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Manual vs. Mechanical Chest Compressions in Out-of-Hospital Cardiac Arrest

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Case Study:

A 60-year-old male is cheering on his son at his soccer game. All of a sudden the father collapses and goes into cardiac arrest. A bystander performs CPR while emergency medical services are contacted and a crowd gathers around the child's father. When the ambulance arrives, an automated chest compression device is available for use. Do automated chest compressions improve outcome compared to manual chest compressions in adults that experience out of hospital cardiac arrest?

Abstract:

Objective: The objective was to conduct an analysis of literature that examined whether the use of mechanical vs. manual chest compressions results in outcomes (e.g. quality of CPR, return of spontaneous circulation (ROSC), neurologic outcome, survival) that are significantly increased or decreased in adults that experienced out of hospital cardiac arrest (OHCA). **Methods:** Systematic searches were conducted through the James Madison University Library. The inclusion criteria included human adults that experienced out of hospital cardiac arrest that were treated by Emergency Medical Services (EMS) with and/or without a mechanical chest compression device. **Results:** A statistically significant difference was not found between the manual chest compression study arm and the automated chest compression study arm. **Conclusion:** Because P-values were not statistically significant, when comparing manual to automated chest compressions, the researchers were unable to confidently state recommendations. However, there was moderate clinical significance for improved outcome with manual chest compressions.

Abbreviations used: Automated cardiopulmonary resuscitation (iA-CPR); Emergency medical services (EMS); Manual cardiopulmonary resuscitation (M-CPR) Modified Rankin Score (mRS); Odds ratio (OR) Out of hospital cardiac arrest (OHCA); Return of spontaneous circulation (ROSC); Circulation Improving Resuscitation Care (CIRC); Do not resuscitate (DNR); Load distributing band CPR (LDB-CPR);

Introduction:

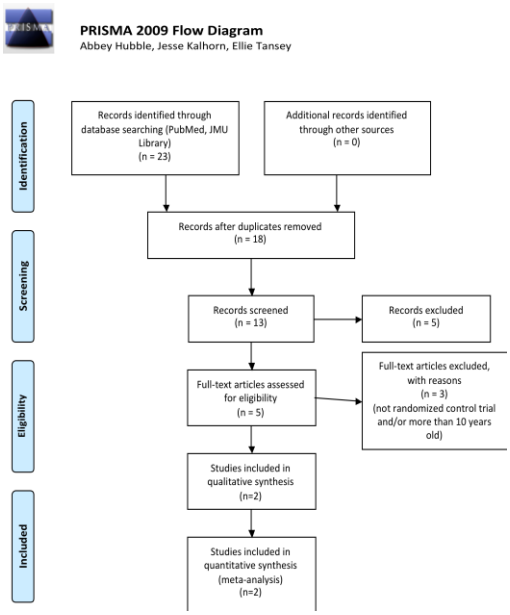
Performing high quality chest compressions consistently during OHCA is very challenging. For this reason, mechanical chest compression devices are now on the rise in OHCA.[1] The data is conflicting in several studies whether or not mechanical chest compression devices improve outcome in adults with OHCA. There is significant variation in OHCA survival rates according to region. Patients who were treated by EMS had a survival range from 3.0% to 16.3%. The survival range increased to 7.7% to 39.9% in patients that presented with ventricular fibrillation.[2]

Several factors account for an increase in survival in OHCA. The American Heart Association, a leader in guidelines for OHCA, made a 'chain of survival' that includes early access (i.e. witnessed cardiac arrest by someone that is able to call for help), early and

effective CPR, early defibrillation, early advanced care (i.e. advanced life support equipped EMS), and post care (i.e. hospital with adequate resources for the post resuscitation patient). Due to the variability of these factors it is hard to determine which factor is the reason for poorer outcomes of OHCA. If any of the links in the chain are missing or delayed then the outcome becomes significantly worse.[3] We aim to analyze and interpret high quality studies to find if there is a significant difference in outcome from mechanical CPR versus manual CPR in order to possibly identify a weak link in the chain of survival.

Methods

A search of "automated vs. manual CPR" through the James Madison University library online database resulted in 23 results with no filters used. Four of the 23 articles were duplicates, leaving 19 original articles. Five more articles were excluded after screening to see if the studies were measuring outcome and if they were out of hospital cardiac arrests. Only randomized control trials that were less than 10 years old were included, therefore in the end, two studies were assessed for this review.



