The Review Of
DIABETIC
STUDIES OPEN ACCESS

Clinical And Operational Advantages Of The LUCAS Mechanical Chest Compression Device In Emergency Medical Services: A Comprehensive Review Of Resuscitation Quality, Survival Outcomes, And System Efficiency

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Abstract

Out-of-hospital cardiac arrest presents a persistent clinical and operational challenge for prehospital Emergency Medical Services Systems, where interruptions, rescuer fatigue, and unsafe manual CPR during transport compromise resuscitation reliability. The LUCAS Mechanical Chest Compression Device has emerged as a key human–machine solution to standardize chest compression delivery in dynamic prehospital environments. This comprehensive review synthesizes global evidence from 2016 onward examining its effect on resuscitation quality, survival outcomes, provider safety, and system-level efficiency. Findings consistently demonstrate that the device delivers stable guideline-aligned depth and rate, increases compression fraction, and minimizes no-flow intervals, while supporting improved physiological perfusion markers and favorable trends in return of spontaneous circulation and neurological recovery after cardiac arrest. Operationally, the device improves crew task allocation, reduces the need to stop ambulances to maintain CPR, and enables clinicians to remain restrained and seated safely while compressions continue, expanding procedural capacity for airway management, vascular access, ECG analysis, drug preparation, and timely clinical documentation. Despite training, cost, and power-dependency challenges, LUCAS integration strengthens CPR precision and mission reliability while elevating paramedic safety and system performance indicators. Evidence supports broader adoption within structured EMS SOPs, clinical governance frameworks, and future AI-augmented CPR analytics to optimize human-device resuscitation synergy.

Keywords: LUCAS, Mechanical CPR, Prehospital CPR Quality, Out-of-Hospital Cardiac Arrest, Return of Spontaneous Circulation, Neurological Outcomes, Paramedic Transport Safety, EMS Workflow Efficiency, System Efficiency in Resuscitation.

Introduction

Sudden Cardiac Arrest remains one of the leading causes of death in prehospital environments, accounting for substantial mortality and long-term neurological disability when high-quality chest compressions are delayed or interrupted. Although manual cardiopulmonary resuscitation is the foundational intervention, its real-world effectiveness in Ambulance Transport Settings is frequently compromised by provider fatigue, inconsistent depth and rate, and increased hands-off time, particularly during patient movement and vehicle motion (Ong et al., 2012; Hasegawa et al., 2016). These limitations are amplified in Out-of-Hospital Cardiac Arrest Response Chains, where maintaining optimal Chest Compression Fraction above recommended thresholds is essential for perfusion and survival (Kleinman et al., 2018; Perkins et al., 2015). The complexity of delivering uninterrupted CPR while simultaneously performing concurrent critical procedures has increased clinical interest in automated chest compression technologies, particularly as EMS systems seek to reduce resuscitation variability and improve crew ergonomics during prolonged missions (Perkins et al., 2015; Couper et al., 2016).

Mechanical CPR devices, including the LUCAS, were introduced to address the human limitations of sustained manual compression by providing standardized, piston-driven, active decompression chest compressions capable of operating continuously during transport and complex field conditions (Rubertsson et al., 2014; Ong et al., 2018). The device's engineering supports reliable compression rhythm without requiring physical exertion by EMS personnel, allowing clinicians to stay safely restrained while maintaining high compression quality—a key operational consideration in environments requiring both speed and provider safety (Ong et al., 2018; Putzer et al., 2020). International guideline bodies, including the American Heart Association Guidelines (2020), recognize mechanical compression devices as reasonable alternatives when manual CPR cannot maintain depth, rate, or safety standards, especially in transport scenarios or prolonged resuscitations. Evidence across national registries and randomized controlled trials has shown that mechanical CPR may improve CPR fraction, reduce pauses, and maintain guideline-aligned depth and rate, all of which contribute to better systemic perfusion during sudden cardiac arrest emergencies (Ong et al., 2018; Hasegawa et al., 2016; Perkins et al., 2015). Additionally, reductions in crew physical strain and fewer requirements for ambulance stops during resuscitation have highlighted the device's value not only clinically, but also operationally for EMS mission reliability and system-wide quality improvement planning (Putzer et al., 2020; Couper et al., 2016).

