Evaluating the Effectiveness of Mechanical CPR Devices Used by Paramedics on Cardiac Arrest Patient Outcomes in a Tertiary Care Setting

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Abstract

Background: Out-of-hospital cardiac arrest (OHCA) remains a leading cause of mortality globally. Mechanical CPR devices, such as LUCAS-2 and AutoPulse, were developed to provide consistent and uninterrupted chest compressions, addressing the limitations of manual CPR.

Objective: This study evaluates the effectiveness of mechanical CPR devices in improving ROSC, survival, and neurological outcomes compared to manual CPR in a tertiary hospital setting.

Methods: A retrospective cohort study was conducted on 420 OHCA patients treated by paramedics. Patients were divided into two groups: mechanical CPR (n=210) and manual CPR (n=210). Primary outcomes included survival to hospital discharge, while secondary outcomes assessed pre-hospital ROSC and neurological recovery using the Cerebral Performance Category (CPC) score.

Results: Pre-hospital ROSC rates were significantly higher in the mechanical CPR group (58.6%) compared to manual CPR (45.7%, *p=0.01*). Survival to hospital admission was also greater (71.4% vs 60.0%, *p=0.01*). Although survival to discharge favored mechanical CPR (33.3% vs 26.2%), it was not statistically significant (*p=0.08*). Neurological outcomes were significantly better in the mechanical CPR group, with 65.7% achieving favorable CPC scores (CPC 1–2) compared to 50.9% in the manual group (*p=0.04*).

Conclusion: Mechanical CPR devices improve ROSC rates, survival to admission, and neurological outcomes compared to manual CPR. While survival to discharge did not achieve statistical significance, mechanical CPR remains a valuable tool in prolonged resuscitation scenarios and patient transport.

Keywords: Mechanical CPR, Manual CPR, Out-of-Hospital Cardiac Arrest, ROSC, Neurological Outcomes, Cerebral Performance Category, Tertiary Hospital, Pre-hospital Care.

Introduction

Out-of-hospital cardiac arrest (OHCA) remains one of the leading causes of mortality globally, with survival rates consistently low despite advancements in cardiopulmonary resuscitation (CPR) techniques. Effective chest compressions are critical for patient survival and neurological outcomes following cardiac arrest, as high-quality CPR ensures optimal circulation and oxygenation (Perkins et al., 2015). However, manual CPR can often be inconsistent due to provider fatigue, variable conditions, and extended resuscitation times during transport to tertiary hospitals (Couper et al., 2016).

To address these limitations, mechanical CPR devices have been introduced to deliver consistent, uninterrupted chest compressions during resuscitation efforts. Devices such as the **LUCAS** (Lund University Cardiopulmonary Assist System) and the **AutoPulse** have demonstrated the potential to improve CPR quality and survival rates compared to manual methods (Ong et al., 2018; Tranberg et al., 2015). Mechanical CPR devices are particularly advantageous during prolonged resuscitation scenarios, transport, or when performing advanced interventions such as airway management or defibrillation (Lamhaut et al., 2017).

Despite these advantages, the clinical effectiveness of mechanical CPR devices remains a topic of ongoing debate. Several studies, including the PARAMEDIC trial, found no significant improvement in survival outcomes when comparing mechanical CPR to manual CPR in pre-hospital settings (Perkins et al., 2015). Conversely, other reports highlight improved survival-to-discharge rates and better neurological recovery when mechanical devices are deployed, particularly in cases requiring extended transport times or refractory cardiac arrest (Jennings et al., 2012; Couper et al., 2018).

This study aims to evaluate the effectiveness of mechanical CPR devices used by paramedics for cardiac arrest patients in a tertiary care setting. By analyzing survival rates, return of spontaneous circulation (ROSC), and neurological outcomes, this research seeks to provide evidence for optimizing CPR delivery in pre-hospital and hospital transitions. Additionally, it will explore barriers and facilitators influencing the deployment of mechanical CPR devices by paramedics.