Inclusion criteria included adults with OHCA, studies that were comparing mechanical vs. manual chest compressions, studies that were measuring outcome, randomized control trials, and studies that were less than ten years old. The two studies that were used both had a large sample size (n= 5302 combined), were within the last ten years, measured multiple outcomes, and were randomized control

trials. Only 12 patients, in study #1, had a loss to follow-up and this was because signed consent was unable to be obtained before discharge by the patient or next of kin.

A double blind study was not possible because providers and patients were aware of the treatment assigned. Both studies began by randomizing which location would have manual chest compressions and which would have automated, but once the studies began, they knew which assignments they had been given. The randomization process for who received manual and who received automated compressions was not detailed, however the sites regularly rotated the teams who performed each.

Study 1

Manual vs. integrated automatic load-distributing band CPR with equal survival after out of hospital cardiac arrest.[4]

Study Objective: To determine equivalence, superiority, or inferiority in survival to hospital discharge in OHCA of presumed cardiac origin.

Study Design: This study was a randomized, un-blinded, controlled group sequential trial held from March 5, 2009 to January 11, 2011. Three United States locations, Fox Valley Region, WI, Hillsborough County, FL, and Houston, TX, and two European locations, Vienna, Austria, and the Netherlands were study sites. There were 4231 patients enrolled in the study. Patients who experienced OHCA of presumed cardiac origin initially received manual CPR (M-CPR) and were randomized to either continue receiving M-CPR, or receive automatic load-distributing band CPR (iA-CPR) once the device was ready for use. The M-CPR study group included 2132 patients and iA-CPR study group included 2099 patients. Per 2005 cardiopulmonary resuscitation (CPR) guidelines, EMS providers evaluated patients for respirations, rhythm, and pulse every three minutes.

A maximum sample size of 7390 was pre-defined. The study could be stopped before this maximum sample size was met if the "pre-defined stopping rules" were met, however these pre-defined stopping rules were not provided. It was not stated why the study was stopped when it was.

Inclusion criteria included age ≥18 years of age and OHCA of presumed cardiac origin. Exclusion criteria included patients believed to be pregnant, patients with a do not resuscitate (DNR) order, patients presumed to be too large for the device (greater than 300 pounds or chest circumference greater than 51 inches), prisoner or ward of state, patients who received iA-CPR prior to randomization, or EMS arrival 16 minutes after the emergency call.

There were three phases of the study. The first phase was the "In Field Phase", in which EMS providers used iA-CPR on all OHCA patients in order to gain experience with the device. The second phase was the "Run In Phase", in which eligible patients received randomized treatment. The third phase, the "Inclusion Phase," randomized eligible patients and collected data for statistical analysis.

Most data were obtained through hospital medical records and EMS documentation. Electronic defibrillator records were also evaluated by subjects that were blinded to the patients' outcome, but not to the method of CPR. If data from the electronic defibrillator was unclear, two reviewers evaluated the data and collectively determined results. Data was collected and follow up was continued until patients were discharged from the hospital or died.

Many potential covariates were adjusted for, however disease severity and prior medical history were not included in the list of potential covariates for survival to hospital discharge. Potential covariates included patient age, gender, initial rhythm, witnessed cardiac arrest, bystander CPR, response interval, and site location. Three age categories

were used which included ages 18-59 years, 60-74 years, and 75+ years. Witnessed cardiac arrest was divided into four groups, which included bystander witness, EMS witnessed, not witness, and unknown if witnessed. Response intervals included 0-5 minutes, 6-10 minutes, 11-15 minutes, >15 minutes, and unknown.

Comparisons of the study population by treatment arm included age, gender, location (public vs. non-public), witnessed, bystander CPR, initial rhythm, number of EMS shocks, average time from defibrillator on to first recorded shock, average response interval, first method of prehospital vascular access, prehospital drug administration, hypothermia treatment, percutaneous transluminal coronary intervention, average time from arrival to transport, CPR fraction, average compressions in a minute, and termination in field. Most categories were comparable in both study arms. The authors made mention of the difference in initial rhythm when comparing study arms. In the M-CPR study arm there were 519 (25%) patients with ventricular fibrillation or ventricular tachycardia as their initial rhythm, compared to 451 (21%) patients in the iA-CPR group. Due to the fact that ventricular fibrillation and ventricular tachycardia are rhythms that may be shocked, the authors hypothesized that this may have resulted in better outcome in the M-CPR group. Another category that was noticeably different when comparing study arms was the average compressions in a minute (average of the first 10 minutes). M-CPR group received an average of 89.2 compressions per minute, while the iA-CPR group received an average of 66.3 compressions per minute. This may be due to interruptions in CPR while switching from M-CPR to iA-CPR.

