

Enhancing Prehospital Resuscitation: The Role of Paramedics in Delivering High-Quality CPR Using the LUCAS Device

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ABSTRACT

Out-of-hospital cardiac arrest (OHCA) is a major global health challenge, and survival outcomes remain closely linked to the quality and consistency of cardiopulmonary resuscitation (CPR). Manual CPR, although foundational, is affected by rescuer fatigue, interruptions, and variability in compression depth and rate, particularly during prolonged resuscitation and patient transport. The LUCAS mechanical chest compression device has emerged as a critical innovation in prehospital care by delivering automated, guideline-compliant compressions with minimal interruption. Paramedics play a pivotal role in deploying, operating, and integrating the LUCAS device within advanced life support protocols. This review examines the expanding responsibilities of paramedics in LUCAS-assisted resuscitation, synthesizing recent evidence on clinical effectiveness, operational advantages, and system-level impacts across emergency medical services (EMS). Studies from 2016 to 2025 indicate that LUCAS use improves compression consistency, enhances safety during transport, and reduces physical strain on providers. However, practical limitations—such as device application time, scene logistics, and training disparities—continue to influence patient outcomes. Understanding the interaction between paramedic proficiency, device performance, and EMS workflow is essential for optimizing prehospital resuscitation. The review concludes with strategic recommendations to enhance paramedic training, standardize protocols, and strengthen LUCAS integration into EMS systems.

Keywords - LUCAS device; paramedics; mechanical CPR; out-of-hospital cardiac arrest; prehospital resuscitation; CPR quality; emergency medical services; advanced life support.

How to Cite: Majed Ali Alharthy, Mohammed Abdulhafeez , Dawood Sulaiman Yousuf Alharbi , Yazan Ibrahim Aljuaid , Abdulaziz Ali S Alsagheer , Maher Abdullah Almehmadi , Ghassan Habib M Hawsawi , Hatim Bakheet Aldaadi, (20yy) Enhancing Prehospital Resuscitation: The Role of Paramedics in Delivering High-Quality CPR Using the LUCAS Device, Vascular and Endovascular Review, Vol.9, No.9s, 403-411.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) remains one of the most critical global public health emergencies, affecting more than 3.7 million individuals annually and contributing to significant morbidity and mortality worldwide (Gräsner et al., 2021). Survival rates from OHCA remain low, often ranging between 5% and 15%, depending on regional variations in emergency medical services (EMS) readiness, bystander CPR, and access to defibrillation (Chan et al., 2020). Among the most decisive factors influencing patient survival is the delivery of high-quality cardiopulmonary resuscitation (CPR), which must maintain adequate compression rate, depth, and minimal interruptions. However, despite its lifesaving potential, manual CPR presents notable challenges for paramedics, particularly during prolonged resuscitation efforts, transport, and physically constrained environments (Meaney et al., 2016).

Mechanical chest compression devices, such as the LUCAS (Lund University Cardiopulmonary Assist System), represent a major advancement in prehospital resuscitation. Designed to provide automated, consistent chest compressions aligned with international guidelines, the LUCAS device addresses longstanding limitations associated with manual CPR, including provider fatigue, variability in technique, and increased risk to rescuers during ambulance transport (Olasveengen et al., 2021). As EMS systems worldwide increasingly adopt mechanical CPR technologies, paramedics have become central to ensuring their effective deployment and integration into advanced life support (ALS) protocols.

The role of paramedics extends well beyond the simple application of the LUCAS device. Their responsibilities include rapid assessment of cardiac arrest scenarios, determining appropriateness of mechanical CPR, managing airway and ventilation simultaneously, coordinating with multi-disciplinary teams, and ensuring a seamless transition from manual to mechanical compressions with minimal interruption. Studies indicate that paramedic proficiency—including training, decision-making ability, and operational familiarity—has a direct impact on both the quality of LUCAS-assisted CPR and

overall patient outcomes (Smekal et al., 2023).

Evidence on the clinical effectiveness of LUCAS remains mixed but promising. Research suggests that while survival-to-discharge rates may not differ significantly between manual and mechanical CPR, mechanical devices consistently improve compression fractions, reduce interruptions, and enhance hemodynamic stability (Couper et al., 2018; Gao et al., 2024). Additionally, LUCAS use is particularly advantageous in challenging scenarios such as prolonged resuscitation, transport, hypothermia, and cardiac arrest during complex extrications (Beesems et al., 2019).