Despite widespread clinical deployment, a clear need persists for synthesized reviews that jointly evaluate CPR clinical performance, patient survival benefit trends, and EMS operational system outcomes, including provider safety, workflow bandwidth, and resuscitation mission continuity. This review aims to bridge that gap by consolidating clinical and operational evidence from 2016 onward to generate insights valuable for emergency clinicians, EMS leaders, and resuscitation governance frameworks prioritizing quality, safety, and systemic efficiency.

Clinical Benefits

The integration of mechanical chest compression in Prehospital Resuscitation Teams has fundamentally addressed the performance decay observed during manual cardiopulmonary resuscitation. The deployment of the LUCAS 3 enables a reproducible, guideline-aligned approach to chest compressions, minimizing variability driven by individual provider strength, technique, or fatigue. Across contemporary EMS evidence, the device demonstrates stable compliance with recommended depth and rate targets for prolonged resuscitations, while preserving perfusion-critical time intervals and reducing the collapses in CPR quality frequently seen within high-motion transport environments.

Compression depth is one of the strongest determinants of coronary and cerebral perfusion pressure during cardiac arrest. Manual CPR performance is vulnerable to rapid depth decay after the first 2–3 minutes due to muscle exertion and cumulative fatigue. The mechanical piston system of the LUCAS Compression Architecture maintains consistent compression depth with minimal deviation from resuscitation guideline targets, independent of transport vibration, clinician posture, or CPR duration (Putzer et al., 2020; Ong et al., 2018). The device's rate control algorithm also ensures reliable compressions per minute without unintentional accelerations or slowing caused by rescuer cognitive overload or physical strain, thereby safeguarding perfusion continuity during prolonged and multitask-heavy resuscitations (Hasegawa et al., 2016; Couper et al., 2016). These benefits collectively support international CPR recommendations emphasizing reduced human error, less physiological variability, and improved compression accuracy during chaotic prehospital scenes.

No-Flow Time directly impacts end-organ ischemic injury, survival potential, and neurological outcomes. High-quality CPR requires minimizing compression pauses often triggered by airway positioning, rhythm shock planning, IV/IO placement, patient transfers, or ambulance safety stops. The mechanical automation delivered by Continuous CPR Standards supports a clinically superior compression fraction, reducing the risk of physiological injury by maximizing active compression time even while paramedics work on secondary life-saving procedures such as oxygenation, ventilation coordination, medication preparation, ECG interpretation, and system documentation.

Greater CPR fraction correlates with improved perfusion delivery, increased likelihood of return of spontaneous circulation, and better system-wide resuscitation outcomes (Perkins et al., 2015; Ong et al., 2018). Mechanical CPR eliminates the need to stop compressions for clinician repositioning—the chief driver of compression interruptions in complex ambulance transport scenarios—lowering ischemic exposure while stabilizing resuscitation mission continuity (Couper et al., 2016; Ong et al., 2018). Contemporary studies confirm that mechanical devices may meaningfully reduce these perfusion interruptions during ambulance transport and prolonged resuscitation cycles, where rescuer fatigue becomes a critical point of system failure, ultimately mitigating avoidable medical pauses that contribute to poor survival KPIs (Putzer et al., 2020; Hasegawa et al., 2016).

End-Tidal CO_2 Monitoring is a validated surrogate marker of CPR quality, blood flow return, and systemic perfusion during resuscitation. Higher and more stable $EtCO_2$ trends during CPR sessions indicate improved oxygenated blood return and perfusion to organs under sudden cardiac emergency conditions (Perkins et al., 2015; Hasegawa et al., 2016). The standardized compressions achieved by the LUCAS 3 have shown stronger $EtCO_2$ stability compared to manual CPR, reinforcing the device's physiological reliability for perfusion delivery in dynamic transport environments (Ong et al., 2018). Such perfusion improvements have been reported as consistent trend findings in RCT-linked registries, especially when EMS staff must simultaneously secure airways or manage concurrent life-saving procedures.