Study Results: There were several outcomes measured in this study. The primary outcome of the study was survival to hospital discharge. This outcome was measured for all but 12 of the 4231 patients enrolled, which was largely due to inability to obtain patient

consent to be included in the study. Survival to hospital discharge in the M-CPR study arm was 233(11%) compared to 196(9.4%) in the iA-CPR study arm. Covariates adjusted odds ratio (OR) for iA-CPR compared to M-CPR was 0.89. Covariates and interim analysis adjusted OR was 1.06. Authors concluded that results show no statistically significant difference in survival to hospital discharge in M-CPR compared to iA-CPR. Although authors did not find statistical significance in outcome, it may be argued that there was a clinically significant difference in outcomes because when you compare raw data, without considering statistical significance, there were better outcomes for patients who received manual chest compressions.

Secondary outcomes measured included sustained return to spontaneous circulation (ROSC), survival to 24 hours, and modified Rankin Scale (mRS). Sustained ROSC was defined as hospital admittance with perfusing blood pressure. Of the M-CPR study arm, 689(32.2%) of patients were determined to have sustained ROSC compared with 600(28.6%) of patients in the iA-CPR study arm. Covariate adjusted OR for sustained ROSC was 0.84. Survival to 24 hours was measured at 532(25%) for patients of the M-CPR study arm compared to 456(21.8%) patients of the iA-CPR study arm with covariate adjusted OR of 0.86. Modified Rankin Score (mRS) data was used to evaluate neurologic outcome. The range of mRS is 0-5 with a score ≤3 indicating a good neurologic outcome. At discharge, mRS of 0-3 was determined in 112(48.1%) patients of the M-CPR study arm compared to 87(44.4%) patients of the iA-CPR study arm with a covariate adjusted OR of 0.80. An mRS score of 4-5 was determined in 60(25.8%) of patients in the M-CPR study arm compared to 59(30.1%) of patients in the iA-CPR study arm. There was no adjusted OR given for mRS. The authors determined the differences of mRS in study arms to not be statistically significant. A summary of outcomes in both study arms can be seen in **Table 1**.

Table 1.
Outcome by treatment arm.

Outcome	M-CPR (*n*=2132)	iA-CPR (*n*=2099)	Covariates Adjusted OR (95% CI)	Covariate & interim analyses adjusted OR (95% CI)
Survival to Hospital Discharge	233 (11%)	196 (9.4%)	0.89 (0.72-1.10)	1.06 (0.83-1.37)
Survival to 24 hours	532 (25%)	456 (21.8%)	0.68 (0.74-0.998)	
Sustained ROSC	689(32.3%)	600 (28.6%)	0.84 (0.73-0.96)	
Discharge mRS Score	*n*=233	*n*=196		
Score of 0-3	112 (48.1)	87 (44.4%)	0.80 (0.47-1.37)	
Score of 4-5	61 (26.2%)	50 (25.5%)		
Unknown score	60 (25.8%)	59 (30.1%)		

Injuries sustained by patients during the trial were compared in both study arms as well [**Table 2**]. Of the types of injuries evaluated, rib fractures and subcutaneous edema were notably higher in the iA-CPR study arm. Of the patients in the M-CPR group, 31 patients sustained rib fractures compared with 69 patients in the iA-CPR group. Subcutaneous emphysema was seen in 6 patients in the M-CPR group compared with 21 patients in the iA-CPR group. Although subcutaneous emphysema and rib fracture rates were higher in the iA-CPR group, the overall percentage of patients who sustained injury during the trial was comparable in both groups with 225 or 11% of patients reporting injuries in the M-CPR group and 242 or 12% of patients in the iA-CPR group (OR 1.10, 95% CI 0.91–1.34, p = 0.31). Although not mentioned in the article, total number of injuries in each group was calculated. This showed that the M-CPR group had a total of 243 (11.4%) injuries reported, while the iA-CPR group had a total of 290 (13.8%) injuries reported.

Table 2.
Differences in injury by treatment arm.

Injury	M-CPR (*n*=2132)	iA-CPR (*n*=2099)
Pneumothorax	20	33
Pulmonary Edema	176	159
Rib Fractures	31	69
Spine Fracture	2	4
Sternum Fracture	4	1
Subcutaneous Emphysema	6	21

Study Critique: The sample size of this study was large with 4231 patients used in the final analysis. Assignment of patients to treatment was randomized with the use of concealed envelopes that were drawn by EMS providers, however once treatment was started, it was impossible to blind either medical providers or patients to the treatment that they received.