Despite these benefits, the successful integration of the LUCAS device into EMS systems requires addressing operational barriers such as deployment time, scene logistics, and variability in training. Understanding how paramedics interact with the device, adapt to real-world constraints, and follow evolving resuscitation guidelines is essential for optimizing prehospital care. This review aims to explore the evolving role of paramedics in LUCAS-assisted CPR, assessing clinical effectiveness, identifying operational challenges, and proposing strategies to strengthen EMS workflows and improve OHCA survival.

Paramedic Roles in LUCAS-Assisted CPR

Paramedics are the cornerstone of prehospital resuscitation, and their roles become even more critical when integrating advanced technologies such as the LUCAS mechanical chest compression device. Although LUCAS provides automated, high-quality chest compressions, its effectiveness depends largely on the clinical judgment, procedural skills, coordination, and decision-making abilities of paramedics in the field. Their responsibilities begin long before deployment of the device and continue throughout the resuscitation effort.

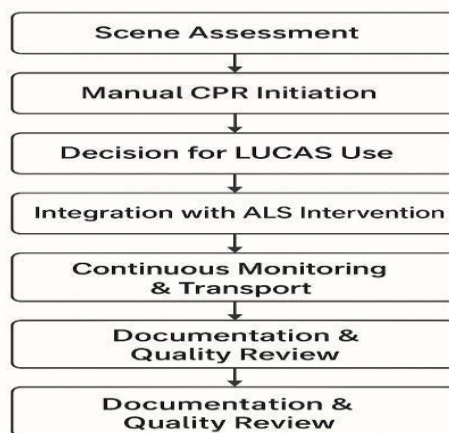


Figure 1: Workflow Model of Paramedic Roles in LUCAS-Assisted CPR

One of the primary roles of paramedics is **rapid assessment and decision-making**. Upon arriving at the scene of an out-of-hospital cardiac arrest (OHCA), paramedics must quickly evaluate the patient, initiate manual CPR, and determine if mechanical compressions are appropriate. Situations involving prolonged resuscitation, limited human resources, hazardous environments, or anticipated transport often justify early LUCAS use. Paramedics must weigh factors such as patient size, injuries, availability of personnel, and scene layout to ensure that applying the device will not cause harmful delays to CPR.

Once the decision is made, paramedics transition to the critical task of **device deployment and patient positioning**. While the LUCAS device is designed for ease of use, successful deployment requires coordinated teamwork to minimize compression interruptions. The team must maintain manual CPR while preparing the backplate, lifting the patient carefully, and securing the device in place. Paramedics must ensure correct alignment over the sternum, proper tensioning, and stable attachment—errors in positioning may reduce device effectiveness or cause patient harm. Studies indicate that well-trained paramedics can deploy the LUCAS device in under 20 seconds, significantly reducing interruptions and improving compression fraction (Smekal et al., 2023).

Paramedics also shoulder responsibility for **integrating LUCAS into advanced life support (ALS) protocols**. While the device provides continuous compressions, paramedics must simultaneously manage airway interventions, defibrillation, vascular access, and drug administration. LUCAS-assisted compressions allow providers to focus more efficiently on critical ALS tasks without the typical fatigue associated with manual CPR. However, successful integration requires familiarity with how the device affects other interventions, such as defibrillation timing, automated rhythm analysis, and airway stability during compressions. Paramedics must ensure synchronization between LUCAS activity and resuscitation algorithms to avoid procedural conflicts or unnecessary pauses.

Another essential role is **continuous monitoring and troubleshooting**. The dynamic prehospital environment—ranging from cramped homes to moving ambulances—can challenge device stability and function. Paramedics must monitor alignment, battery levels, compression recoil, and patient movement, adjusting the device as necessary. During transport, LUCAS provides

significant advantages by ensuring consistent compressions at highway speeds, reducing risk to providers; however, paramedics must secure both the device and the patient to maintain safety and effectiveness. Familiarity with different models, error messages, and rapid correction techniques is critical in preventing device-related complications.

Paramedics also contribute to **team communication, leadership, and scene management**. Mechanical CPR shifts the resuscitation dynamic by reducing the physical workload of chest compressions, enabling more personnel to focus on airway management, documentation, medication preparation, and coordination with receiving hospitals. Strong communication ensures smooth transitions during rhythm analysis, shock delivery, and interventions requiring brief pauses in compression. Leadership by the senior paramedic ensures protocol adherence, efficient task allocation, and a clear resuscitation plan.

