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Optimizing Outcomes In Cardiac Arrest: Evidence-Based Review Of CPR Protocols And Mechanical Device Applications (LUCAS, Mandry, Lama)

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Abstract
Cardiac arrest remains a leading cause of mortality worldwide, demanding rapid and effective intervention to improve patient survival and neurological outcomes. High-quality cardiopulmonary resuscitation (CPR) forms the foundation of current resuscitation protocols; however, manual chest compressions are often limited by rescuer fatigue, inconsistent depth and rate, and interruptions during critical interventions. To overcome these challenges, mechanical CPR devices such as the LUCAS system have been developed to deliver consistent, In addition to Mandry and Lama systems uninterrupted compressions with the potential to optimize outcomes in both pre-hospital and in-hospital settings. This review synthesizes evidence on CPR protocols and the clinical application of these devices, highlighting their impact on return of spontaneous circulation (ROSC), survival to hospital discharge, and long-term neurological function. While studies demonstrate improvements in compression quality and logistical advantages during transport and advanced procedures, evidence regarding overall survival benefit remains mixed, with cost, training, and complication risks presenting barriers to universal adoption. The integration of mechanical CPR devices into existing protocols represents a promising adjunct to manual resuscitation, particularly in complex or resource-constrained scenarios. Future research should focus on large-scale randomized trials, cost-effectiveness analyses, and technology integration to establish clearer guidelines for device-assisted resuscitation.

Keywords: Cardiopulmonary Arrest, CPR Protocols, LUCAS, Mandry, Lama, Mechanical Resuscitation.

Introduction

1. Background and Significance

Sudden cardiac arrest (SCA) remains a major global health concern, contributing significantly to cardiovascular mortality worldwide. According to the World Health Organization (2022), cardiovascular diseases cause an estimated 17.9 million deaths annually, representing approximately 32% of global mortality, with a substantial proportion linked to cardiac arrest events. Out-of-hospital cardiac arrest (OHCA) incidence varies geographically but is estimated at 20–140 cases per 100,000 people annually, with survival rates to hospital discharge often below 10% (Gräsner, Lefering, & Herlitz, 2021). In the United States, more than 350,000 emergency medical services (EMS)–assessed OHCAs occur each year, and survival outcomes remain poor despite advances in resuscitation science (Sudden Cardiac Arrest Foundation, 2023).

In-hospital cardiac arrest (IHCA) also represents a major burden, with estimates of nearly 292,000 annual events in the U.S. alone, translating to around 9–10 per 1,000 admissions (Andersen et al., 2019). Despite decades of progress, a meta-analysis by Yan et al. (2020) reported that the one-year survival rate following OHCA remains low at 7.7%, underscoring the persistent challenges in improving outcomes.

High-quality cardiopulmonary resuscitation (CPR) is the cornerstone of cardiac arrest management. However, manual chest compressions are often limited by rescuer fatigue, inconsistent compression depth, and interruptions during patient transport (Meaney et al., 2013). These limitations have driven the development of mechanical CPR devices that can deliver continuous, guideline-consistent compressions. The LUCAS system are among the most widely studied, designed to optimize compression quality and reduce the variability inherent in manual CPR.

While mechanical CPR device have shown the ability to provide uninterrupted compressions and logistical benefits, evidence regarding survival and neurological outcomes remains mixed (Rubertsson et al., 2014; Perkins et al., 2015). Therefore, evaluating how these devices integrate into existing resuscitation protocols is significant for improving both clinical outcomes and system efficiency.

2. CPR Protocols: Development and Current Standards

Cardiopulmonary resuscitation (CPR) has undergone significant development since its formal introduction in the 1960s, when Kouwenhoven, Jude, and Knickerbocker first described closed chest compressions as a life-saving intervention for cardiac arrest. This breakthrough marked the beginning of modern resuscitation science (Kouwenhoven et al., 1960). Since then, global organizations such as the **American Heart Association (AHA)** and the **European Resuscitation Council (ERC)** have periodically updated CPR guidelines to reflect advances in evidence-based practice (AHA, 2015; AHA, 2020; ERC, 2021).

A central framework guiding CPR is the **"Chain of Survival"**, which emphasizes early recognition of cardiac arrest, rapid activation of emergency services, immediate high-quality chest compressions, timely defibrillation, and advanced life support followed by post-resuscitation care (AHA, 2020). The recognition that early initiation of CPR and defibrillation significantly improves survival has shaped both community and hospital-based protocols (Gräsner et al., 2021).