Literature Review

1. Overview of Mechanical CPR Devices

Mechanical CPR devices, including the **LUCAS** (Lund University Cardiopulmonary Assist System) and the **AutoPulse**, were developed to address limitations of manual CPR such as fatigue, inconsistent depth and rate of compressions, and prolonged resuscitation efforts. These devices automate chest compressions, ensuring consistent high-quality CPR delivery during resuscitation (Jennings et al., 2012; Lamhaut et al., 2017). Their use is particularly advantageous in scenarios requiring extended transport or during invasive procedures like intubation or defibrillation (Ong et al., 2018).

2. Effectiveness of Mechanical CPR Devices in Pre-hospital Settings

Studies examining the effectiveness of mechanical CPR devices have reported mixed outcomes. The **PARAMEDIC trial**, one of the largest pragmatic randomized controlled trials, compared mechanical CPR (LUCAS-2) to manual compressions. Perkins et al. (2015) found no significant difference in 30-day survival rates between the two groups, suggesting mechanical CPR may not confer a clear survival advantage. Similarly, Couper et al. (2016) conducted a meta-analysis and reported no improvement in survival-to-discharge rates when mechanical devices were used during in-hospital cardiac arrest.

However, other studies highlight specific scenarios where mechanical devices may improve outcomes. A study by Tranberg et al. (2015) demonstrated higher CPR quality and improved ROSC rates in prolonged cardiac arrests when the **LUCAS-2 device** was used. Lamhaut et al. (2017) reported that mechanical CPR devices were particularly beneficial in pre-hospital extracorporeal cardiopulmonary resuscitation (ECPR) cases, where uninterrupted compressions during transport optimized perfusion.

3. Impact on CPR Quality and Consistency

Manual CPR is inherently prone to variability in compression depth, rate, and interruptions, especially in physically challenging environments or during extended resuscitation (Couper et al., 2018). Mechanical devices offer uninterrupted, standardized compressions, which maintain cardiac output and coronary perfusion pressure. Jennings et al. (2012) demonstrated that mechanical devices provided more consistent CPR quality compared to manual techniques, particularly during transport or in confined spaces.

Studies comparing CPR quality found that mechanical CPR resulted in fewer interruptions and higher compression rates meeting guideline standards (Couper et al., 2016). These findings emphasize the value of mechanical devices in maintaining CPR quality over prolonged periods, which is crucial for improving neurological outcomes (Lamhaut et al., 2017; Ong et al., 2018).

4. Survival and Neurological Outcomes

The survival benefits of mechanical CPR devices remain contentious. While some studies, such as those by Tranberg et al. (2015), report improved ROSC rates and better neurological recovery, others, including the PARAMEDIC trial, found no significant survival advantage (Perkins et al., 2015). However, Couper et al. (2018) argue that mechanical devices may offer greater benefits in select patient populations, such as those requiring prolonged resuscitation, extended transport times, or refractory cardiac arrests.

For neurological outcomes, studies suggest that uninterrupted compressions provided by mechanical devices improve cerebral perfusion, which may translate to better recovery. Lamhaut et al. (2017) demonstrated improved neurological outcomes in patients receiving pre-hospital mechanical CPR as part of an ECPR protocol. These findings underscore the importance of targeted use of mechanical CPR in specific clinical contexts.

5. Challenges and Barriers to Implementation

Despite their potential benefits, several challenges limit the widespread use of mechanical CPR devices. Studies highlight issues such as device cost, training requirements, and delays in deployment during time-critical resuscitation efforts (Ong et al., 2018). Additionally, concerns about device-induced injuries, including rib fractures and internal organ damage, have been raised in some studies (Couper et al., 2016). Ensuring adequate training and addressing logistical challenges are critical for optimizing the use of mechanical CPR devices in pre-hospital settings.

6. Clinical Guidelines and Future Directions

Current clinical guidelines acknowledge the role of mechanical CPR devices but emphasize their use as a supplement rather than a replacement for high-quality manual CPR (AHA Guidelines, 2015). Future research should focus on identifying patient subgroups that may benefit most from mechanical CPR, optimizing device deployment protocols, and evaluating long-term outcomes such as neurological recovery and quality of life (Couper et al., 2018; Lamhaut et al., 2017).

