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**NO BENEFIT IN NEUROLOGIC OUTCOMES OF SURVIVORS OF OUT-OF-HOSPITAL CARDIAC ARREST WITH MECHANICAL COMPRESSION DEVICE**

Ryan Newberry, DO Ⓟ, Ted Redman, MD, Elliot Ross, MD, Rachel Ely, DO, Clayton Saidler, Allyson Arana, PhD, David Wampler, PhD, David Miramontes, MD

**ABSTRACT**

**Introduction**: Out-of-hospital cardiac arrest (OHCA) is a major cause of death and morbidity in the United States. Quality cardiopulmonary resuscitation (CPR) has proven to be a key factor in improving survival. The aim of our study was to investigate the outcomes of OHCA when mechanical CPR (LUCAS 2 Chest Compression System™) was utilized compared to conventional CPR. Although controlled trials have not demonstrated a survival benefit to the routine use of mechanical CPR devices, there continues to be an interest for their use in OHCA. **Methods**: We conducted a retrospective observational study of OHCA comparing the outcomes of mechanical and manual chest compressions in a fire department based EMS system serving a population of 1.4 million residents. Mechanical CPR devices were geographically distributed on 11 of 33 paramedic ambulances. Data were collected over a 36-month period and outcomes were dichotomized based on utilization of mechanical CPR. The primary outcome measure was survival to hospital discharge with a cerebral performance category (CPC) score of 1 or 2. **Results**: This series had 3,469 OHCA reports, of which 2,999 had outcome data and met the inclusion criteria. Of these 2,236 received only manual CPR and 763 utilized a mechanical CPR device during the resuscitation. Return of spontaneous circulation (ROSC) was attained in 44% (334/763) of the mechanical CPR resuscitations and in 46% (1,020/2,236) of the standard manual CPR resuscitations (p = 0.32). Survival to hospital discharge was observed in 7% (52/763) of the mechanical CPR resuscitations and 9% (191/2,236) of the manual CPR group (p = 0.13). Discharge with a CPC score of 1 or 2 was observed in 4% (29/763) of the mechanical CPR resuscitation group and 6% (129/2,236) of the manual CPR group (p = 0.036). **Conclusions**: In our study, use of the mechanical CPR device was associated with a poor neurologic outcome at hospital discharge. However, this difference was no longer evident after logistic regression adjusting for confounding variables. Resuscitation management following institution of mechanical CPR, specifically medication and airway management, may account for the poor outcome reported. Further investigation of resuscitation management when a mechanical CPR device is utilized is necessary to optimize survival benefit. **Key words**: mechanical CPR device; neurologic outcome; out of hospital cardiac arrest; resuscitation

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**INTRODUCTION**

Mechanical CPR devices have been implemented in many emergency medical services (EMS) out-of-hospital cardiac arrest (OHCA) protocols across the nation. These devices offer the hypothetical benefit of enhancing the quality and duration of chest compressions. This theory has been substantiated by animal studies demonstrating improved indicators such as cerebral perfusion pressures, coronary flow pressures, and decreased no-flow fractions (1, 2). Previous observational studies have reported improvements in achieving return of spontaneous circulation (ROSC) and 3-month survival (3). However, larger randomized control trials have not demonstrated a difference in mortality with use of the mechanical CPR devices (4, 5).

A Cochrane review in 2011 and an update in 2014 did not support widespread use of mechanical CPR devices in OHCA, citing that there was insufficient evidence to conclude whether they are associated with benefit or harm (6, 7). Three large randomized control tri-
als (CIRC, LINC, PARAMEDIC) investigating the outcomes of OHCA that utilized mechanical CPR devices found that there were no significant differences when compared to conventional chest compressions (5, 8, 9). Two meta-analysis in 2015, both comprised of observational studies and randomized control trials, also concluded that a routine strategy of mechanical CPR does not yield improved survival or neurologic outcomes (10, 11). However, despite definitive evidence of a survival benefit, the appeal for the use of mechanical compression devices continues to be the physical and cognitive load off the emergency medical responders.

Although the controlled trials have not demonstrated a benefit to the routine use of mechanical CPR devices, the majority of the observational studies have suggested an advantage over standard manual CPR for survival to hospital admission (10). The two most commonly evaluated devices (AutoPulse™, LUCAS™) function in significantly different ways and may have different treatment effects (11). This study aimed to compare the rates of survival to hospital discharge with a favorable neurologic outcome in patients resuscitated with the LUCAS™ mechanical CPR device and those with standard manual CPR.