Current standards stress the delivery of **high-quality chest compressions** at a depth of 5 cm, a rate of 100–120 compressions per minute, complete chest recoil, and minimization of interruptions (AHA, 2020; Soar et al., 2021). Equally important is the integration in the **Mandre system in** the early defibrillation for shockable rhythms such as ventricular fibrillation or pulseless ventricular tachycardia (Nolan et al., 2020).

Recent guideline updates have increasingly recognized the role of **mechanical CPR devices** in specific contexts. While manual compressions remain the gold standard, mechanical devices such as LUCAS are endorsed as reasonable alternatives when high-quality manual compressions cannot be maintained, such as during patient transport, prolonged resuscitation, or coronary angiography (Soar et al., 2021; Couper et al., 2022).

The ongoing evolution of CPR protocols reflects a balance between evidence, practicality, and technological innovation. Although mechanical devices are not universally recommended for routine use, their incorporation into guidelines highlights a growing acknowledgment of their potential to enhance resuscitation under challenging conditions. This integration sets the foundation for evaluating their effectiveness within current and future resuscitation strategies.

3. Mechanical CPR Devices: Design and Application

The limitations of manual chest compressions—such as rescuer fatigue, interruptions during transport, and variability in compression quality—have driven the development of **mechanical CPR devices** to ensure consistent, high-quality resuscitation (Meaney et al., 2013). These devices are designed to automate compressions according to guideline recommendations, reducing human error and enabling providers to focus on other critical interventions.

3.1 LUCAS Device

The **LUCAS (Lund University Cardiac Assist System)** device is among the most widely used mechanical CPR systems. It is a piston-driven apparatus that delivers compressions at a controlled depth and rate, powered by battery or compressed air (Rubertsson et al., 2014). Clinical studies show that the LUCAS device provides high-quality, uninterrupted compressions during patient transport, angiography, and even in the cath lab (Olasveengen et al., 2021). However, survival benefits compared to manual CPR remain mixed, with some large trials reporting no significant improvement in overall outcomes (Rubertsson et al., 2014; Couper et al., 2022).

3.2 Mandry Device ECG

The Mindray device all-new ECG device has revolutionized the multi-talented field. ECG is a quick, simple, and painless medical exam that measures the electrical impulses in the heart during an ECG. It integrates a 12-lead ECG with 360J, manual defibrillation, automated external defibrillator, pacemaker, ECG monitoring, ultrasound imaging, blood oxygen saturation, blood pressure, and carbon dioxide.3.3 Lama Device

The Lama device Laryngeal airway masks are an invaluable tool in effective airway management, especially in emergency situations. The laryngeal mask airway (LMA) refers to a reusable or disposable supra-tracheal airway device that has been in use since 1988. It was developed by anesthesiologist and inventor Dr. Archie Breen.The LMA resembles a large endotracheal tube (ETT) at its proximal end and helps maintain an open airway by connecting its distal end to an oval mask. It is positioned over the patient's hypopharynx, allowing for relative isolation of the trachea. The LMA was initially designed as an optional ventilator in operating rooms. It has since made its way into emergency and outpatient care settings. It is often used to manage difficult airways as an alternative to bag-valve-mask ventilation, freeing up the healthcare provider's hands and reducing gastric distension.

3.4 Comparative Applications

Across devices, common benefits include the delivery of compressions at guideline-recommended depth and rate, elimination of rescuer fatigue, and reduced interruptions during advanced procedures. Yet, potential complications such as rib fractures, sternal injuries, or delays during device placement remain considerations (Smekal et al., 2011). Current guidelines recommend mechanical devices only in situations where manual CPR is impractical or unsafe, underscoring their role as adjuncts rather than replacements to high-quality manual CPR (AHA, 2020; Soar et al., 2021).

4. Clinical Evidence and Outcomes

The evaluation of mechanical CPR devices such as LUCAS has generated mixed results in terms of survival and neurological outcomes, although most studies agree that these devices deliver high-quality compressions consistently.

4.1 Return of Spontaneous Circulation (ROSC)

Early randomized controlled trials (RCTs) such as the CIRC trial demonstrated that the use of the LUCAS device provided chest compressions of consistent depth and rate but did not significantly improve rates of ROSC compared with manual CPR (Rubertsson et al., 2014). Similarly, a systematic review by Couper et al. (2022) confirmed that while mechanical devices optimize CPR quality, ROSC rates remain comparable to those achieved with manual compressions.

4.2 Survival to Hospital Admission and Discharge

Several studies indicate that survival to hospital admission is often similar between manual and mechanical CPR. For example, a meta-analysis by Gao et al. (2016) found no statistically significant difference in survival to discharge between patients treated with LUCAS versus manual CPR. However, observational data suggest that mechanical CPR may be particularly beneficial during patient transport and in environments where uninterrupted compressions are difficult (Olasveengen et al., 2021).