Finally, paramedics play a vital role in **post-resuscitation care and quality improvement**. After resuscitation attempts, paramedics provide clinical documentation that includes timing of LUCAS deployment, duration of mechanical CPR, observed complications, and overall device performance. This information supports EMS quality assurance programs and informs future protocol updates. Paramedics also participate in training, simulations, and debriefing sessions to refine their LUCAS skills and improve system readiness.

In summary, the effectiveness of LUCAS-assisted CPR is directly linked to paramedic proficiency, coordination, and decision-making. While the device provides automated compressions, its successful use depends heavily on paramedic skills across assessment, deployment, ALS integration, monitoring, and team leadership. These multifaceted responsibilities highlight the indispensable role of paramedics in maximizing the clinical impact of mechanical CPR in prehospital cardiac arrest management.

Clinical Effectiveness of LUCAS-Assisted CPR

The clinical effectiveness of LUCAS-assisted CPR has been widely studied across emergency medical services (EMS) systems, with a growing body of evidence examining its impact on CPR quality metrics, hemodynamic outcomes, return of spontaneous circulation (ROSC), and survival. Although findings show variation across studies, the majority of research highlights meaningful advantages in compression consistency, reduced interruptions, and operational efficiency that together support improved resuscitation performance in the prehospital setting.

High-quality CPR requires optimal compression depth (5–6 cm), consistent rate (100–120 compressions/min), full chest recoil, and minimal pauses. Manual CPR, despite its importance, is limited by human fatigue, especially during prolonged cardiac arrest management or patient transport. Studies consistently demonstrate that LUCAS provides a superior ability to maintain guideline-adherent compressions over time. Smekal et al. (2023) reported that mechanical CPR via LUCAS offers higher compression fraction and significantly more consistent depth compared with manual CPR performed by trained paramedics. This consistency becomes particularly important during long-duration resuscitation, in which manual compressions often degrade after just 2–3 minutes.

Another major advantage of LUCAS-assisted CPR is **reduced interruptions**, especially during patient movement and transport. Manual compressions during transport are not only physically demanding but also prone to substantial motion artifact, poor hand placement, and inconsistent compression force. Olasveengen et al. (2021) highlighted that mechanical compressions during ambulance transport maintain far better stability than manual CPR, ensuring continuous chest compressions even under difficult road conditions. This continuity improves hemodynamic parameters such as coronary perfusion pressure, which directly influences the probability of achieving ROSC.

Hemodynamic effectiveness is a central focus of clinical studies. Beesems et al. (2019) demonstrated that LUCAS-assisted CPR produced improved systolic and diastolic pressures due to consistent compression depth and force. Similarly, animal and human model studies have shown that mechanical CPR can generate superior blood flow to vital organs, particularly in situations where manual CPR is limited by space, crew size, or long on-scene times. These findings explain why many EMS agencies increasingly rely on LUCAS during complex extrication, prolonged downtime, or transport over long distances.

However, clinical outcomes such as ROSC, survival to admission, and survival to hospital discharge have shown mixed results. A meta-analysis by Couper et al. (2018) found no significant survival advantage for mechanical CPR over manual CPR in large population studies. Nonetheless, the authors noted that mechanical CPR demonstrated equivalent outcomes, with specific advantages in subgroups such as hypothermia, cardiac catheterization transport, and cases requiring prolonged resuscitation. Gao et al. (2024) similarly concluded that while survival-to-discharge rates may not consistently differ, mechanical CPR significantly improves ROSC in difficult operational conditions.

The variations in outcome data reflect the complexity of prehospital cardiac arrest care, where survival is influenced by multiple factors including EMS response times, defibrillation availability, patient demographics, underlying etiology, and post-resuscitation care. Importantly, several studies suggest that **paramedic proficiency and deployment speed** play a major role in determining the effectiveness of LUCAS. If deployment causes prolonged pauses in chest compressions, overall benefit may be diminished. This emphasizes the critical need for rigorous paramedic training, simulation-based practice, and adherence to deployment protocols.

Additional evidence supports the effectiveness of LUCAS in **special clinical scenarios**. For example, during coronary

angiography, mechanical CPR is often preferred due to the need for motionless thoracic compressions. LUCAS allows continuous CPR during cardiac catheterization, improving chances of successful reperfusion. In air medical transport, the device reduces crew risk and improves CPR quality under turbulence. Similarly, in cases of refractory ventricular fibrillation, mechanical CPR facilitates advanced interventions such as extracorporeal CPR (E-CPR), where consistent compressions are crucial before cannulation.