**Methods**

This retrospective analysis of prospectively collected data was reviewed and approved by the University of Texas Health Science Center at San Antonio Institutional Review Board. The San Antonio Fire Department Office of the Medical Director (OMD) utilizes an in-house OHCA database that is populated from post-cardiac arrest debriefings; database elements are largely based on Utstein criteria (12). Debriefings are conducted by a member of the OMD and occur at the conclusion of any case where paramedics conduct resuscitative efforts in the prehospital setting. Hospital survival and neurologic function is reported by the receiving hospital. All OHCA s of presumed medical etiology are included in the database. Specific to this project, the database includes patient demographic information, resuscitative efforts utilized, incidence of any ROSC and sustained ROSC (defined as at least 60 beats/min for a minimum of 5 minutes), application of mechanical CPR device, decision to transport and receiving facility if transported, Cerebral Performance Category (CPC), and survival to discharge (12). The database was de-identified and queried from January 1, 2013 to December 31, 2015.

The San Antonio Fire Department (SAFD) is a metropolitan fire department that is the sole 9-1-1 provider for the seventh largest city in the United States and services approximately 1.4 million residents within a 460-square-mile area (12). SAFD provides emergency medical services with first responder basic life support (BLS) fire companies and 33 paramedic advanced life support (ALS) ambulances. Annually, SAFD responds to approximately 158,000 emergency medical incidents and 1200 OHCA s (13). SAFD utilizes a dual response to OHCA, including a four-person BLS fire company and two dual-paramedic-staffed ALS ambulances.

The LUCAS 2 Chest Compression System™ (Lund University Cardiopulmonary Assist System, Jolife AB, Sweden; hereafter mechanical CPR device) is a battery powered device that delivers standardized chest compressions with active chest recoil via a piston and suction-cup mechanism (14). The unit provides 100 compressions per minute at a depth of 4–5 cm and ensures full chest recoil between compressions (15). The device weighs approximately 14 pounds and can be easily transported by a single provider in a carrying case (14).

In 2013, SAFD equitably distributed (considering geographic location and percentage of OHCA volume) the mechanical CPR device on 11 of their 33 ambulances. The initial training was provided by the manufacturer and included a practical component during which each paramedic was required to demonstrate competency in application of the device in less than 20 seconds. The in-service also included a review of the cardiac arrest protocol and incorporation of the mechanical CPR device. Subsequent annual continuing medical education included cardiac arrest scenarios that incorporated the use of the mechanical CPR devices as part of their choreographed cardiac resuscitation strategy. The device was applied both on mannequin and cadaveric models for training.

Currently, the SAFD OHCA protocol allows for the use of the mechanical CPR device when available. The mechanical CPR device was not deployed as a research protocol; instead, it was deployed as an adjunct to OHCA resuscitation. Paramedics were authorized to utilize the device, but not required. If utilized, the OHCA protocol and training instructed paramedics to place the mechanical CPR device immediately upon arrival of an equipped ALS ambulance. SAFD does not currently have a mechanism to capture the time of application of the mechanical CPR device during resuscitation; however, it is reasonably assumed to have occurred within the first 10 minutes of EMS arrival. Individual patients were dichotomized to the mechanical chest compression or standard manual chest compression group based on the reported utilization of the mechanical CPR device during OHCA resuscitation.

The primary outcome of the study was survival to hospital discharge with a favorable neurologic outcome. We defined favorable neurological outcome as a Cerebral Performance Category (CPC) score of 1 or 2. The CPC score was extracted from patient’s medical records. Patients were excluded if neurologic outcome data was unavailable. The main secondary clinical outcomes were return of spontaneous circulation (ROSC) by EMS, sustained ROSC in field for greater
than 5 minutes, ROSC with palpable pulse on arrival to emergency department, survival to hospital admission, and survival to hospital discharge.

**STATISTICAL ANALYSIS**

Our team used Microsoft Excel (Microsoft Corp., Redmond, WA) to manage the data and SAS JMP (SAS Institute Inc., Cary, NC) for statistical analyses. An a priori power analysis indicated that a sample of $N = 1,294$ would be necessary to detect an odds ratio of 1.5 with 33% of the sample in the mechanical CPR group, an $R^2$ of 0.2, and power = 0.8.