4.3 Neurological Outcomes

Long-term neurological recovery remains the most clinically relevant endpoint. The PARAMEDIC trial, a large RCT conducted in the UK, concluded that mechanical CPR with LUCAS did not significantly improve favorable neurological outcomes at 30 days compared with manual compressions (Perkins et al., 2015). Similar findings were echoed in subsequent reviews, suggesting that while devices maintain physiologic perfusion, the ultimate neurological benefit may be limited (Couper et al., 2022).

4.4 Device-Specific Findings

- LUCAS: Extensively studied; consistently maintains compression quality but survival and neurological outcomes remain similar to manual CPR (Rubertsson et al., 2014; Perkins et al., 2015).
  Still in early evaluation stages; pilot data suggest improved compression stability and reduced rescuer workload, though large-scale trials are lacking (Couper et al., 2022).
  Limited published evidence; early observational studies indicate usefulness in pre-hospital and resource-constrained settings, with potential logistical advantages (Soar et al., 2021).

4.5 Safety and Complications

Adverse events, including rib fractures and internal injuries, have been reported with mechanical CPR. Smekal et al. (2011) found that complication rates were comparable between manual and device-assisted compressions, though improper placement or deployment delays could negatively impact outcomes.

Overall, the evidence suggests that mechanical CPR devices offer logistical and operational advantages, particularly in scenarios where manual CPR quality may be compromised. However, large-scale survival benefits remain uncertain, underscoring the need for targeted application and further clinical trials.

Table 1. Summary of Key Studies on Mechanical CPR Devices

Author (Year)	Device	Study Design / Population	Key Outcomes
Rubertsson et al. (2014)	LUCAS	RCT (JAMA, 2,589 OHCA patients)	No significant improvement in survival to 4 hours or discharge vs. manual CPR.
Perkins et al. (2015)	LUCAS (PARAMEDIC trial)	Cluster RCT (4,471 OHCA patients, UK)	No improvement in 30-day survival or neurological outcome compared with manual CPR.
Gao et al. (2016)	LUCAS	Systematic review & meta-analysis (12 studies)	No survival-to-discharge advantage; improved consistency of compressions.
Smekal et al. (2011)	LUCAS / Mechanical CPR	Observational study	Comparable complication rates (rib fractures, internal injuries) to manual CPR.
Olasveengen et al. (2021)	LUCAS,	International Consensus (ILCOR/ERC)	Devices useful in transport, PCI, and prolonged resuscitation; routine use not recommended.
Couper et al. (2022)	LUCAS	Evidence review	Devices improve CPR quality and logistics; survival benefit remains uncertain.
Mandry pilot studies (2019–2021)	Mandry	Early clinical evaluations	Improved compression stability; insufficient large-scale data (Couper et al., 2022).
Early observational reports (2020–2021)	Lama	EMS case series	Portable, feasible in pre-hospital settings; limited evidence on survival benefit (Soar et al., 2021).

5. Integration into Emergency Care

The integration of mechanical CPR devices into emergency medical systems (EMS) and hospital protocols has become an area of growing interest. While manual chest compressions remain the gold standard, the operational benefits of device such as **LUCAS** are increasingly recognized in both pre-hospital and in-hospital settings.

Mechanical devices are particularly valuable in the **out-of-hospital cardiac arrest (OHCA)** environment, where providers must deliver compressions under physically challenging conditions such as confined spaces, moving ambulances, or long transport times. Studies have shown that mechanical CPR ensures consistent compression quality during transport and frees rescuers to perform parallel interventions such as device lama in the airway management and drug administration (Olasveengen et al., 2021). The PARAMEDIC trial also highlighted that while survival outcomes were not superior, device deployment improved operational logistics during resuscitation in the field (Perkins et al., 2015).

In-hospital settings, mechanical CPR devices are frequently used during **interventional cardiology procedures** such as percutaneous coronary intervention (PCI). The LUCAS device has demonstrated feasibility in maintaining continuous compressions without interrupting angiography or stent placement, improving coronary perfusion pressures during prolonged resuscitations (Rubertsson et al., 2014; Couper et al., 2022). And must that Mandry ECG and Lama devices may be advantageous in intensive care units (ICUs) where prolonged resuscitation is often required, though robust data are still lacking (Soar et al., 2021).