Conclusion of Literature Review

While mechanical CPR devices offer significant advantages in maintaining CPR quality and reducing

interruptions, evidence regarding their impact on survival and neurological outcomes remains inconclusive. Studies suggest that these devices may be particularly beneficial in specific scenarios, such as prolonged resuscitation, extended transport times, or as part of ECPR protocols. Addressing barriers to implementation and conducting further research will be essential to define the role of mechanical CPR in pre-hospital cardiac arrest management.

Methodology

Study Design

A **retrospective cohort study** was conducted to evaluate the effectiveness of mechanical CPR devices in improving outcomes for cardiac arrest patients treated by paramedics in a pre-hospital setting and subsequently admitted to a tertiary hospital. The study compared the use of **mechanical CPR devices** with **manual CPR** in out-of-hospital cardiac arrest (OHCA) cases.

Study Setting

The study was conducted at a **tertiary care hospital** with an active emergency department receiving a high volume of cardiac arrest patients. Paramedic teams were part of a well-established pre-hospital emergency medical services (EMS) network operating in the hospital's catchment area.

Study Population

The study population consisted of **adult cardiac arrest patients (aged ≥18 years)** who experienced OHCA and were treated by paramedics using either manual or mechanical CPR devices. Inclusion and exclusion criteria were as follows:

- **Inclusion Criteria:**
    1. Adults (≥18 years) with non-traumatic OHCA.
    2. Patients who received CPR from paramedics prior to admission.
    3. Documented use of either mechanical CPR or manual CPR.
    4. Patients admitted to the emergency department of the tertiary hospital.
- **Exclusion Criteria:**
    1. Patients under 18 years of age.
    2. Cardiac arrests resulting from trauma.
    3. Patients with incomplete EMS or hospital records.
    4. Cases where resuscitation efforts were terminated pre-hospital.

Intervention

The intervention group comprised patients who received **mechanical CPR** using devices such as the **LUCAS-2** or **AutoPulse**. The control group consisted of patients who received **manual CPR** following standard EMS protocols.

Data Collection

Data were collected retrospectively from paramedic records, hospital emergency department logs, and electronic health records (EHRs). The following information was extracted:

1. **Pre-hospital Variables:**
    - Patient demographics (age, gender, comorbidities).
    - Initial rhythm (shockable/non-shockable).
    - Time to first CPR initiation.
    - Duration of CPR (manual or mechanical).
    - Use of advanced airway management (intubation, supraglottic devices).
    - Use of defibrillation and administration of medications (e.g., epinephrine, amiodarone).
    - ROSC (Return of Spontaneous Circulation) in the field.
2. **Hospital Variables:**
    - Emergency department ROSC rates.
    - Survival to hospital admission.
    - Survival to hospital discharge.
    - Neurological outcomes measured using the **Cerebral Performance Category (CPC)** score.
3. **Outcome Measures:**
    - **Primary Outcome:** Survival to hospital discharge.
    - **Secondary Outcomes:**
        1. ROSC rates (pre-hospital and in-hospital).
        2. Neurological outcomes (CPC score at discharge).
        3. Duration of resuscitation efforts.
        4. Time from EMS arrival to definitive care.

Data Analysis

- Data were entered and analyzed using **SPSS (Version 25.0)**.
- Descriptive statistics were used to summarize demographic and clinical variables, with means, medians, and standard deviations for continuous data and proportions for categorical data.
- A **chi-square test** was used to compare ROSC and survival rates between the mechanical CPR and manual CPR groups.
- A **logistic regression analysis** was performed to identify independent predictors of survival to discharge, adjusting for confounders such as age, initial rhythm, and duration of CPR.
- Neurological outcomes were analyzed using the **CPC score**, categorized into favorable (CPC 1–2) and unfavorable (CPC 3–5) outcomes.

Ethical Considerations

Ethical approval was obtained from the ethics committee. Data were anonymized to protect patient confidentiality, and the study adhered to the **Declaration of Helsinki** guidelines.

Here's a detailed **Findings** section for your research paper, including relevant **tables** to display the data. The findings are written as though the study has been completed.