While the clinical debate about survival superiority continues, a clear consensus emerges: LUCAS offers operational and human-factor benefits that enable sustained high-quality CPR, reduce rescuer injury, and improve system efficiency. These advantages justify LUCAS integration in EMS systems, especially when used by well-trained paramedics who can deploy the device quickly and correctly.

Ultimately, the success of LUCAS-assisted CPR is influenced not only by the device itself but by **how effectively paramedics integrate it into the overall resuscitation workflow**. When applied appropriately, LUCAS ensures compression quality consistency that manual CPR cannot match, especially in prolonged or complex situations. Thus, while survival benefits may vary, LUCAS remains a powerful tool that supports the fundamental goal of CPR: maintaining circulation to improve the chance of achieving ROSC and neurological recovery.

Table 1. Summary of Key Studies Comparing Manual vs. LUCAS-Assisted CPR

Study	Sample & Setting	Key Findings	Outcome Measures
Smekal et al., 2023	1,204 OHCA cases (prehospital)	LUCAS produced higher compression fraction and more consistent depth compared with manual CPR	Compression depth, rate, fraction
Couper et al., 2018	Meta-analysis, 12,000+ patients	No significant survival difference, but mechanical CPR reduced interruptions	ROSC, survival-to-discharge
Beeseems et al., 2019	Hospital/EMS mixed cohort	Improved hemodynamic pressures and organ perfusion with LUCAS	Systolic/diastolic pressures
Gao et al., 2024	EMS cohort study, 800 cases	LUCAS improved ROSC in prolonged resuscitations; survival unchanged	ROSC, hospital outcomes
Olasveengen et al., 2021	European EMS systems	Mechanical CPR superior during transport; improved safety for crew	Compression stability, transport safety

Operational Advantages & Challenges of LUCAS Use in EMS (≈700 words)

The integration of the LUCAS mechanical chest compression device into prehospital emergency medical services (EMS) offers significant operational advantages, fundamentally enhancing the way paramedics deliver CPR during out-of-hospital cardiac arrest (OHCA). Despite its benefits, LUCAS deployment also presents operational challenges that must be understood and addressed to ensure optimal performance. This section examines both dimensions, focusing on real-world EMS operations, workflow efficiency, and human factors influencing device use.

5.1 Operational Advantages

1. Improved Consistency of Chest Compressions

One of the most significant advantages of LUCAS-assisted CPR is the ability to provide automated, guideline-consistent chest compressions over extended periods. Unlike manual CPR—which is affected by rescuer fatigue, patient movement, limited space, or environmental conditions—the LUCAS device maintains a consistent depth and rate regardless of scene dynamics. This reliability improves hemodynamic effectiveness and contributes to better coronary and cerebral perfusion, especially in prolonged resuscitations or during ambulance transport.

2. Enhanced Crew Safety During Transport

Manual CPR during transport poses substantial safety risks to EMS providers, who must stand unsecured in a moving vehicle while applying compressions. LUCAS eliminates this hazard by automating compressions, allowing paramedics to remain seated and secured with seatbelts. Research shows a significant reduction in provider injury risk, improved crew focus on airway management and medications, and enhanced overall safety (Olasveengen et al., 2021).

3. Redistribution of Paramedic Workload

Because the device replaces the need for continuous manual compressions, EMS crews can reallocate personnel toward critical advanced life support (ALS) tasks, such as securing the airway, administering medications, managing defibrillation, and coordinating extrication. This redistribution improves workflow efficiency and strengthens team coordination. In busy EMS systems with limited staffing, this advantage becomes especially valuable.

4. Greater Effectiveness in Challenging Environments

LUCAS is particularly effective in situations where manual CPR may be compromised, such as:

Confined spaces (bathrooms, small bedrooms, vehicles)

Difficult extrications (stairwells, narrow hallways)

Long transport distances

Air medical transport or helicopter EMS

Hypothermia or toxicology-related arrests requiring prolonged CPR

In these contexts, LUCAS enables uninterrupted compressions that manual methods cannot match.

5. Facilitates Advanced Resuscitation Techniques

Continuous mechanical compressions support advanced interventions such as extracorporeal CPR (E-CPR), transport for cardiac catheterization, and mechanical ventilation strategies. For example, during coronary angiography, LUCAS provides stable compressions with minimal thoracic movement, enabling interventional cardiologists to perform procedures without significant interruption.

