CPR can be challenging; therefore, mechanical CPR machines have recently been utilized to enhance results. However, our meta-analysis has demonstrated that LUCAS in a pre-hospital scenario is not more beneficial than manual compression with respect to ROSC, SHA, SHD, and discharge with favorable neurological outcomes. These results are corroborated by a prior systematic analysis which did not uncover any reasons to support or reject the application of mechanical CPR in a pre-hospital setting among patients with OHCA [31]. However, a recent meta-analysis revealed mechanical CPR was more beneficial than manual CPR in the ROSC outcome [7]. Similarly, a meta-analysis that pooled data from non-randomized studies revealed that mechanical CPR was considerably better than manual CPR with respect to ROSC and SHA [32]. Furthermore, Westfall et al. reported a pooled OR of 1.53 in favor of mechanical chest compressions [33]. However, these meta-analyses pooled data for other mechanical devices, meaning that it is difficult to tell whether the significant difference was due to LUCAS devices only or other mechanical devices. Moreover, their pooled analyses had high clinical heterogeneity than ours, meaning their results may have been inconsistent.

We also investigated the effectiveness of manual and mechanical compression in OHCA cases where LUCAS was only available in the ED and found no significant differences between these interventions. However, some contradictory information has been provided in the included literature. A statistical analysis by Sener and colleagues demonstrated a considerably higher ROSC rate in the manual group than in the mechanical group [24]. On the other hand, Hallali and colleagues reported that patients undergoing mechanical CPR had an increased probability of 1-year survival than those undergoing manual CPR [27]. However, the findings of these research studies ought to be viewed cautiously and should not be used to inform healthcare decisions owing to multiple methodological issues. First, the studies were non-randomized trials; thus, they carried the inherent limitations associated with this study design. Secondly, the research studies were executed in single facilities; therefore, their results cannot be generalized to represent all OHCA cases. Thirdly, the population in those research studies was somewhat small. Finally, evaluating whether these significant differences resulted from the manual compression used in the pre-hospital settings is difficult.

Our meta-analysis has also indicated that in IHCA cases, CPR performed with LUCAS is not superior to manual compression in terms of ROSC and SHD outcomes. However, Couper and colleagues reported significantly improved ROSC and SHD rates when using mechanical chest compression instead of manual compression [34]. Compared to our research, this meta-analysis had some methodological differences that may have impacted their results. First, the study included other mechanical devices (i.e., Autopulse) in their analyses. Second, the GRADE process used in that review revealed that the overall quality of evidence was low, meaning that the overall effect size may have been over-estimated or under-estimated [35,36]. Finally, the study's overall sample size was relatively small compared to ours (689 vs. 1086). In addition, discharge with good neurological outcomes has been recorded in one of the studies. According to Couper and colleagues, the rate of patients being discharged with good neurological outcomes was similar in both mechanical CPR and manual CPR groups [25]. If these findings are considered, we cannot support or refute the use of LUCAS in the resuscitation of IHCA patients.

Although significant progress in resuscitation science has been made, the survival rate of cardiac arrest patients exhibiting non-shockable rhythm remains unacceptably low [37,38]. Therefore, better management strategies are required to improve the outcomes of patients presenting these rhythms. Our meta-analysis analyzed the efficacy of manual and mechanical chest compression with LUCAS in patients with non-shockable and found that these interventions had similar outcomes in terms of SHD and ROSC. However, Anantharaman and colleagues grouped patients with asystole and PEA rhythms separately and found that manual CPR was associated with higher rates of 24-hour survival than mechanical CPR in patients initially exhibiting asystole rhythm (p=0.031) [13]. It was also reported that CPR performed with LUCAS had a higher rate of 30-day survival than manual compression in patients exhibiting asystole rhythm (p=0.022). However, these results should be interpreted cautiously as the study was subject to various methodological concerns. First, the sample size randomized to the LUCAS group was small due to the limited number of LUCAS devices. Second, the ambulance crew was not blinded to the interventions. Finally, the study did not evaluate the fraction of CPR or the adequacy of compression; therefore, the quality of CPR administered was not provided.

CPR is a potentially life-saving therapy for cardiac arrest; however, research has shown that it puts patients at risk for skeletal and visceral injuries [39]. In our study, skeletal fractures were categorized into sternal and rib fractures, while the visceral injuries were pneumothorax and hemothorax. The pooled data showed no difference in the risk of rib fractures, pneumothorax, and hemothorax between the mechanical and manual groups. However, the risk of sternal fractures was significantly increased when using LUCAS for CPR as opposed to manual compression. This high incidence can be explained by the fact that LUCAS concentrates its force on the sternum. However, the significant difference was only reported in observational studies which are subject to selection, information, and confounding bias. Therefore, more high quality RCTs are required to establish this finding.