All patients were accounted for at the end of the study. Reasons for exclusion before and after randomization were included. Additionally, the number of patients excluded for each specific reason was listed. Only 310 of 429 patients who made it to hospital discharge (iA-CPR arm 70%, M-CPR arm 74%) were evaluated for mRS scores. It was noted that this was largely due to discharge before consent was obtained.

A variety of study sites and EMS system types were used which may increase external validity of the study. That being said, there was little information provided on specific details of EMS system types or study sites used (e.g. rural or urban areas). There was also no information provided about the healthcare facilities used and their capabilities of caring for post cardiac arrest patients. This made it difficult to standardize the post resuscitation and hospital care. Although covariates were adjusted for each of the study sites listed, it was not mentioned anywhere in the article how many participants were from each of the five locations.

The list of covariates that were adjusted for was extensive, however there were no categories for disease severity or past medical history. Although difficult to define in some cases, disease severity may have a significant impact on survival to hospital discharge as well as neurologic outcome. Cause of death was also not mentioned.

CPR quality was measured electronically and with the use of CPR fraction (the percentage of time in which chest compressions are done by rescuers during a cardiac arrest), but depth of chest compressions was not measured. Still, this information was helpful in determining if the treatments were comparable. The average number of chest

compressions per minute in the first 10 minutes for each group was provided. There was a noticeable decrease in average chest compression per minute in the iA-CPR group, which may be due to the time taken to put the automated device on the patient. The authors did not address this difference in average compression per minute or the average time needed to correctly attach the device to the patient.

Outcomes measured included sustained ROSC, survival to 24 hours, survival to hospital discharge, neurologic outcomes measured with mRS scores, and injuries sustained during trial. This allowed us to get an idea of the overall condition of the patient. Although these outcomes were useful in determining the immediate outcomes of patients in both study arms, patients were not followed after hospital discharge. This information would be helpful in determining long-term outcomes and potential complications from injuries sustained during the trial. This is important to note because of the noticeable increase in rate of injuries in the iA-CPR arm.

The results of the study showed a numeric decrease in sustained ROSC, 24-hour survival, survival to hospital discharge, and neurologic outcomes in the iA-CPR group. The authors acknowledged these numeric differences, but they were not statistically significant. When dealing with morbidity and mortality, it is important to also evaluate clinical significance. Using the covariates adjusted OR for survival to hospital discharge the number needed to treat (NNT) was calculated at 63. This means that 63 participants would need to be treated with manual CPR only to prevent one additional death before hospital discharge.

It was mentioned briefly that there were 12 cases of serious and unexpected adverse events that did not occur equally in both study arms. It was not mentioned how many of these adverse events occurred in each arm or what the nature of these adverse

events were. The authors concluded that there were no new risks or safety concern for trial participants, but did not state specifics on how they came to this conclusion.

This study used odds ratios with 95% confidence intervals to analyze data. Authors stated that one-sided P-values for testing non-inferiority of each intervention were calculated, however these values were not listed anywhere in the paper. Three separate papers were referenced for more information of the statistical analysis and P-values calculated, but specific P-values calculated for this study were not found.

All odds ratios were adjusted for covariates. Survival to hospital discharge odds ratio was adjusted again for covariates and interim analysis. The authors stated that this was necessary because the iA-CPR group had reached a low point compared to the M-CPR group at the time the study was stopped. It was stated that, "not performing the adjustment would be like letting the winning sports team decide when to stop the game". This adjustment changed the OR from a negative effect for iA-CPR (OR 0.89), to a small positive effect for iA-CPR (OR 1.06) after the adjustment was made. The specifics on how this adjustment was made were not further discussed.

Lastly, it is important to address the funding for this study. The study was funded by ZOLL Medical, which is the manufacturer and seller of the of the automated load distributing band device, known as AutoPulse®. Additionally, all authors' institutions received funding for their participation in the trial from ZOLL Medical. This was clearly stated by the authors; however, it is still a major concern for potential bias.

Study 2

Manual Chest Compression vs. Use of an Automated Chest Compression Device During Resuscitation Following Out-of-Hospital Cardiac Arrest A Randomized Trial [5]

Objective: This study compares three endpoints pertaining to mortality and morbidity of cardiac arrest with the use of manual chest compressions vs. automated chest

compressions. The primary endpoint of this study was survival to 4 hours after the 911 call. Secondary endpoints were survival to hospital discharge and neurological status among survivors.