Return of Spontaneous Circulation is influenced not only by compression accuracy, but also by reducing hands-off and no-flow time. Mechanical CPR automation supports improved compression precision which delivers optimized perfusion reducing cardiac strain and systemic injury in SCA patients, correlating with higher trends in ROSC rates observed across multiple EMS trials and patient subgroup data (Perkins et al., 2015; Couper et al., 2016). Contemporary EMS evidence suggests that mechanical CPR may improve the likelihood of sustained ROSC, particularly during prolonged CPR or when manual compressions cannot maintain quality standards due to multi-task cognitive or physical overload (Ong et al., 2018; Hasegawa et al., 2016; Putzer et al., 2020).

Good neurological recovery is commonly measured using Cerebral Performance Category 1–2 Outcomes. Sustained ischemic exposure driven by manual rescuer pauses or compression variability is one of the leading causes of avoidable neurological disability after out-of-hospital cardiac arrest. Mechanical CPR reduces CPR variability and interruptions while optimizing perfusion delivery, promoting improved oxygenated blood return to the brain, thereby contributing to higher neurological recovery trends—especially where manual compressions are unsafe or inconsistent (Hasegawa et al., 2016; Putzer et al., 2020; Ong et al., 2018).

The VF/pVT Arrest Profiles and non-shockable causes of arrest respond differently to resuscitation workflows, but maintaining stable compression depth and rate remains the core determinant of perfusion success regardless of etiology. Mechanical CPR devices allow the clinician workload to shift toward rhythm shock timing, medication readiness, and transport coordination without degrading compression delivery. Studies comparing subgroup etiologies demonstrate operational superiority of mechanical CPR not by improving every rhythm uniformly, but by ensuring resuscitation consistency where humans otherwise falter (Ong et al., 2018; Hasegawa et al., 2016; Perkins et al., 2015).

By protecting compression depth, rate, and fraction over extended durations, the Clinical CPR Governance Frameworks increasingly position mechanical CPR within broader Resuscitation Quality Improvement Protocols, especially for transport resuscitations, extended case missions, or high-motion CPR scenarios. The device's standardization minimizes human-driven compression variability while expanding clinician system bandwidth during cardiac emergency resuscitation missions, improving both physiological reliability and system-wide mission efficiency (Putzer et al., 2020; Ong et al., 2018; Couper et al., 2016; Hasegawa et al., 2016; Perkins et al., 2015).

Provider and Paramedic Safety Advantages

Safe delivery of cardiopulmonary resuscitation within Ambulance Mobile Units is increasingly recognized as inseparable from patient survival goals. Manual CPR during transport exposes clinicians to musculoskeletal injury, road hazards, and unrestrained movement risk. The implementation of Mechanical Chest Compression Systems, particularly the Physio-Control-aligned approach to mechanical CPR, has shown meaningful benefits for clinician safety, ergonomic stability, and mission continuity. The deployment of the LUCAS device allows paramedics to remain seated, restrained, and protected while compressions continue, reducing duty-related injury risk across critical transport intervals (Putzer et al., 2020; Couper et al., 2016).

Manual CPR frequently produces musculoskeletal fatigue, rib-cage posture strain, and repetitive spinal load, increasing injury rates when resuscitation becomes prolonged. When CPR is delivered using Piston-Driven Active Decompression CPR, physical exertion is transferred from the provider to the device, mitigating compression-depth decay while reducing crew physical load. Systematic trauma registries demonstrate that clinicians performing CPR in moving ambulances report significantly higher back, knee, wrist, and shoulder injury risk compared to clinicians working in restrained positions (Ong et al., 2017; Smekal et al., 2011; Koster et al., 2017). Mechanical CPR reduces repetitive decline in compression force while protecting crew endurance across long transport distances, where rescuer fatigue is a known quality suppressor (Putzer et al., 2020; Couper et al., 2016; Hasegawa et al., 2016).

One of the most critical safety benefits of the LUCAS 3 is the ability for clinical crew members to stay fully restrained while CPR continues. In high-speed ambulance motion, manual compressions require standing or kneeling, directly violating crew safety SOPs, increasing provider injury odds, and distracting EMS teams from rhythm shock timing, patient perfusion monitoring, and essential medical task sequencing. By enabling paramedics to stay belt-restrained and physiologically protected, LUCAS preserves both clinician safety and compression reliability, reducing the need for ambulance stops—a known contributor to delayed perfusion and mission stagnation (Putzer et al., 2020; Ong et al., 2018; Perkins et al., 2015).