Mechanical CPR also has applications in **special circumstances**. For example, during **air and ground transport**, automated compressions maintain CPR quality in conditions where manual performance is nearly impossible (Couper et al., 2022). During the COVID-19 pandemic, mechanical devices reduced rescuer exposure to infection by limiting the number of personnel required at the bedside (Olasveengen et al., 2021). Furthermore, portable systems like lucas may prove useful in **resource-limited settings** where trained manpower is scarce, though evidence remains preliminary.

Successful integration requires adequate training and clear protocols to prevent deployment delays, which can offset potential benefits. Studies emphasize that outcomes are optimized when EMS and hospital staff are trained to rapidly position devices LUCAS, Mandry, Lama and minimize interruptions (Smekal et al., 2011). Integration into **standard operating procedures** also demands consideration of cost, device availability, and context-specific barriers to implementation (Gao et al., 2016).

6. Ethical, Logistical, and Economic Considerations

The adoption of mechanical CPR devices such as **LUCAS, Mandry, and Lama** is not solely a clinical question—it also raises important ethical, logistical, and economic considerations that shape their implementation in practice.

The use of mechanical devices in cardiac arrest management presents ethical challenges related to **resource allocation and equity of care**. High-income countries may integrate these devices into standard protocols, while resource-limited settings struggle to access them, creating disparities in outcomes (Couper et al., 2022). Furthermore, ethical dilemmas arise when device use prolongs resuscitation in patients with poor prognosis, potentially increasing suffering without improving survival or neurological recovery (Perkins et al., 2015). Decisions about deployment should therefore align with patient-centered care, advanced directives, and local end-of-life care policies (Soar et al., 2021).

Integrating mechanical CPR devices requires comprehensive training to avoid delays in initiation of compressions during device deployment, which may otherwise reduce their effectiveness (Smekal et al., 2011). Logistical issues also include device availability**,** maintenance, and ensuring functionality across diverse environments such as ambulances, helicopters, and catheterization laboratories (Olasveengen et al., 2021). The portability of newer systems, such as LUCAS, Mandry, and Lama makes them attractive for rural or remote EMS systems, but deployment protocols need standardization to optimize outcomes (Soar et al., 2021).

From an economic perspective, the cost-effectiveness of mechanical CPR devices remains debated. The initial purchase price of devices such as LUCAS is high, with additional costs for maintenance, staff training, and replacement parts (Gao et al., 2016). While studies suggest potential indirect benefits such as freeing personnel for other tasks and improving operational efficiency during resuscitation, large-scale analyses have not consistently demonstrated a clear survival benefit to justify widespread routine adoption (Rubertsson et al., 2014; Perkins et al., 2015). In contrast, in high-resource systems where devices are available, their utility in special scenarios—such as prolonged transport, PCI procedures, or pandemics—may justify investment (Couper et al., 2022).

In summary, while mechanical CPR devices offer clear operational advantages, their use must be guided by ethical principles, supported by robust training, and justified by context-specific cost-benefit analyses. Policymakers should balance clinical effectiveness with equitable access, ensuring that investments in such technologies do not exacerbate healthcare disparities.

7. Future Directions

While the current evidence on mechanical CPR devices such as LUCAS, Mandry, and Lama highlights their ability to improve CPR quality and operational efficiency, the next decade of resuscitation science will likely focus on technological innovations, integration into broader emergency care systems, and patient-centered outcomes**.**

Future designs are expected to emphasize smaller, lighter, and more portable devices, allowing easier deployment in pre-hospital and rural environments. New prototypes aim to reduce complications through adaptive force-sensing technology that adjusts compressions based on patient physiology (Couper et al., 2022). Emerging models may also integrate real-time physiological monitoring to optimize perfusion pressures during resuscitation.

Artificial intelligence (AI) has the potential to revolutionize CPR delivery by providing real-time feedback on compression depth, rate, and patient response. AI-driven systems could guide rescuers in adjusting protocols dynamically, reducing human error and standardizing performance (Olasveengen et al., 2021). Integration with wearable or sensor-based monitoring may allow closed-loop resuscitation where devices automatically adapt compressions to maximize hemodynamic effectiveness (Gräsner & Herlitz, 2021).

Telemedicine-enabled resuscitation may allow remote oversight by specialists during cardiac arrest, particularly in rural or low-resource areas. Combining mechanical devices with telehealth platforms could improve decision-making, guide advanced interventions, and ensure adherence to protocols even in settings without experienced physicians (Nolan et al., 2020).

Future studies should move beyond ROSC and survival-to-discharge as primary endpoints, focusing instead on long-term neurological recovery, quality of life, and functional outcomes (Perkins et al., 2015). Understanding how devices influence these broader measures will be essential to determine their true clinical value.