Study Design: This study adhered to "emergency exception from informed consent," which requires the authors to inform the community of the proposed trial and seek out their views and agreement, since direct consent cannot be obtained immediately. It is required that the community also be informed of the final results. This study assembled a neutral safety and data supervising board which consisted of a paramedic, an EMS physician, a biostatistician, and a clinical investigator. The location of this study was in Calgary, Alberta; Columbus, Ohio; suburbs of Pittsburgh, Pa; Seattle, Wash; and Vancouver, British Columbia and ran from late July to mid November 2004. Within each site there were two "clusters" created. The two clusters were randomized to the control (manual CPR) and half to the intervention (load distributing band CPR (LDB-CPR)) with successive alternation between the control and the intervention.

It was hypothesized that 4-hour survival would be greater among patients randomized to LDB-CPR compared with those to manual CPR. Secondary outcomes were survival to hospital discharge and neurological function at hospital discharge. 1377 cases were initially included in the study but only 373 in the manual CPR group and 394 in the LDB-CPR group were eligible for study enrollment and thus considered the "primary population," the remaining cases were considered "non-primary" or were excluded entirely. There were 304 "non-primary" cases that included those who had non-cardiac origin, cardiac arrest after EMS arrival, and Advanced Life Support >90s before the ambulance arrived.

The study's inclusion criteria assimilated adults with out-of-hospital cardiac arrest that received resuscitation efforts by an identified EMS agency. Cardiac etiology was determined by the site "study coordinator" or an "investigator" based on hospital records and EMS forms. The background of the coordinator or investigator was not identified. Patients included in this study were deemed to have a cardiac origin to their arrest. Patients were excluded if they were under 18, prisoners of wards of the state, if they had a DNR order, if they were dead on arrival (signs incompatible with life), if it was a trauma scene or if they had recent surgery.

Table 3.

COHORT	CASES EXCLUDED
Manual	(3) Prisoner or Ward of State
n=156	(20) Do Not Resuscitate Order
	(40) Dead on Arrival With CPR Only
	(51) Trauma
	(1) Recent Surgery
	(25) No Study Vehicle or Personnel
Automated Cohort	(30) Aged 18 yo
n=150	(5) Prisoner or Ward of State
	(20) Do Not Resuscitate Order
	(40) Dead on Arrival With CPR Only
	(48) Trauma
	(2) Recent Surgery
	(27) No Study Vehicle or Personnel

Study Results: Study 2 concluded that a difference did not exist in the primary endpoint of survival to 4 hours between the manual CPR and LDB-CPR overall (primary and non-primary) (N = 1071; 29.5% vs. 28.5%; ***P* = .74**) or among the primary population (n = 767; 24.7% vs. 26.4%, respectively; ***P* = .62**).

There was a difference however, when considering different, non-primary, end points. Survival to hospital discharge was 9.9% in the manual CPR group and 5.8% in the LDB-CPR group (***P*=.06**, adjusted for covariates and clustering). Additionally, a cerebral performance category (CPC) of 1 or 2 at hospital discharge was recorded in 7.5% of patients in the manual CPR group and in 3.1% of the LDB-CPR group (***P*=.006**).

Survival to hospital discharge was lower in the LDB-CPR group among *primary* episodes (5.8% vs. 9.9% [***P* = .04**]; adjusted for covariates and clustering, ***P* = .06**), but similar among the non-primary cases (10.6% vs. 11.9%; ***P*=.72**). [**Table 4**]. This was not considered statistically significant, because once covariates were adjusted for the P-value exceeded .05. The survival rate among the LDB-CPR device cohort had some variability according to the initial rhythm (ventricular fibrillation, pulseless electrical activity, or asystole) but it was not statistically significant (***P* = .37**). [**Table 4**]

Table 4.

OUTCOME	**% of Manual Patients**	**% of LDB-CPR Patients**	**P-value**
Survival to 4 hours (overall)	29.50%	28.50%	0.72
Survival to 4 hours (primary)	24.70%	26.40%	0.62
Survival to discharge (primary)	9.90%	5.80%	**0.06** (adjusted covariates and clustering)
Survival to discharge (non primary)	10.60%	11.90%	0.72
CPC of 1 or 2	7.50%	3.10%	**0.006**
4 hour survival after asystole	10.40%	17.40%	0.72
Hospital discharge after asystole	0.60%	1.70%	0.37

Risk factors for typical unsuccessful resuscitation (older age, unwitnessed collapse, longer response time, nonpublic location, and initial rhythm of asystole or pulseless electrical activity) are listed in **Table 5** using a logistic regression analysis and odds ratios. This analysis is used to compare multiple independent variables that affect an outcome. The ORs higher than 1 indicate a greater chance of survival, and below 1, indicate the opposite. For example, the odds of survival decrease by 0.98 for each year of age, and the odds of survival decrease by 0.36 if found in PEA versus VF. The P-values for these comparisons are all statistically significant.