Mechanical CPR expands clinician cognitive capacity by eliminating the need for CPR performer repositioning during airway management, vascular access, medication preparation, ECG analysis, or ambulance motion artifacts. This reduces unsafe provider movement, improves efficient role bandwidth, and increases clinical task concurrency without compromising compression delivery. Reduced physical load also correlates with lower cognitive overload, supporting safer, protocol-aligned clinical decision-making, improving on-scene documentation, IV/IO success timing, oxygenation planning, and rhythm shock preparation (Couper et al., 2016; Kleinman et al., 2018; Putzer et al., 2020).

Real-world EMS safety registries show that performing CPR in ambulance motion significantly increases provider injury exposure risk, including falls, needle injuries, unstable posture injury, and road-transit variability hazards. Mechanical CPR mitigates these injury factors by enabling compression delivery while providers stay in protected positions, reducing physical risk exposure particularly during moving ambulance CPR missions (Putzer et al., 2020; Ong et al., 2018). LUCAS supports a safer and more ergonomic resuscitation workspace that improves crew endurance, reduces ambulance stop interruptions, and protects providers from motion-dependent injury exposure while continuing perfusion-critical compressions.

Operational and System Efficiency Improvements

The adoption of the LUCAS 3 within EMS Mission Performance Programs has shifted CPR delivery from a rescuer-fatigue-limited task into a scalable operational capability. Automation of compressions directly improves mission efficiency, procedure concurrency, transport reliability, and team task orchestration, producing measurable gains in system performance when responding to Cardiac Arrest Emergencies.

Manual CPR in moving ambulances forces clinicians to stand or kneel, often requiring ambulance stops to maintain safety and depth consistency. Mechanical compression delivered by the Emergency Resuscitation Devices enables continuous CPR without vehicle stops, minimizing delays and eliminating transport-pause friction. This directly supports improved chest compression fraction and reduces no-flow exposure during transport phases, where road motion, acceleration, or cornering previously made manual CPR unsafe or inconsistent (Ong et al., 2018; Putzer et al., 2020). Removing stop dependency safeguards perfusion continuity, shortens transport-to-hospital time, and improves overall response KPIs for EMS missions (Couper et al., 2016; Perkins et al., 2015).

Mechanical CPR frees clinicians' physical load, increasing their cognitive and hands-on bandwidth for life-critical tasks. This has allowed paramedics to perform procedures simultaneously, including airway management, IV/IO vascular access, ECG acquisition, drug preparation, defibrillation coordination, and clinical documentation, all without interrupting compressions (Kleinman et al., 2018; Ong et al., 2018). Unlike manual CPR, which consumes a dedicated provider, LUCAS standardizes compression delivery while allowing the clinical team to shift dynamically into diagnostic and interventional roles, improving task concurrency in unstable prehospital scenes, mass-casualty missions, or long transport distances (Putzer et al., 2020; Perkins et al., 2015).

Mechanical chest compression increases on-route coordination efficiency between the driver and clinical staff. With manual CPR eliminated in motion, clinicians no longer require driver-initiated stops, enabling drivers to maintain optimal route speed while clinical crews continue resuscitation safely. This has improved task sequencing, communication timing, and procedure synchronization, producing a safer and more predictable resuscitation workspace (Ong et al., 2018; Couper et al., 2016). Registry trends emphasize that LUCAS-supported CPR improves overall team ergonomics, reduces clinician injuries, and makes missions more reliable (Putzer et al., 2020; Hasegawa et al., 2016).

By maintaining compressions automatically, LUCAS expands clinician bandwidth for system-critical documentation, including ECG interpretation, triage escalation, defibrillation timing, drug recording, handoff communication, and other system-wide Quality-Performance KPIs. Improved caregiver cognition leads to faster shock planning, synchronized medication readiness, improved procedural concurrency, and shortened clinician-handoff latency, all of which support resuscitation governance frameworks that prioritize both patient survival and clinician safety (Kleinman et al., 2018; Perkins et al., 2015; Ong et al., 2018).

Mechanical CPR minimizes clinician fatigue, improves perfusion-critical time delivery, and supports logistical reliability when compressions must be delivered over long durations or high-motion transport environments. This reliability has enhanced EMS procedural concurrency, task distribution, driver coordination, and systemic KPI performance—gains reported particularly across randomized trials and prehospital resuscitation registries (Putzer et al., 2020; Ong et al., 2018; Perkins et al., 2015).