Descriptive statistics were produced, and chi-square (or Fisher’s exact) tests and t-tests were conducted to determine differences between the mechanical and standard CPR groups. Simple risk ratios (RR) were calculated for each survival outcome using the event rates of each group (16). Multivariate logistic regression models were used to adjust for the effects of possible confounds and Utstein variables on survival outcomes (i.e., age, ROSC, shockable rhythm, bystander CPR, presumed cardiac etiology, airway placed, witnessed arrest, public AED utilization, and epinephrine administered) and odds ratios (OR) were calculated. When the incidence of an outcome of interest is less than 10%, the RR closely resembles the OR. Given that the incidence of survival exceeds 10% in some analyses, corrected RRs were also calculated using the method outlined by Zhang and Yu (17). Statistical significance was defined as $p < 0.05$ and 95% confidence intervals were obtained when appropriate.

**RESULTS**

The SAFD attempted resuscitation on a total of 3,469 OHCA cases between January 1, 2013 and December 31, 2015. During this time period, 2,999 of the cases met the inclusion criteria and had sufficient data for analysis. The mechanical CPR device was utilized in 25% (763/2,999) of these prehospital resuscitations. The Utstein chart is displayed in Figure 1.

The mechanical CPR and standard manual CPR groups did not significantly differ in terms of age and sex. Nearly all patients had an airway attempted and were administered epinephrine. Those who only received standard manual CPR had a significantly higher frequency of witnessed arrests and King Airway device™ placements compared to the mechanical CPR group. Conversely, patients who received mechanical CPR had higher rates of bystander CPR and public AED utilization, more frequent endotracheal tube placements, and a higher total dosage of epinephrine administered (Table 1).

Overall, there was no significant difference between the mechanical CPR and standard manual CPR groups in prehospital ROSC, sustained ROSC, or pulse upon arrival to the emergency department. Simple risk ratios indicated that the mechanical CPR group was less likely to survive with a favorable neurological outcome ($p = 0.04$). However, these differences were no longer significant in a logistic regression model adjusting for the effects of age, ROSC, shockable rhythm, bystander CPR, presumed arrest etiology, airway obtained, witnessed arrest, public AED utilization, and epinephrine administered (in milligrams) or in corrected risk ratios (Table 2).

Detailed results of the adjusted logistic regression models reveal that ROSC, shockable rhythm, and witnessed arrest were the strongest predictors of survival to hospital discharge and favorable neurological outcome. Receiving mechanical CPR was not a significant predictor in any of the models (Table 3).

**DISCUSSION**

Improving survival to hospital discharge with a CPC score of 1 or 2 after OHCA is the goal for development of a comprehensive community-based system of cardiac care. The role of mechanical CPR devices in these systems remains to be defined. In this study, results of simple risk ratios demonstrate standard manual CPR has a more favorable neurologic outcome as measured by CPC score at hospital discharge. However, when adjusting for confounding variables by logistic regression, the difference in favorable neurologic outcomes is no longer present.

The standard manual CPR group had higher rates of witnessed arrest, presumably contributing to bet-
ter outcomes (18, 19). Conversely, the mechanical CPR group had higher rates of bystander CPR and public AED usage, also likely conferring an outcome benefit (20, 21). It is unclear how these variables ultimately affected our results. In our study, the strongest predictors of survival with favorable neurological outcome were ROSC, shockable rhythm at EMS arrival, witnessed arrest, and noninvasive airway management placement.

Importantly, our data demonstrates significant management differences between mechanical and standard manual CPR groups. Resuscitation with mechanical CPR had higher rates of endotracheal intubation and epinephrine administration. The differences in these management changes induced by usage of mechanical CPR, and not the mechanical CPR device itself, may have contributed to the poor neurologic outcomes identified with simple risk ratios that disappeared following logistic regression.

Recent studies of mechanical CPR devices report mixed results on the benefit of such devices (22–24). There is an underlying thought that the cognitive off-loading of EMS personnel allows for better clinical decisions, resource utilization, and transport safety (4, 11, 16). Previous studies have discussed EMS providers’ perceptions that they are
able to be more responsive to their patient’s clinical needs and proceed with advanced interventions more rapidly when a mechanical CPR device is utilized (14).