Table 5: Logistic Regression of Survival to Hospital Discharge		

	Univariable OR (95% CI)	P-value	Multivariable OR (95% CI)	P-value
Age per y	0.97	0.002	0.98	0.01
PEA to VF	0.28	0.001	0.36	0.001
Asystole to VF	0.05	0.001	0.09	0.001
Witnessed	5.3	0.001	2.4	0.02
Site C	3.7	0.001	3.7	0.001
Response time of first vehicle	0.72	0.001	0.7	0.001
Public location	4	0.001	1.8	0.06
LDB-CPR treatment group	0.57	0.045	0.56	0.06

† **Odds Ratio** (OR) measures the "odds" that a particular outcome will happen when considering a particular exposure, versus the odds of it happening without that exposure.

After the study, researchers identified that survival was pointedly higher at site C, and this also rang true in this study. However, the association between survival and treatment group did not fluctuate within site C (***P* = .12**). It was noted that the EMS personnel at site C had better protocol adherence and administered automated LBD-CPR quicker than other sites.

It was also concluded that patients in the LDB- CPR cohort were more likely to receive epinephrine (***P* = .03**) as well as experience longer time intervals to the first shock (***P* = .001**), termination of resuscitative effort (***P* = .01**), and hospital transport (***P* = .01**).

Overall, an analysis of multiple variables, it was concluded that as response time shortened, patients in the manual CPR group were more likely to survive to hospital discharge compared to patients in the LDB-CPR group (interaction ***P* = .06**). The analysis also revealed that at 6.6 minutes of response time the treatment groups would have equal rates of survival.

Study Critique: The *primary* end point identified in Study 2 was "survival with spontaneous circulation 4 hours after the 911 call." The rationale for which this endpoint was decided upon was favorable because it evades the inescapable variations of site-to-site differences when trying to define "admittance to the hospital."[5] The study did not evaluate

the design of the LDB-CPR device and stated that, “device design or implementation strategies require further evaluation.” This further evaluation was not expounded upon or able to be located.

Research data was collected from EMS reports, defibrillator recordings, study questionnaires as well as hospital records. The defibrillator digital electrocardiographic recording or electrocardiographic paper strips were initially interpreted by study personnel. Additionally, the electrocardiographic records were reviewed by an arrhythmia research nurse. If those two reports were conflicting, the authors were assigned to read the initial rhythm. While this method was very thorough, the study did not specify the authors’ qualifications or ability to interpret rhythm strips.

Analyses were conducted using SPSS version 12.0 (SPSS, Chicago, Ill) and R version 2.3 (R Foundation for Statistical Computing) statistical software. When evaluating the cluster sizes, there were a total of 51, and the average number of episodes per cluster per rotation interval ranged from 1.8 to 25; a large range. The number of patient episodes at sites also varied quite a bit, from 120 to 391. This study made assessments using intention-to-treat, which may have affected the accuracy of results. Intention-to-treat overlooks noncompliance, protocol deviations, withdrawal, and anything that happens after randomization, so these factors need to always be taken into account when considering research that utilizes intention-to-treat. The specific factors left out as a result of intention-to-treat were not mentioned by the authors.

Upon critique of an additional examination of initial rhythm of asystole, ventricular fibrillation/ventricular tachycardia or pulseless electrical activity, it was found that in 6.1% (47/767) of participants, there was no electrocardiographic rhythm and the automated external defibrillator did not advise to shock (asystole or pulseless electrical activity was assumed). As a result, 3 of those 47 cases were assigned the rhythm witnessed at the

following EKG analysis. In the remaining 44 cases, the initial rhythm was assigned using factors that "discriminated significantly between patients with initial rhythm of pulseless electrical activity and asystole," however, these factors were not listed.

When evaluating the study's statistical analysis, it was found that unless overtly stated, *P*-values were unadjusted for covariates and clustering, making the P-values less accurate. For the primary and secondary endpoints, P- values were "generally adjusted," which is not explicit. The researchers used this term again when they stated that, "demographic features, cardiac arrest circumstances, and treatment characteristics were 'generally' similar between the treatment groups," which does not give the reader specific information. Overall, the study could not draw many impactful conclusions because of the lack of statistically significant values.