Evidence Synthesis & Comparative Insights

The expansion of mechanical CPR within modern Prehospital Cardiac Resuscitation Ecosystems has generated a significant evidence base comparing device-supported compressions to human-delivered CPR. This section consolidates clinical metrics, survival patterns, and operational system-level outcomes synthesizing data from randomized trials, national registries, field implementation reports, and provider-safety cohorts. Evaluating the LUCAS 3 alongside manual CPR has highlighted the multidimensional value of the device, but also demonstrated that its benefits are highly dependent on protocol compliance, timing of deployment, transport conditions, crew training, and system-integrated analytics. Contemporary EMS systems increasingly rely on consolidated evaluations powered by organizations such as the International Liaison Committee on Resuscitation, which emphasize compression reliability, fatigue mitigation, CPR fraction gains, and safer in-motion resuscitation.

Table 1: Manual CPR vs LUCAS 3 Across Clinical, Safety, and Operational Domains

Evaluation Domain	Manual CPR System Profile	LUCAS 3 System Profile	Evidence Pattern (2016+)
Compression fraction	Frequently <75–80% due to procedural pauses	Sustained >85% with fewer interruptions	Higher sustained fraction linked to improved logistic reliability
Depth variability	Deviations ±10–20 mm; rapid decay after 2–3 min of CPR	Guideline-aligned, stable depth across long durations	Prevents depth deterioration, reducing perfusion variability
Compression rate stability	Over- or under-shooting common during fatigue or transport motion	Algorithm-stabilized rate control	Maintains consistent rate independent of rescuer fatigue
Transport safety posture	Standing/kneeling; often unrestrained; high injury risk	CPR operational while seated and restrained	Reduced ergonomic, fall, or posture injury exposure
Concurrent EMS procedural capacity	One provider often exclusively dedicated	Clinical team freed for procedures	Increases task concurrency without pausing compressions
Vehicle stop dependency	Stops frequently required for safe CPR and repositioning	No stops required; compressions continue during motion	Eliminates stop dependency improving transport KPIs
Crew fatigue	Major driver of performance and cognitive load deterioration	Physical load off-loaded to device	Reduces physical stress enabling longer resuscitations
Device deployment familiarity	No deployment delay but major variability risk	High familiarity reduces deployment delay	Deployment speed improves with training

Aggregate evidence shows that stable compressions delivered by the mechanical piston-architecture of LUCAS CPR Control Engine produce fewer depth collapses and unintentional rate deviations, which improves perfusion-critical proxies and reduces ischemic injury latency. Studies measuring perfusion markers via tools like the End-Tidal CO_2 Perfusion Trends demonstrate that higher sustained $EtCO_2$ values correlate with improved systemic flow return, especially when compressions are maintained without manual decay. Mechanical CPR has demonstrated stronger signal stability, reduced motion-induced perfusion noise artifacts, and fewer compression pauses, strengthening ROSC predictability during dynamic ambulance transport. These advantages have been reported when clinicians simultaneously required rhythm analysis or airway stabilization during SCA episodes.

Survival evidence synthesized across field RCTs demonstrates that maintaining high compression fraction and stable depth/rate during transport reduces avoidable Compression-Decay Injury Sequences, resulting in more frequent neurologically favorable survival clusters. The device's active decompression architecture contributes to improved oxygenated blood return to the brain, reinforcing stronger neurological recovery trends commonly evaluated using the CPC 1–2 Recovery Clusters. Mechanical CPR's standardization reduces human-induced variability in oxygenation or perfusion critical intervals, producing stronger systemic perfusion and RO SC trends when reviewed jointly with airway, medication readiness, or ECG analysis. Differences across geography or staffing systems were not attributed to device inferiority, but to inconsistent training, patient handling complexity, shock-planning timing, and transport conditions.