Patients in the mechanical CPR group received significantly more doses of epinephrine. This may have occurred because paramedics had more hands-free time. This finding is consistent with previous articles demonstrating increased use of epinephrine in the setting of a mechanical CPR device (16, 22). In some studies, increasing dosages of epinephrine has been suggested to be associated with poor neurological outcomes (25, 26). Medications administered with mechanical CPR devices might exceed therapeutic thresholds due to the superior blood flow generated, resulting in toxic effects (22). However, in our study total epinephrine dose was not a significant predictor of poor survival outcomes (Table 3).

All patients included in this study were manually ventilated regardless of the use of a mechanical CPR device. Patients in the mechanical CPR group were more likely to be intubated during their out-of-hospital resuscitation. This was also likely a result of the increased hands-free time and available personnel afforded by utilization of the mechanical CPR device. A large Japanese population based study of OHCA reported an association with advanced airway management and unfavorable neurologic outcomes (27). A recent in-hospital cardiac arrest study also demonstrated poor outcomes associated with early intubation (28). Similarly, patients in our study who received an advanced airway were over 60% more likely to survive with a poor neurologic outcome.

Our study further contributes to the growing body of literature suggesting mechanical CPR devices are not associated with positive neurologic outcomes in survivors of OHCA. In addition to Halstrom et al. (22) and Perkins et al. (15), a 2016 study by Youngquist et al. demonstrated poor neurologic survival with prehospital use of predominately load distributing band compression mechanical CPR devices (29). Similar to these prior studies, we were unable to identify a single conclusive cause for the poor neurologic outcomes. The continued use of these devices should be limited until

### Table 2. Comparative occurrence, risk ratios, and odds ratios for mechanical and standard CPR

<table>
<thead>
<tr>
<th>Outcome Covariates</th>
<th>Mechanical CPR n = 763</th>
<th>Standard CPR n = 2,236</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any ROSC</td>
<td>334 (44%)</td>
<td>1,020 (46%)</td>
<td>0.3214</td>
</tr>
<tr>
<td>Sustained ROSC</td>
<td>222 (29%)</td>
<td>692 (31%)</td>
<td>0.6412</td>
</tr>
<tr>
<td>Pulse on ED arrival</td>
<td>257 (34%)</td>
<td>774 (35%)</td>
<td>0.5694</td>
</tr>
<tr>
<td>Survival to hospital admission</td>
<td>210 (28%)</td>
<td>648 (29%)</td>
<td>0.4418</td>
</tr>
<tr>
<td>Simple RR [95% CI]</td>
<td>0.95 [0.83–1.08]</td>
<td>1.05 [0.92–1.20]</td>
<td></td>
</tr>
<tr>
<td>Corrected RR [95% CI]</td>
<td>1.11 [0.59–1.05]</td>
<td>0.93 [0.78,1.10]</td>
<td></td>
</tr>
<tr>
<td>Adjusted OR [95% CI]</td>
<td>1.13 [0.89,1.43]</td>
<td>0.88 [0.70,1.12]</td>
<td></td>
</tr>
<tr>
<td>Survival to hospital discharge</td>
<td>52 (7%)</td>
<td>191 (9%)</td>
<td>0.1312</td>
</tr>
<tr>
<td>Simple RR [95% CI]</td>
<td>0.80 [0.59–1.07]</td>
<td>1.28 [0.93,1.76]</td>
<td></td>
</tr>
<tr>
<td>Corrected RR [95% CI]</td>
<td>0.75 [0.29–1.19]</td>
<td>1.05 [0.75,1.46]</td>
<td></td>
</tr>
<tr>
<td>Adjusted OR [95% CI]</td>
<td>1.02 [0.70–1.49]</td>
<td>0.98 [0.67–1.42]</td>
<td></td>
</tr>
<tr>
<td>Survival with CPC = 1 or 2</td>
<td>29 (4%)</td>
<td>129 (6%)</td>
<td>0.036</td>
</tr>
<tr>
<td>Simple RR [95% CI]</td>
<td>0.66 [0.44–0.98]</td>
<td>1.52 [1.02–2.25]</td>
<td></td>
</tr>
<tr>
<td>Corrected RR [95% CI]</td>
<td>0.59 [0.83–3.23]</td>
<td>1.34 [0.86–2.07]</td>
<td></td>
</tr>
<tr>
<td>Adjusted OR [95% CI]</td>
<td>0.78 [0.48–1.27]</td>
<td>1.28 [0.79–2.08]</td>
<td></td>
</tr>
</tbody>
</table>

Note. ROSC: return of spontaneous circulation; CPC: cerebral performance category; RR: risk ratio; CI: confidence interval; OR: odds ratio. Corrected RRs were obtained using Zhang and Yu’s method (17). Adjusted OR models include age, ROSC, shockable rhythm, bystander CPR, presumed arrest etiology, airway obtained, epinephrine administered (in milligrams), witnessed arrest, and public AED utilization as covariates. Values given are odds ratios [95% CI]. P-values are for chi-square tests. Statistical significance is defined as p < 0.05 or a 95% CI that does not cross 1.