Another future priority is ensuring equitable access to mechanical CPR technology. While high-income countries may rapidly integrate advanced devices, low- and middle-income countries face barriers such as cost, training, and maintenance (Soar et al., 2021). Research into cost-effective designs, such as simplified versions may help reduce global disparities.

In summary, the future of mechanical CPR lies in technological refinement, integration with AI and telemedicine, and a stronger focus on meaningful patient-centered outcomes**.** Achieving these goals will require multinational collaboration, large-scale randomized controlled trials, and innovative policies to ensure equitable implementation.

8. Discussion

This review examined the evolution of CPR protocols and the clinical application of mechanical CPR devices—namely LUCAS, Mandre, and Lama—within cardiac arrest management. The findings reinforce that while LUCAS device provide consistent, high-quality compressions, the translation of these advantages into improved survival and neurological outcomes remains uncertain.

One of the main themes across the literature is the contrast between compression quality and survival outcomes**.** Devices such as LUCAS have demonstrated the ability to maintain compressions at guideline-recommended depth and rate, reduce fatigue, and ensure uninterrupted CPR during transport or interventions (Rubertsson et al., 2014; Olasveengen et al., 2021). However, large randomized trials, including the PARAMEDIC trial, have consistently reported no significant survival or neurological advantage compared with manual compressions (Perkins et al., 2015). This paradox may reflect the complexity of cardiac arrest physiology, where outcomes are influenced by multiple factors beyond chest compressions alone, such as time to defibrillation, quality of post-resuscitation care, and underlying patient comorbidities (Couper et al., 2022).

Another important point is the context-specific utility of devices. Evidence indicates that mechanical CPR may be particularly beneficial in challenging operational environments—such as prolonged transport, angiography suites, or during pandemics—where high-quality manual compressions are difficult to sustain (Soar et al., 2021). Emerging devices may further address specific gaps by providing adaptive force control or enhanced portability, although robust large-scale evidence is still lacking (Couper et al., 2022). This suggests that the greatest value of mechanical CPR lies not in routine use but in targeted application where manual CPR is impractical.

The ethical and logistical considerations also weigh heavily on integration. In high-income settings, device use can support advanced resuscitation scenarios, but cost and training remain barriers in resource-limited regions (Gao et al., 2016). Furthermore, ethical concerns arise when mechanical devices prolong resuscitation without meaningful survival prospects, potentially straining resources and impacting quality of end-of-life care (Perkins et al., 2015). This underscores the need for evidence-based guidelines that balance technological opportunities with patient-centered values.

Looking ahead, future directions should prioritize large multicenter RCTs, cost-effectiveness evaluations, and technological refinement. Integration of AI and real-time physiologic monitoring may bridge the gap between high-quality compressions and meaningful patient outcomes (Gräsner & Herlitz, 2021). At the same time, policies must ensure equitable access to avoid widening disparities in resuscitation care across regions (Soar et al., 2021).

In summary, mechanical CPR devices provide clear operational and logistical benefits but are not a substitute for established resuscitation protocols. Their optimal role is as adjuncts in complex or resource-challenging scenarios, guided by evidence, ethical considerations, and context-specific needs.

Conclusion

Cardiac arrest remains a global health challenge with persistently low survival and neurological recovery rates despite decades of progress in resuscitation science. High-quality manual cardiopulmonary resuscitation (CPR) continues to serve as the cornerstone of treatment, yet its limitations—including provider fatigue, inconsistent quality, and interruptions—have fueled the development of mechanical devices such as LUCAS, Mandry, and Lama**.**

This review highlights that mechanical CPR devices reliably deliver compressions at guideline-recommended depth and rate, reduce interruptions, and provide significant logistical advantages, particularly during transport, invasive procedures, and prolonged resuscitations. However, large randomized controlled trials and systematic reviews consistently demonstrate that survival to hospital discharge and favorable neurological outcomes remain similar between mechanical and manual CPR. These findings suggest that while devices optimize the mechanics of resuscitation, survival is influenced by multifactorial elements including rapid defibrillation, post-arrest care, and patient comorbidities.

The integration of devices into emergency care should therefore be targeted rather than universal**,** focusing on scenarios where manual CPR is impractical or unsafe. Ethical considerations around equitable access, economic feasibility, and patient-centered decision-making must also guide their deployment. Looking forward, advances in device technology, integration with artificial intelligence, and telemedicine support may enhance both effectiveness and accessibility.

In conclusion, mechanical CPR devices represent a valuable adjunct to current protocols rather than a replacement, and their optimal role lies in complementing high-quality manual resuscitation to improve operational efficiency while research continues to clarify their impact on patient outcomes.

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