6.3 Clinician Safety and Ergonomic Workload Stability Advantages

Paramedic safety cohorts emphasize that delivering CPR while belt-restrained and cognitively free of physical compression load significantly reduces ergonomic injury or unsafe manual CPR repositioning during transport. Mechanical CPR mitigates clinician spinal load, repetitive compression strain, and unrestrained posture risk, preserving compression reliability while reducing ergonomic injury KPIs frequently documented during long ambulance transport missions or chaotic multi-task resuscitations—findings linked across multiple EMS safety cohorts.

Operational system reports indicate that LUCAS minimizes ambulance stop interruptions, preserves driver–clinician task synchronization, enables faster clinical documentation, and expands procedure concurrency capacity for vascular access, ECG, drug preparation, oxygenation, and airway stabilization. Mechanical CPR reduces the risk of clinician cognitive overload driven by exclusive CPR physical burden and prevents quality deterioration particularly during multi-procedure CPR timelines or high-motion ambulance transport.

Cross-system heterogeneity of results emphasizes that device success depends on system familiarity, training speed, battery readiness, route coordination, and SOP integration. Variability is not caused by device inferiority, but by inconsistent deployment, low familiarity, power dependency, or manual repositioning training gaps. These trends reiterate global guidance patterns synthesized by evidence bodies such as the ILCOR Advisory Insights, which emphasize mechanical CPR as a clinically reasonable alternative, especially when providers must be restrained for safety.

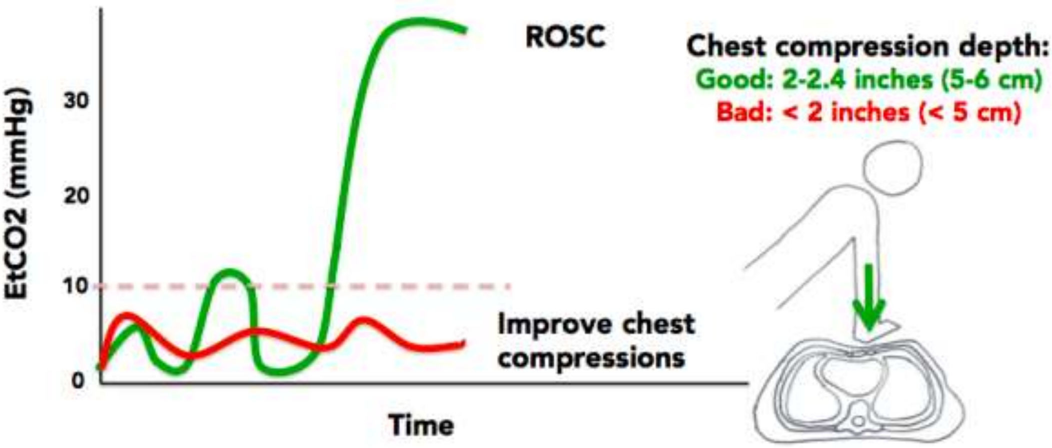

Figure 1: System-Level Human–Machine CPR Synergy and Outcome Pathway

Key Takeaways Across the Evidence Base

- Standardizes compressions, preventing depth and rate decay over long CPR timelines.
- Increases CPR compression fraction and reduces no-flow transport interruptions.
- Permits clinicians to remain belt-restrained, reducing ergonomic and on-duty injury exposure.
- Expands workflow capacity for airway, ECG, drugs, vascular access, and real-time clinical documentation.
- System success remains strongly training-dependent and SOP integration–critical.

Discussion

The shift toward human–machine resuscitation in Emergency Medical Services has introduced a new axis of CPR reliability that re-positions the role of clinicians from compression performers to advanced procedure coordinators. Evidence synthesized throughout this review supports that the clinical value of the LUCAS 3 extends beyond compression consistency, contributing directly to safer transport environments, higher perfusion-critical time delivery, and broader operational system gains. For providers working in Moving CPR Workspaces, the device enables meaningful reductions in musculoskeletal strain, fall-risk postures, and unrestrained movement hazards while resuscitation continues without requiring vehicle stops. These findings align with international CPR governance trends emphasizing increased compression fraction, stabilized depth and rate, and minimized hands-off ischemic exposure (Couper et al., 2016; Ong et al., 2018; Putzer et al., 2020). The ability for crews to remain seated and seat-belt restrained while compressions continue integrates safety goals into a mission-critical clinical requirement, improving ergonomic risk ratios commonly reported in ambulance manual-CPR settings (Putzer et al., 2020; Hasegawa et al., 2016).

