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ORIGINAL RESEARCH

Mechanical, Team-Focused, Video-Reviewed Cardiopulmonary Resuscitation Improves Return of Spontaneous Circulation After Emergency Department Implementation

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BACKGROUND: Outcomes in cardiac arrest remain suboptimal. Mechanical cardiopulmonary resuscitation (CPR) has not demonstrated clear clinical benefit; however, video review provides the capability to monitor CPR quality and provide constructive feedback to individuals and teams to improve their performance. The aim of our study was to evaluate cardiac arrest outcomes before and after initiation of a mechanical, team-focused, video-reviewed CPR intervention.

METHODS AND RESULTS: In 2018, our emergency department began using mechanical CPR; a new team-focused strategy with nurse-led Advanced Cardiovascular Life Support; and biweekly, multidisciplinary video review of cardiac arrests. A revised approach to resuscitation was generated from a performance improvement session, and in situ simulation was used to disseminate our approach. The primary outcome of this study was the return of spontaneous circulation rate before and after our mechanical, team-focused, video-reviewed CPR intervention. Secondary outcomes included survival to admission and discharge. Multivariable logistic regression modeling was used. The pre- and postintervention groups were similar at baseline. A total of 248 patients were included in our study (97 before and 151 after mechanical, team-focused, video-reviewed CPR). Return of spontaneous circulation was higher in the intervention group (41% versus 26%; P=0.014). There were nonsignificant increases in survival to admission (26% versus 20%; P=0.257) and survival to discharge (7% versus 3%; P=0.163). After controlling for covariates, the odds of return of spontaneous circulation remained higher after the intervention (odds ratio, 2.11; 95% CI, 1.14–3.89).

CONCLUSIONS: Implementation of our mechanical, team-focused, video-reviewed CPR intervention for cardiac arrest patients in our emergency department improved return of spontaneous circulation rates. Survival to hospital admission and discharge did not improve.

Key Words: cardiac arrest ■ cardiopulmonary resuscitation ■ emergency department ■ high performance ■ mechanical chest compressions ■ quality improvement ■ team-based care

Survival from cardiac arrest remains suboptimal, despite recent improvements in public health measures, resuscitation science research, and technological advances. In 2016, out-of-hospital cardiac arrest (OHCA) survival remained low at 12%.[1] A 2018 scientific statement by the American Heart Association suggests that enhanced resuscitation education has the potential to improve patient outcomes as much as any new scientific breakthroughs in the field.[2] Additionally, several studies have demonstrated that monitoring the quality of cardiopulmonary resuscitation (CPR) is associated with improved cardiac arrest outcomes.[3–5]

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CLINICAL PERSPECTIVE

What Is New?

- In a large, tertiary care emergency department, a three-component intervention to improve quality of cardiac arrest resuscitation including mechanical cardiopulmonary resuscitation, team-focused training, and video review feedback improved return of spontaneous circulation.
- This study was unique in its use of video review to monitor the quality of cardiac arrest resuscitation, to provide feedback to improve mechanical chest compression device placement, to modify the roles of cardiac arrest team members with specific defined tasks, and to identify recurrent opportunities for improvement in the care of patients with cardiac arrest.

What Are the Clinical Implications?

- Emergency departments interested in improving cardiac arrest resuscitation should consider implementation of a mechanical, team-focused, video-reviewed cardiopulmonary resuscitation program.
- This study, demonstrating an improvement in a resuscitation outcome with the use of video review, may make it easier for hospitals to obtain approval for video review quality improvement programs in the future.

Nonstandard Abbreviations and Acronyms

MTV-CPR	mechanical, team-focused, video-reviewed cardiopulmonary resuscitation
MCCD	mechanical chest compression device
OHCA	out-of-hospital cardiac arrest
IHCA	In-hospital cardiac arrest
ECMO	extracorporeal membrane oxygenation
E-CPR	extracorporeal cardiopulmonary resuscitation
LUCAS	Lund University Cardiopulmonary Assist System
EMS	emergency medical services
BVM	bag-valve-mask
ETCO2	end-tidal carbon dioxide
CVC	central venous catheter

Recent research on team-focused, or high performance, CPR has shown improvements in neurologically intact survival in a prehospital setting, revealing the importance of teamwork, education, and quality improvement programs on cardiac arrest outcomes.[6,7] Video review of cardiac arrest resuscitation provides a unique opportunity to both monitor the quality of the resuscitation and provide feedback and education to individuals and teams to improve the quality of cardiac arrest resuscitation. Previous video review research in the trauma setting has demonstrated improved team functioning, compliance with Advanced Trauma Life Support guidelines, and time to definitive care.[8,9]

Manual CPR has been found to be difficult both in and out of the hospital.[10,11] Mechanical CPR with a mechanical chest compression device (MCCD) rather than manual CPR should improve the quality of CPR that is delivered by ensuring adequate chest compression depth and rate. In addition, it provides the ability to transport patients safely in an ambulance and for safe defibrillation with ongoing chest compressions. Despite these potential benefits, large randomized controlled trials using mechanical CPR in the prehospital setting have failed to demonstrate a survival benefit.[12,13] Further, the AutoPulse Assisted Prehospital International Resuscitation (ASPIRE)[14] randomized controlled trial, observational studies,[15,16] and a Cochrane meta-analysis suggest that outcomes may be worse with mechanical CPR, compared with manual CPR.[17] One system where mechanical CPR appears to be producing benefit is the Minnesota Resuscitation Consortium's use of an MCCD as a bridge from the prehospital setting directly to the cardiac catheterization suite for extracorporeal membrane oxygenation (ECMO), or extracorporeal CPR (E-CPR), in refractory ventricular fibrillation and ventricular tachycardia OHCA.[18]

In our hospital emergency department (ED), we implemented a mechanical, team-focused, and video-reviewed CPR (MTV-CPR) intervention to improve cardiac arrest resuscitation. We performed a pre- and postinterventional study to determine if MTV-CPR improved return of spontaneous circulation (ROSC) and assess other process and outcome measures important in the care of cardiac arrest patients.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Design

The study is a pre-post analysis of a pilot program of our ED's cardiac arrest resuscitation strategy using MTV-CPR. The preintervention period was from January 1, 2017, to December 31, 2017; the post-intervention period was from January 1, 2018, to July 31, 2019. The conduct of this study was approved by our health system's Institutional Review Board with exempt status.