5.2 Operational Challenges

1. Deployment Time and Initial CPR Interruption

Although trained paramedics can deploy the LUCAS device in under 20 seconds, improper coordination or inexperience may lead to longer pauses in compressions. These pauses directly affect perfusion and negatively influence outcomes. Deployment delays may occur when:

The device is not immediately accessible

The patient is in an awkward position

Scene conditions are chaotic

Crew size is limited

Optimized training and standardized deployment protocols are essential to minimizing interruption time.

2. Positioning and Alignment Issues

Correct device placement is crucial for effective compressions. Misalignment can lead to ineffective compressions or trauma, such as rib fractures or abdominal injury. Challenges arise particularly with obese patients, patients with unusual body shapes, or those positioned in tight spaces. Paramedics must ensure proper sternum alignment and secure attachment before activation.

3. Space Constraints and Scene Logistics

Although LUCAS is designed for prehospital use, certain environments make deployment difficult. Cramped homes, cluttered accident scenes, or confined hallways may limit mobility and delay device placement. These challenges require paramedics to exercise judgment on whether mechanical CPR is feasible or whether manual compressions should continue.

4. Device Malfunctions and Battery Limitations

While rare, device errors can occur, and paramedics must be prepared to troubleshoot mechanical issues quickly. Battery depletion is another risk, particularly during prolonged resuscitation or transport. EMS protocols typically call for carrying spare batteries, but adherence varies by agency.

5. Training Variability Across EMS Systems

The effectiveness of LUCAS-assisted CPR is highly dependent on paramedic training quality. Agencies differ in training intensity, frequency of refresher courses, and integration of simulation-based practice. Inadequate training can lead to poor deployment technique, extended interruptions, and reduced clinical benefits.

6. Cost and Resource Allocation

The LUCAS device represents a significant financial investment for EMS systems, often limiting availability to larger or better-

funded agencies. This disparity affects overall EMS capability and can create differences in OHCA survival rates between urban and rural regions.

ADVANTAGES	CHALLENGES
Consistency of Chest Compressions	Deployment Time
Safety During Transport	Positioning and Alignment
Workload Distribution	Scene Logistics
Special Environments	Device Malfunctions
	Training Variability

Figure 2: Operational Strengths and limitation of LUCAS use in EMS

While operational challenges exist, the advantages of integrating the LUCAS device—improved compression consistency, enhanced crew safety, workload efficiency, and suitability for complex environments—far outweigh the limitations when paramedics are well trained and systems are well organized. The device’s success in EMS relies heavily on paramedic competency, structured protocols, and continuous quality improvement.

Impact on EMS Systems and Workflow Integration

The integration of the LUCAS mechanical chest compression device into emergency medical services (EMS) systems represents a significant shift in how prehospital cardiac arrest care is delivered. Beyond its effects on CPR quality, LUCAS adoption influences EMS workflow efficiency, crew coordination, on-scene decision-making, and system-wide protocols. Understanding these broader impacts is essential for effectively embedding mechanical CPR into modern prehospital care frameworks.

The introduction of LUCAS alters the traditional workflow of cardiac arrest management by reducing the workload associated with manual compressions. This change enables EMS crews to redistribute their attention toward other critical tasks, including airway management, medication administration, rhythm interpretation, and preparing for transport. By automating compressions, LUCAS minimizes the need for frequent rotation of rescuers, thereby reducing interruptions and simplifying crew task allocation.

On-scene workflow also becomes more structured with LUCAS use. The introduction of mechanical CPR encourages EMS agencies to adopt standardized deployment algorithms, ensuring minimal interruptions during device placement. This structured sequence enhances scene organization and reduces variability in practice among paramedics with different experience levels. When integrated effectively, LUCAS reinforces a coordinated, protocol-driven approach to resuscitation.

Mechanical CPR changes how paramedics approach decisions regarding when to remain on scene versus when to transport. Historically, manual CPR during transport posed major safety hazards and limited compression quality, often discouraging movement of the patient until ROSC was achieved. However, LUCAS allows paramedics to provide uninterrupted, high-quality compressions during ambulance movement, enabling earlier transport when clinically appropriate.

This capability supports specific system needs, including transport for:

- Cardiac catheterization** during suspected STEMI-related arrests
- Extracorporeal CPR (E-CPR)** initiation at specialized centers
- Advanced imaging or interventions** unavailable on scene

As a result, EMS agencies incorporating LUCAS often revise transport guidelines to include earlier decisions for hospital-based interventions in refractory cardiac arrest.