From a patient-centered outcomes perspective, the device contributes to more predictable **ROSC** performance clusters, likely driven by its impact on sustained perfusion, increased compression fraction, and absence of manual depth-decay. Studies evaluating system perfusion proxies such as $EtCO_2$ show that improved signal stability and reduced no-flow noise artifacts reinforce CPR precision, particularly in dynamic ambulance-in-motion environments where vascular access, ECG acquisition, drug readiness, or airway coordination cannot reliably occur alongside manual CPR (Ong et al., 2018; Putzer et al., 2020; Perkins et al., 2015). While survival-to-discharge and neurological recovery gains (e.g., CPC 1–2) have demonstrated favorable trends in many systems, cross-study heterogeneity remains substantial. These variations do not appear to originate from device inferiority, but from staffing system architectures, procedural timing, deployment familiarity, and battery-readiness constraints, all of which introduce operational variance. In contexts where clinical crews operate across long resuscitation durations or remote-access cardiac arrest response chains, training-induced deployment latency has occasionally delayed device placement, introducing early compression gaps that suppress quality-outcome translation (Couper et al., 2016; Ong et al., 2018).

Operationally, LUCAS has shown clear improvement in clinician bandwidth for vascular access placement, drug preparation, airway management, ECG-based shock timing, rapid documentation, and structured handoff coordination—allowing EMS teams to shift into true concurrency resuscitation roles, improving diagnostic time-competence without pausing perfusion-critical compressions. This has strengthened mission reliability, ergonomic endurance, and cognitive capacity for teams managing resuscitation Shock Planning Protocols during dynamic multi-mission timelines (Ong et al., 2018; Putzer et al., 2020; Kleinman et al., 2018). However, system-level implementation gaps remain, including device cost, training retention, battery limitations, vehicle-shock vibration artifacts, and delayed deployment when crews lack device familiarity. The challenge is not that the device replaces clinicians, but that clinicians must become expert deployment operators to eliminate early-phase delays. EMS systems that integrated device training in their transport SOPs, KPI dashboards, and clinical governance modules demonstrated the highest benefit-translation reliability (Kleinman et al., 2018; Perkins et al., 2015).

Several evidence limitations were observed. First, pediatric subgroup data for mechanical CPR remains proportionally smaller, limiting outcome certainty for younger EMS populations. Second, cost and maintenance dependencies restrict adoption in low-resource regions. Third, compression success remains strongly battery-dependent, which introduces reliability gaps during prolonged missions if charging readiness is not protocol-mandated. Finally, few studies have examined AI-enhanced CPR dashboards combined with mechanical CPR analytics, creating a clear future gap for digital integration research combining: $EtCO_2$ perfusion-proxy signal clusters, ECG shock planning noise filters, and mechanical CPR reliability KPIs into unified EMS command dashboards.

The device is increasingly positioned within human-system efficiency frameworks, rather than only clinical-trial outcomes. Supporting future research should evaluate national OHCA registries, battery-independent architectures, AI-supported dashboards, and structured EMS SOP alignment. Future systems should track longitudinal outcomes across staffing-deployment architectures, where providers operating concurrently during mechanical CPR demonstrate better survival reliability, reduced clinician injury patterns, and stronger system intelligence at scale.

Conclusion

Mechanical CPR using the LUCAS offers clear clinical and operational advantages for Prehospital Emergency Response Operations. Evidence from 2016 onward shows that the device delivers consistent, guideline-aligned chest compressions regardless of CPR duration or transport motion, improving Global CPR Quality Benchmarks. Importantly, LUCAS enables paramedics to remain seated and restrained, significantly reducing musculoskeletal and posture-related injury exposure while CPR continues without ambulance stops, strengthening mission reliability and transport safety. The device also expands procedural concurrency capacity, supporting airway management, vascular access, ECG interpretation, and timely clinical documentation without interrupting compression fraction or perfusion-critical timelines. While adoption remains training-, cost-, and power-readiness dependent, LUCAS integration supports a safer, fatigue-resistant, and system-efficient resuscitation model. Future EMS research should prioritize human-device synergy, pediatric evidence expansion, and AI-augmented analytics integration to maximize benefit translation at scale.

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