After the study there was more data collected. This data included chest compression duration in the first 5 minutes of the resuscitation, drugs administered prior to the patient arriving at the hospital, mode of in-hospital death, and other details indicating lung, heart, or cerebral damage. This information was considered helpful in further examining the study's outcomes. The study had to be terminated by the safety and monitoring board after the first round, and it is assumed the reason is because they were finding that manual chest compressions had a better outcome, however this is not explicitly stated.

Comparison of Studies: Both studies used in this review were randomized control trials with large sample sizes. Study #1 was slightly larger with 4231 participants whereas study 2 had 767 participants in the final analysis. According to the American Heart Association, out of hospital cardiac arrest survival rate in the US is 10.6% and survival with good neurologic outcome is even lower at 8.3%.[4] This high mortality rate means that a large

sample size is needed to accurately evaluate the superiority or inferiority of different methods of CPR.

The inclusion and exclusion criteria for both studies were very similar. Both studies used adults 18 years and older with OHCA. Study #1 also included OHCA of presumed cardiac origin in the inclusion criteria. Study #1 excluded participants due to weight and waist circumference, whereas study #2 did not. Study #1 also excluded cases where EMS arrived 16 minutes after the emergency call. This may have lead to an overall increase in survival rates of both arm in study #1, as timely initiation of CPR plays a significant role in survival of OHCA.

Study #1 used five different locations in the US and Europe. Study #2 used US and Canadian sites. Both studies gave minimal information about study sites, EMS types, and hospitals used. This information would have been useful in determining if post cardiac arrest treatment was comparable. A positive aspect of using these different sites and quality of care is an increased external validity of both studies.

There was some overlap in the outcomes measured in both studies, which made it easier to compare results. Both studies measured neurologic outcome and survival to hospital discharge. Study #1 also measured sustained ROSC, injuries sustained during the trial, and 24-hour survival, while study #2 measured 4-hour survival. Both studies only followed patients to hospital discharge. Study outcomes are summarized in **Table 6**.

Study #2 used P-values that were unadjusted for covariates and clusters. Study #1 used odds ratios with 95% confidence intervals that were adjusted for covariates and then again for interim analysis, although how these adjustments were made was not mentioned. Study #1 stated that P-values were calculated; however, these values were not found.

Study #1 concluded that there were trends towards but not statistically significant differences in mechanical and manual CPR. Differences in gross values showed worse neurologic outcomes, sustained ROSC, 24-hour survival, and survival to discharge in the mechanical CPR study arm of Study #1. Study #2 showed better outcomes in 4-hour survival in the mechanical CPR group, but worse neurologic and survival to hospital discharge outcomes. Study #1 concluded that mechanical and manual CPR were equivalent, whereas Study #2 concluded that manual CPR was superior.

Table 6.

Comparison of Studies

	Study 1	**Study 2**
Study Type	Randomized Control Trial	Randomized Control Trial
Sample Size	M- CPR(*n*=2132) iA-CPR(*n*=2099) Total(*n*=4231)	M-CPR(*n*=362) iA-CPR(*n*=405) Total(*n*=767)
Inclusion Criteria	≥18 years of age with OHCA of presumed cardiac origin	≥18 years of age with OHCA
Exclusion Criteria	Pregnancy, DNR order, presumed too large for the device (greater than 300 pounds or chest circumference greater than 51 inches), prisoner or ward of state, received mechanical chest compressions prior to randomization, and EMS arrival 16 minutes after the emergency call.	<18 years old, prisoners of wards of the state, DNR order, dead on arrival, trauma scene, and recent surgery
	OUTCOME	
	Sustained ROSC	
M-CPR	689(32.3%)	_
iA-CPR	600 (28.6%)	_
	4 Hour Survival	
M-CPR	_	189(24.7%)
iA-CPR	_	202(26.4%)
	24 Hour Survival	
M-CPR	532 (25%)	_
iA-CPR	456 (21.8%)	_
	Survival to Hospital Discharge	
M-CPR	233 (11%)	76(9.9%)
iA-CPR	196 (9.4%)	44(5.8%)
	Favorable Neurologic Outcome	
M-CPR	112 (5.3%)	57(7.5%)
iA-CPR	87 (4.1%)	24 (3.1%)
Conclusion	There is a numeric difference showing worse sustained ROSC, 24 hour survival, survival to discharge, and neurologic outcomes in the iA-CPR group, but authors deny a statistically significant difference	Use of automated LBD-CPR devices showed worse survival to hospital discharge and neurologic outcomes.
Study Critique	P-values were not included in this study. This study was funded by ZOLL, the manufacturer of AutoPulse®. Participating institutions were also paid by ZOLL.	