Findings

A total of **420 patients** were included in this study, with 210 patients in the **mechanical CPR group** and

210 in the **manual CPR group**. The primary outcome of survival to hospital discharge and secondary outcomes, including ROSC and neurological status, are presented below.

Patient Demographics

Table 1 summarizes the demographic and clinical characteristics of the patients in both groups.

Variable	Mechanical CPR (n=210)	Manual CPR (n=210)	p-value
Mean Age (years)	58.7 ± 12.3	60.2 ± 11.8	0.31
Male (%)	65.7	63.8	0.72
Comorbidities (%)			
- Hypertension	45.2	43.3	0.64
- Diabetes	28.6	30.5	0.61
Initial Shockable Rhythm (%)	50.0	47.1	0.56
CPR Duration (minutes)	24.1 ± 5.2	27.3 ± 6.4	0.002*
ROSC Pre-hospital (%)	58.6	45.7	0.01*

Values are expressed as mean ± standard deviation or percentages.

Note:*p<0.05 is statistically significant.*

Observations:

- Patients in both groups had similar baseline characteristics.
- The **mechanical CPR group** had a significantly shorter CPR duration compared to the manual CPR group (p=0.002).
- Pre-hospital ROSC rates were significantly higher in the mechanical CPR group (58.6% vs 45.7%, p=0.01).

Primary Outcome: Survival to Hospital Discharge

Table 2 shows the survival outcomes for both groups.

Outcome	Mechanical CPR (n=210)	Manual CPR (n=210)	p-value
Survival to Hospital Admission (%)	71.4	60.0	0.01*
Survival to Hospital Discharge (%)	33.3	26.2	0.08

Observations:

- Patients receiving mechanical CPR had higher survival rates to hospital admission compared to the manual CPR group (71.4% vs 60.0%, p=0.01).
- While survival to discharge was higher in the mechanical CPR group (33.3%) compared to the manual group (26.2%), this difference did not reach statistical significance (p=0.08).

Secondary Outcome: Neurological Outcomes

Neurological outcomes were assessed using the **Cerebral Performance Category (CPC)** score at discharge. Favorable outcomes were defined as CPC 1–2.

Neurological Outcome (CPC Score)	Mechanical CPR (n=70)	Manual CPR (n=55)	p-value
CPC 1–2 (Favorable Outcome) (%)	65.7	50.9	0.04*
CPC 3–5 (Unfavorable Outcome) (%)	34.3	49.1	0.04*

Observations:

- Among patients who survived to discharge, the **mechanical CPR group** had significantly better neurological outcomes, with 65.7% achieving a favorable CPC score compared to 50.9% in the manual CPR group (p=0.04).

Summary of Findings

1. **Pre-hospital ROSC Rates**: Significantly higher in the mechanical CPR group compared to the manual group (58.6% vs 45.7%, p=0.01).
2. **Survival to Hospital Admission**: Higher in the mechanical CPR group (71.4% vs 60.0%, p=0.01).
3. **Survival to Hospital Discharge**: Higher in the mechanical CPR group but did not reach statistical significance (33.3% vs 26.2%, p=0.08).
4. **Neurological Outcomes**: Patients in the mechanical CPR group had significantly better CPC scores at discharge compared to the manual CPR group (p=0.04).

Discussion

This study evaluated the effectiveness of mechanical CPR devices compared to manual CPR in pre-hospital cardiac arrest cases treated by paramedics and admitted to a tertiary care hospital. The findings suggest that mechanical CPR provides several advantages, including improved return of spontaneous circulation (ROSC), higher survival to hospital admission, and significantly better neurological outcomes for patients discharged alive.

Improved ROSC Rates and Survival to Admission

The study demonstrated a significantly higher **pre-hospital ROSC rate** in patients receiving mechanical CPR (58.6%) compared to manual CPR (45.7%, *p=0.01*). These findings align with earlier studies highlighting the role of mechanical CPR devices in delivering consistent and uninterrupted chest compressions, which optimize coronary and cerebral perfusion during cardiac arrest (Jennings et al., 2012; Ong et al., 2018). High-quality compressions are critical in early resuscitation, and mechanical devices appear to overcome the limitations of manual CPR, including fatigue and variability in technique.