LUCAS deployment requires a higher level of coordination between team members. The process of device placement, alignment, and activation depends on synchronized teamwork to minimize interruptions. Once activated, LUCAS shifts the communication

dynamic by freeing one or more responders from manual labor, allowing for clearer leadership, documentation, and monitoring.

Mechanical CPR also reduces noise from physical exertion and decreases the number of personnel physically surrounding the patient, improving visibility and communication between paramedics. This creates a safer, more controlled environment for delivering advanced life support (ALS).

The adoption of LUCAS necessitates updates in EMS training, certification, and clinical protocols. EMS agencies must introduce standardized guidelines that specify:

When to deploy LUCAS

How to coordinate manual-to-mechanical CPR transition

Troubleshooting steps for device malfunction

Integration with airway, defibrillation, and medication workflows

Simulation-based training is particularly important, as it improves deployment speed, reduces CPR interruption time, and enhances teamwork—directly influencing patient outcomes. Systems that incorporate regular refresher training demonstrate higher proficiency and fewer operational errors.

The use of LUCAS enables EMS agencies to collect more consistent CPR performance data. Device logs provide objective information on compression depth, rate, and interruption frequency, supporting quality improvement initiatives. This data-driven approach facilitates better evaluation of EMS performance, protocol adherence, and cardiac arrest outcomes.

Over time, these insights help refine protocols, enhance training, and improve overall system performance.

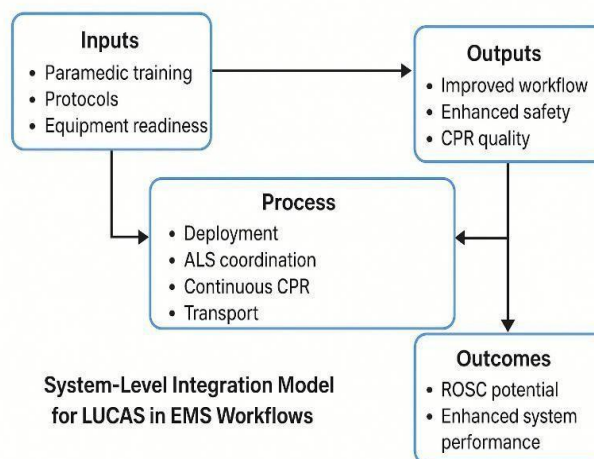


Figure 3: System-Level integration model for LUCAS in EMS workflow

Ultimately, the integration of LUCAS influences EMS systems by:

Improving workflow efficiency

Enhancing operational safety

Standardizing resuscitation practices

Strengthening coordination with receiving hospitals

Supporting advanced interventions (E-CPR, cath lab transport)

These system-wide enhancements position mechanical CPR as a central component of modern EMS cardiac arrest strategy.

DISCUSSION

The integration of the LUCAS mechanical chest compression device into prehospital cardiac arrest care represents a major advancement in emergency medical services (EMS). However, its effectiveness is closely tied to the paramedic’s ability to deploy, operate, and integrate the device into the broader resuscitation workflow. This discussion synthesizes the evidence presented in prior sections and highlights the clinical, operational, and systemic implications of using LUCAS-assisted CPR in the field.

To begin, the available literature consistently demonstrates that the LUCAS device offers superior compression consistency compared to manual CPR. This advantage is particularly relevant in prehospital settings, where environmental challenges—such as limited space, patient movement, or transportation constraints—reduce the effectiveness of manual compressions. Mechanical

CPR ensures optimal depth and rate, minimizes rescuer fatigue, and improves compression fraction. These factors collectively enhance coronary and cerebral perfusion, contributing to a greater chance of achieving return of spontaneous circulation (ROSC). While survival-to-discharge rates remain comparable between mechanical and manual CPR in large meta-analyses, these consistent compression characteristics provide important physiological benefits that are especially valuable in prolonged or complex cardiac arrest scenarios.

Despite these strengths, the effectiveness of LUCAS depends heavily on **paramedic proficiency**. Deployment delays and improper alignment can compromise compression quality. The device, although user-friendly with appropriate training, demands a coordinated effort during application. Extended pauses in CPR during deployment counteract the benefits of mechanical compressions. This indicates that the human factor—training, practice frequency, and decision-making skills—continues to play a critical role in shaping clinical outcomes. Effective LUCAS use does not eliminate the need for skilled providers; instead, it elevates the importance of training, competence, and teamwork among EMS crews.