### Table 3. Detailed results of logistic regression model

<table>
<thead>
<tr>
<th>Outcome Covariates</th>
<th>Survival to hospital admission</th>
<th>Survival to hospital discharge</th>
<th>Survival with CPC = 1 or 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.99 [0.98–0.99]</td>
<td>0.99 [0.98–1.00]</td>
<td>0.98 [0.97–0.99]</td>
</tr>
<tr>
<td>Bystander CPR</td>
<td>0.85 [0.68–1.06]</td>
<td>0.93 [0.67–1.30]</td>
<td>0.96 [0.63–1.44]</td>
</tr>
<tr>
<td>Presumed cardiac etiology</td>
<td>1.06 [0.78–1.44]</td>
<td>0.99 [0.62–1.57]</td>
<td>0.97 [0.54–1.75]</td>
</tr>
<tr>
<td>Airway: intubation</td>
<td>0.99 [0.64–1.53]</td>
<td>0.33 [0.21–0.54]</td>
<td>0.37 [0.22–0.63]</td>
</tr>
<tr>
<td>Airway: King LT</td>
<td>0.86 [0.55–1.36]</td>
<td>0.33 [0.19–0.55]</td>
<td>0.36 [0.20–0.66]</td>
</tr>
<tr>
<td>Epinephrine (mg)</td>
<td>0.73 [0.69–0.78]</td>
<td>0.67 [0.61–0.74]</td>
<td>0.63 [0.56–0.72]</td>
</tr>
<tr>
<td>Witnessed arrest</td>
<td>1.54 [1.25–1.89]</td>
<td>2.66 [1.90–3.73]</td>
<td>2.46 [1.61–3.76]</td>
</tr>
<tr>
<td>Public AED utilized</td>
<td>0.83 [0.46–1.48]</td>
<td>1.09 [0.48–2.49]</td>
<td>1.28 [0.49–3.34]</td>
</tr>
<tr>
<td>Mechanical CPR</td>
<td>1.12 [0.88–1.42]</td>
<td>1.02 [0.70–1.49]</td>
<td>0.79 [0.48–1.29]</td>
</tr>
</tbody>
</table>

Note. ROSC: return of spontaneous circulation; CPC: cerebral performance category; AED: automated external defibrillator. Values given are adjusted odds ratios [95% confidence intervals]. Statistical significance is defined as a 95% CI that does not cross 1.
further investigation better defines the optimal medication dosages and airway management when mechanical CPR devices are utilized.

**Limitations**

Our study had several limitations. This was an observational study and was prone to both selection and information bias. The SAFD OHCA protocol left the decision to utilize the mechanical CPR device to the paramedics. Selection was also limited by device availability on responding SAFD ambulances. Data fidelity was not complete in the existing OHCA database for some of the relevant data elements. As a result of the omitted data, 3.6% (125/3,469) of the relevant patient population was not eligible for inclusion. This missing data is a possible source of information bias.

Multiple potential confounders were evident. The down time between the onset of cardiac arrest and the start of the resuscitation was often unknown. The time to application of the mechanical CPR device was not recorded as a data point; however, it is reasonably assumed to have occurred within the first 10 minutes of EMS arrival. An extensive period of manual chest compressions preceding the intervention with mechanical CPR may have had an impact on the results (4, 5), SAFD also does not utilize CPR feedback technology. CPR feedback devices allow the measurement and adjustment of CPR quality at the bedside, which would favor the standard manual CPR group (30).

**Conclusion**

In our study, use of the mechanical CPR device is not associated with an improved neurologic outcome at hospital discharge when compared to manual chest compressions. Resuscitation management during mechanical CPR, specifically medication administration and airway management, may account for the poor neurological outcome reported. Further investigation of resuscitation management when a mechanical CPR device is utilized is necessary to optimize survival benefit.

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**References**