Similarly, **survival to hospital admission** was significantly higher in the mechanical CPR group (71.4% vs 60.0%, *p=0.01*). These results are consistent with the findings of Lamhaut et al. (2017), who observed improved survival outcomes when mechanical CPR was integrated into structured resuscitation protocols

during transport. The ability of mechanical devices to maintain compressions during complex procedures, such as airway management and defibrillation, likely contributed to these improved outcomes.

Survival to Hospital Discharge

While survival to hospital discharge was higher in the mechanical CPR group (33.3% vs 26.2%), the difference did not reach statistical significance (*p=0.08*). This result mirrors findings from the PARAMEDIC trial (Perkins et al., 2015), which concluded that mechanical CPR does not significantly improve overall survival rates compared to manual CPR. The lack of statistical significance may reflect the multifactorial nature of cardiac arrest outcomes, including patient comorbidities, initial rhythm, response time, and quality of post-resuscitation care.

Despite this, the trend toward improved survival in the mechanical CPR group highlights its potential role in prolonged resuscitation scenarios where manual fatigue can impact the quality of CPR. Further studies with larger sample sizes may help confirm whether this trend translates into a clinically significant survival benefit.

Neurological Outcomes

A key strength of this study is the evaluation of **neurological outcomes** using the **Cerebral Performance Category (CPC)** score. Among patients discharged alive, 65.7% in the mechanical CPR group achieved favorable neurological outcomes (CPC 1–2), compared to 50.9% in the manual CPR group (*p=0.04*). These results suggest that mechanical CPR devices contribute to better cerebral perfusion during resuscitation, reducing the risk of neurological impairment.

Previous research has shown that uninterrupted compressions are critical for maintaining cerebral blood flow during cardiac arrest (Couper et al., 2018). Mechanical CPR devices reduce interruptions associated with manual CPR, such as those occurring during transport or provider fatigue, thereby improving cerebral perfusion. The findings of this study support the use of mechanical CPR in situations where prolonged, high-quality compressions are necessary.

Challenges and Barriers to Mechanical CPR Implementation

While mechanical CPR devices offer clear advantages, their implementation is not without challenges. Delays in device deployment during time-critical resuscitation, cost constraints, and the need for paramedic training have been cited as barriers in previous studies (Ong et al., 2018). Additionally, concerns regarding device-related injuries, such as rib fractures and organ damage, have been reported (Couper et al., 2016). However, these injuries are also common with manual CPR, and their clinical significance remains unclear.

Future studies should focus on optimizing training programs for paramedics and developing standardized protocols for mechanical CPR device use in pre-hospital care. Additionally, cost-effectiveness analyses may help justify the broader adoption of these devices in EMS systems.

Strengths and Limitations

Strengths: This study included a robust sample size and evaluated both survival and neurological outcomes,

providing a comprehensive assessment of mechanical CPR effectiveness. Data were collected from real-world pre-hospital and hospital settings, enhancing the generalizability of the findings.

Limitations: As a retrospective cohort study, the findings are subject to potential biases, including confounding variables such as differences in response time, post-resuscitation care, and patient comorbidities. Additionally, the study was conducted in a single tertiary care hospital, which may limit the generalizability to other healthcare systems.

Implications for Practice

The results of this study highlight the potential role of mechanical CPR devices in improving pre-hospital cardiac arrest outcomes, particularly in terms of ROSC and neurological recovery. Mechanical devices should be considered in cases where prolonged resuscitation is anticipated or during patient transport, where manual compressions may be challenging to maintain. Integrating mechanical CPR into EMS protocols, alongside comprehensive paramedic training, may optimize cardiac arrest management and patient outcomes.

Conclusion

This study found that mechanical CPR devices improve ROSC rates, survival to hospital admission, and neurological outcomes compared to manual CPR. While survival to hospital discharge did not reach statistical significance, the trend toward improved outcomes suggests that mechanical devices are a valuable adjunct to pre-hospital cardiac arrest management. Further research, including multicenter trials and cost-effectiveness analyses, is warranted to confirm these findings and inform clinical guidelines for mechanical CPR device use.

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