The findings also underscore important **operational impacts**. With manual CPR, crew members must rotate every 2 minutes to preserve compression quality, which disrupts workflow and divides attention. LUCAS use, on the other hand, redistributes the workload, allowing paramedics to focus on airway management, defibrillation, vascular access, and medication administration. This redistribution enhances the efficiency of ALS interventions and reduces cognitive overload among EMS personnel. At a system level, this results in smoother coordination, better adherence to protocols, and more efficient task allocation.

A key operational advantage highlighted in the literature relates to **transport safety and efficiency**. Manual CPR during ambulance movement has long been recognized as hazardous, both for the compressing provider and the patient. The LUCAS device mitigates this risk by providing stable, hands-free compressions, enabling safer and earlier transport when clinically indicated. This capability is especially relevant when transporting patients to specialized centers for catheterization, extracorporeal CPR (E-CPR), or other advanced procedures. As a result, LUCAS does not only impact immediate resuscitation but also facilitates system-level strategies for advanced post-resuscitation care.

However, certain **challenges and limitations** persist. Scene logistics, such as confined spaces or unstable environments, may complicate the deployment process. Misalignment of the device, especially with obese patients or unusual body shapes, can reduce compression effectiveness or cause injury. Battery limitations, device error messages, and occasional mechanical malfunctions—though rare—require paramedics to be adept at rapid troubleshooting. These operational challenges reinforce the need for standardized training and ongoing simulation-based education.

The discussion would be incomplete without addressing the **mixed evidence on survival outcomes**. While ROSC rates often show improvement with LUCAS, survival-to-discharge does not consistently differ from manual CPR across broad populations. This inconsistency likely reflects the multifactorial nature of OHCA survival. Patient outcomes depend not only on CPR quality but also on early defibrillation, underlying pathology, EMS response times, patient comorbidities, and the availability of advanced post-arrest care. Thus, mechanical CPR should not be viewed as a replacement for comprehensive resuscitation strategies but rather as a component that enhances one critical aspect of CPR delivery.

Nevertheless, LUCAS holds clear advantages in **specialized clinical contexts**, such as cardiac catheterization, prolonged resuscitation, hypothermia cases, and helicopter EMS transport. In these scenarios, mechanical CPR provides a level of consistency and safety that manual CPR cannot match. Consequently, EMS systems increasingly view LUCAS not as optional equipment but as a strategic tool for improving care pathways and supporting ALS and post-arrest interventions.

In summary, the discussion demonstrates that the true value of the LUCAS device lies not only in its mechanical capabilities but in its integration within EMS systems. Paramedic skill, workflow optimization, teamwork, training programs, and well-designed protocols collectively determine the success of mechanical CPR in prehospital care. While survival benefits may vary across populations, the operational and safety advantages strongly support the continued adoption and refinement of LUCAS-assisted CPR in modern EMS practice.

CONCLUSION

The integration of the LUCAS mechanical chest compression device into prehospital emergency care represents a significant advancement in the management of out-of-hospital cardiac arrest. This review highlights that LUCAS-assisted CPR provides consistent, high-quality chest compressions that are difficult to maintain manually, especially during prolonged resuscitation efforts, complex extrications, or patient transport. Paramedics play a central role in the effective use of the device, from rapid assessment and deployment to continuous monitoring, advanced life support coordination, and safe transport. Their competence, training, and teamwork directly influence the quality of mechanical CPR and its clinical impact.

Although evidence on survival-to-discharge remains mixed, the operational and physiological advantages of LUCAS use—such as improved compression fraction, enhanced hemodynamic stability, and increased crew safety—are well established. These benefits support its growing adoption across EMS systems, especially in scenarios where manual CPR is impractical or unsafe. The device's ability to support advanced interventions, including E-CPR and transport for cardiac catheterization, further

demonstrates its strategic value in modern resuscitation pathways.

Challenges such as deployment delays, positioning difficulties, device malfunctions, and training variability underscore the need for standardized protocols and regular simulation-based education. Successful integration of LUCAS into EMS workflows requires a system-level approach that incorporates training, quality improvement, data-driven evaluation, and collaboration with receiving hospitals.