Discussion

According to Study #1 and Study #2 manual CPR results in better outcomes than mechanical CPR, however when considering statistical significance and P-values, we cannot definitively state recommendations.

When evaluating OHCA there are so many different variables and preexisting conditions and in these studies, the severity of patient's conditions were not evaluated or accounted for. This is a main point of contention and the variability between patients could definitely contribute to differences or inconsistencies within results. There is also a lot of variability between manual chest compressions that is nearly impossible to account for and evaluate.

Another variable to consider is the amount of time that elapsed before EMS personnel arrived on scene and whether the cardiac arrest was witnessed or not. Covariates were adjusted for in both studies, such as use of medications during the call, initial rhythm, gender, age, bystander CPR and time to intervention.

Study #1 was funded by Zoll the company who manufactures AutoPulse®. This funding may have resulted in bias, however the outcome of the study was not in favor of the use of AutoPulse®. One variable to consider is that putting the automated device on can cause delayed compressions. Often due to human error, this can take longer than anticipated.

Mechanical compressions are deemed to be more consistent than manual compressions but have trouble getting over 100 compressions per minute, which is the recommended rate. This defect in the device should be investigated by the company of manufacture. Also, quality of CPR declines the moment a patient is moved toward the ambulance or transported to the hospital due to the logistics of doing chest compressions while in a moving vehicle as well as the narrow space provided in the ambulance.

Mechanical CPR makes the OHCA call go much smoother because it gives the provider more time to think about the patient as opposed to worrying about whether manual CPR is being provided with high quality chest compressions at a rate over 100 compressions per minute.

Considering injury to patients from the mechanical device and also back injuries to the manual CPR deliverer could also be of value. Back injuries are the number one injury leading to EMS providers quitting their career early. In terms of real world current practices, the number one and number two EMS agencies with the best ROSC rates in OHCA use mechanical CPR devices. Despite these real world practices, both studies had similar outcomes in terms of automated chest compressions.

Conclusion

According to Study #1 and Study #2 manual CPR results in better survival to discharge and neurologic outcomes than mechanical CPR, however when considering statistical significance, we cannot definitively state recommendations. Gaps in knowledge among these studies are the various pre-existing conditions and standardization of post-cardiac resuscitation care. Pre-existing conditions drastically impact outcomes of OHCA resuscitation and in these studies the severity of patient's conditions were not evaluated or accounted for. Another gap in knowledge is considering the injuries to patients from the devices and to the providers as a result of manual chest compressions. In Study 1, the rate of subcutaneous edema and rib fractures were significantly higher in the iA-CPR group, however it was difficult to determine the source of these injuries because all patients initially received manual chest compressions before randomization.

Research and development of the AutoPulse® and other load distributing band devices may also influence future clinical practices. The time taken to attach the device to the patient was not addressed in either study, making it difficult to determine the amount of time without adequate chest compressions while patients were fitted with the device. Although this information was not provided, Study #1 did show a lower average number of chest compressions per minute in the iA-CPR group, which was likely due to interruptions in compressions during device fitting. Improvements in device design to eliminate user error, increase the speed of compressions, and eliminate use of batteries may result in less interruptions in CPR and therefore better outcomes.

Interestingly, in 2006 the Richmond Ambulance Authority found that compared with resuscitation using manual CPR, a resuscitation strategy using automated CPR on EMS ambulances is associated with improved survival to hospital discharge in adults with out-of-

hospital non-traumatic cardiac arrest.[5] The outcomes for these patients improved even more when they teamed up with the Virginia Commonwealth University Medical Center to make a new initiative known as the Advanced Resuscitation Cooling Therapeutics and Intensive Care Center, or ARCTIC. This new strategy of treating OHCA with presenting rhythms of ventricular fibrillation or ventricular tachycardia along with the implementation of the Autopulse® resulted in an almost two-fold improvement in ROSC from 25% in 2001 (manual CPR without the ARCTIC protocol) to 46% in 2008 (Autopulse® with ARCTIC protocol). In turn, the survival rate to hospital discharge improved from 9.7% in 2003 to 17.9% at the end of 2008.[6] The national average is 10.6%.[4] This shows that mechanical CPR devices when used in conjunction with a progressive and high performing EMS agency can show significant improvement in outcomes of OHCA.

In 2015 the Richmond Ambulance Authority won the National Association of Emergency Medical Technicians' and EMS World's Dick Ferneau Career EMS Agency of the Year Award. These are the most prestigious awards a EMS agency can win and is for outstanding achievements and contributions in emergency healthcare.[7]

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