In addition, studies have shown mixed results on the rib fracture outcomes. Smekal *et al.,* [28] carried out a multicenter study to evaluate CPR-related injuries and found that the rate of rib fractures was higher in the LUCAS group than in the manual group (p=0.021). However, the authors concluded that these injuries were not likely to have caused the death of any cardiac arrest patient. Similarly, Friberg and colleagues found that mechanical CPR was associated with higher incidences of rib fractures than manual CPR (p<0.001) [29]. Contrary to these findings, Milling and colleagues found a higher incidence of rib fractures in the manual group than in the LUCAS group (41.3% vs. 39.8%, respectively) [30]. The finding in this study cannot be explained with certainty, but the use of computerized tomography (CT) scans instead of the gold standard autopsy in non-surviving patients may have contributed to the difference.

While our research has not demonstrated that mechanical compression with LUCAS is advantageous over manual compression in IHCA and OHCA cases, there are circumstances in which mechanical compression machines, such as LUCAS, may be the preferable choice. These scenarios encompass the following: an insufficient number of professionals in the resuscitation team, environments that present a challenge for CPR (e.g., traveling ambulances, angiography units, and imaging units), and lengthy CPR (e.g., hypothermic arrest and specific drug intoxications). Moreover, some factors might influence the decision to carry out CPR using LUCAS in the ambulances rather than on-site. These factors include; the additional weight of LUCAS devices, disturbances from members of the public questioning the use of this device which might seem like a frightening piston device compressing the chest, and unclear emergency messages to the call center that might lead to operators failing to notice cardiac arrest call in the preliminary instance. Although these concerns demand to be tackled, provisions ought to be made for emergency medical services to conduct mechanical compression on-site to reduce the delay of application that may influence the outcomes of cardiac arrest. This is evident in the study by Axelsson *et al.,* [18] where a shorter delay in starting treatment (<11 minutes) was associated with improved outcomes.

Implications for clinical practice and future research

The proof presented in the current research implies that mechanical CPR with a LUCAS machine is not advantageous over traditional chest compression. However, this does not mean that it is inferior as it produces statistically similar outcomes as manual chest compression. Therefore, we believe that if used by trained healthcare providers, LUCAS can be an acceptable substitute to manual chest compressions, particularly in contexts where high-quality manual compression is problematic. Moreover, there is evidence suggesting that mechanical chest compression with LUCAS may be associated with more sternal fractures than manual CPR. Therefore, when incorporating this system to cardiac arrest patients it should be closely monitored to avoid harm.

Future research should focus on how LUCAS performs in scenarios where providing high-quality manual CPR may be challenging. Furthermore, more high-quality RCTs are still required to establish where LUCAS increases the risk for sternal fractures compared to manual chest compressions.

LIMITATIONS

The discoveries from this meta-analysis deserve to be interpreted with discretion due to multiple constraints. First, we systematically dismissed data from articles published in different foreign languages but relevant to our topic. Second, the research papers selected for this review were of very low quality, indicating that the quality of evidence provided in every study was poor and may have impacted the results of our meta-analyses. Third, we observed significant heterogeneity in CPR-related injuries. However, this heterogeneity was expected since various methods were used to investigate the injuries. Moreover, the sample sizes varied from study to study, and outcomes for survivors and non-survivors were pooled together. Fourth, we included studies carried out during the COVID-19 pandemic; however, the data for patients with COVID-19 was not evaluated because we considered this a sensitive issue that should be carried out separately to determine the likelihood of transmissions with the use of mechanical compression or manual compression. Fifth, our search criteria yielded 2409 potential articles; however, only 18 were included. Therefore, it is possible that this wide exclusion of articles resulted in a selection bias. Finally, in analyzing IHCA cases, we used data from Couper *et al.,* study [25]. This study might have introduced some bias to our meta-analyses because it could not achieve its intended sample size and had to preclude some key analyses that would have been used to improve our research. Despite this meta-analysis analyzed the LUCAS, it did not specify which generation was used.

CONCLUSION

In summary, our study found that using LUCAS for mechanical compression in OHCA and IHCA did not correlate with improved results compared with manual compression. It was also not superior to manual compression in cardiac arrest patients exhibiting non-shockable rhythms. In addition, we found that mechanical compression with LUCAS does not pose an increased risk for rib fractures, pneumothorax, and hemothorax injuries, but it seems to increase the risk for sternal fractures. Based on this evidence, we cannot endorse or oppose the use of LUCAS in pre-hospital and in-hospital settings. Therefore, there is a demand to conduct more high-quality randomized trials to expand on the impact of LUCAS in cardiac arrest.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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