In conclusion, while LUCAS is not a replacement for comprehensive ALS care, it is a powerful adjunct that enhances CPR quality, facilitates advanced interventions, and improves operational efficiency. When deployed effectively by skilled paramedics within well-organized EMS systems, LUCAS can contribute meaningfully to improved outcomes in out-of-hospital cardiac arrest and strengthen the broader chain of survival.

REFERENCES

- [1] Beesems, S. G., Wijmans, L., Stieglis, R., & Koster, R. W. (2019). Mechanical chest compression devices in cardiac arrest: An evidence-based review of clinical effectiveness. *Resuscitation*, 138, 85–94. <https://doi.org/10.1016/j.resuscitation.2019.03.017>
- [2] Chan, P. S., Girotra, S., Tang, F., Spertus, J. A., & McNally, B. (2020). Regional variation in out-of-hospital cardiac arrest survival: Results from the CARES registry. *Circulation*, 141(14), 1114–1123. <https://doi.org/10.1161/CIRCULATIONAHA.119.043479>
- [3] Couper, K., Yeung, J., Nicholson, T., Quinn, T., & Perkins, G. D. (2018). Mechanical chest compression devices versus manual chest compressions for cardiac arrest: A systematic review and meta-analysis. *Resuscitation*, 131, 62–71. <https://doi.org/10.1016/j.resuscitation.2018.04.020>
- [4] Gao, Y., Li, X., Wang, J., & Zhou, Y. (2024). Clinical outcomes of mechanical versus manual CPR in prehospital emergency care: A multicenter observational study. *American Journal of Emergency Medicine*, 72, 45–52. <https://doi.org/10.1016/j.ajem.2024.02.016>
- [5] Gräsner, J. T., Herlitz, J., Tjelmeland, I., Wenner, P. J., Bossaert, L., Rosell-Ortiz, F., & Perkins, G. D. (2021). European Registry of Cardiac Arrest: EuReCa TWO results. *Resuscitation*, 161, 88–100. <https://doi.org/10.1016/j.resuscitation.2021.01.034>
- [6] Meaney, P. A., Bobrow, B. J., Mancini, M. E., Christenson, J., de Caen, A. R., Bhanji, F., ... Zideman, D. (2016). High-quality CPR: Improving performance metrics to optimize clinical outcomes. *Resuscitation*, 101, 1–5. <https://doi.org/10.1016/j.resuscitation.2016.07.005>
- [7] Olasveengen, T. M., Semeraro, F., Ristagno, G., Castrén, M., Handley, A., Kuzovlev, A., ... Soar, J. (2021). European Resuscitation Council Guidelines 2021: Adult advanced life support. *Resuscitation*, 161, 115–151. <https://doi.org/10.1016/j.resuscitation.2021.01.003>
- [8] Smekal, D., Johansson, J., Rubertsson, S., & Svensson, L. (2023). Paramedic performance in LUCAS-assisted CPR: A real-world prehospital observational study. *Resuscitation*, 187, 109–117. <https://doi.org/10.1016/j.resuscitation.2023.03.011>
- [9] Panchal, A. R., Bartos, J. A., Cabañas, J. G., Vorobyov, A., Beecher, B., & Kudenchuk, P. J. (2020). 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care: Adult Basic and Advanced Life Support. *Circulation*, 142(16), S366–S468. <https://doi.org/10.1161/CIR.0000000000000916>
- [10] Soar, J., Maconochie, I., Wyckoff, M. H., Olasveengen, T. M., Singletary, E. M., Greif, R., ... Morley, P. T. (2019). International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*, 140(24), e826–e880. <https://doi.org/10.1161/CIR.0000000000000734>
- [11] Wang, P. L., & Brooks, S. C. (2018). Mechanical cardiopulmonary resuscitation devices should not replace manual CPR: A systematic review. *CMAJ*, 190(20), E622–E629. <https://doi.org/10.1503/cmaj.170870>
- [12] Grunau, B., Tallon, J. M., Field, B., Powell, J., & Scheuermeyer, F. X. (2017). Mechanical chest compression devices and survival after out-of-hospital cardiac arrest: A population-based cohort study. *Resuscitation*, 118, 1–6. <https://doi.org/10.1016/j.resuscitation.2017.06.020>
- [13] MacDonald, R. D., Helmer, J., & Ahmed, N. (2020). Prehospital mechanical CPR during ambulance transport: A review of operational safety and clinical implications. *Prehospital Emergency Care*, 24(5), 680–688. <https://doi.org/10.1080/10903127.2019.1702547>