Setting and Patient Population

Our MTV-CPR intervention was implemented at a large, academic, tertiary care hospital with nearly 90 000 ED visits annually. Patients ≥18 years of age, with any ED diagnosis or chief complaint of cardiac arrest, ventricular fibrillation, pulseless electrical activity, or asystole since January 2017 were identified, and retrospective chart reviews on these patients were performed by trained abstractors (G.H., V.B., J.W.) who were blinded to the outcomes of this study. Data were directly entered into a Research Electronic Data Capture database; the database was maintained in Utstein style. Beginning in January 2018, the resuscitation process of cardiac arrest patients was video recorded, and a page operator notified our team members of patients with cardiac arrest through a mobile application notification, text message, phone call, and email (Everbridge, Burlington, MA). Video reviews are performed with a multidisciplinary team described below, but all video review data are confirmed by one physician (D.R.). We included patients who had mechanical CPR initiated prehospital. We excluded patients who had traumatic cardiac arrest. Additionally, we excluded patients who had sustained ROSC with emergency medical services (EMS) before ED arrival and did not rearrest prehospital or after their ED arrival because these patients would not receive the MTV-CPR intervention. Finally, we excluded patients who received E-CPR directly from the ED because ECMO was the likely cause of their ROSC and survival to admission rather than the MTV-CPR intervention (Figure 1).

Intervention

Our MTV-CPR intervention consisted of 3 major components.

1. Mechanical CPR
   Training on the LUCAS 3® (Stryker Medical, Portage, MI) was completed in November 2017. On January 1, 2018, we began using mechanical CPR for all cardiac arrests. Quarterly MCCD training sessions for our ED staff were led by a product specialist from the manufacturer, Stryker. Additional individual feedback

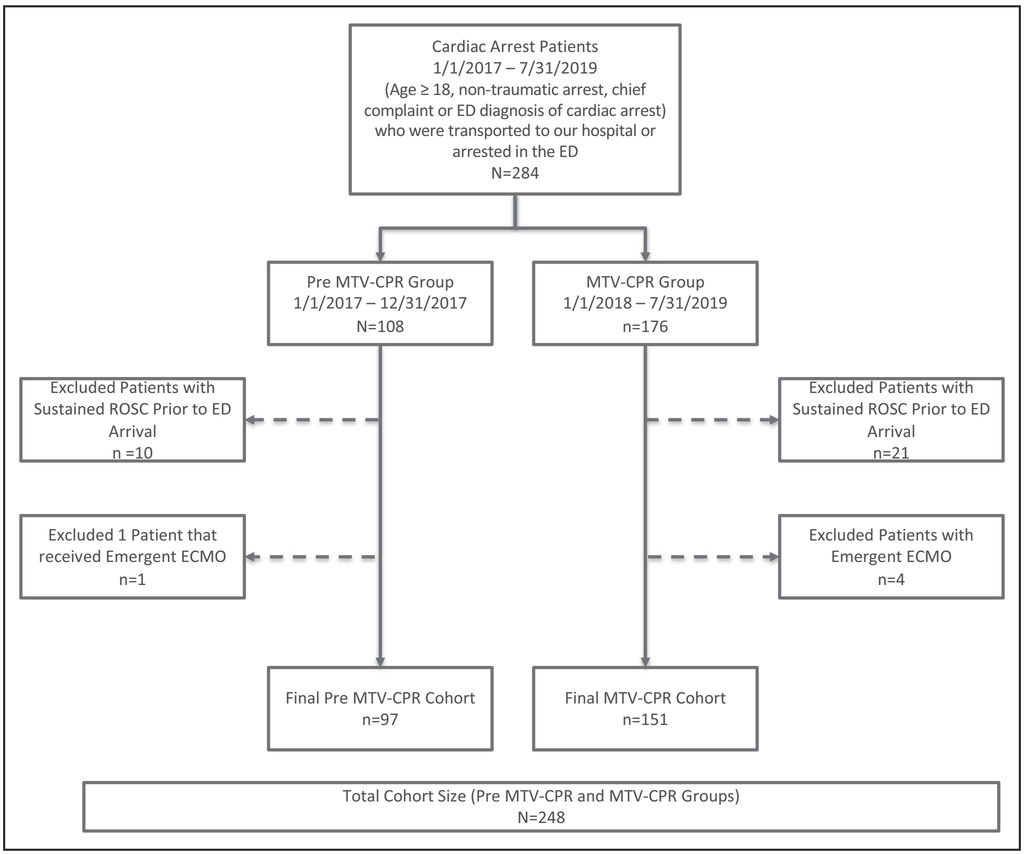

Figure 1. Study sample flowchart.
Patients who had prehospital ROSC before ED arrival but rearrested in the ED were included. Patients who had mechanical CPR prehospital were also included. ECMO indicates extracorporeal membrane oxygenation; ED, emergency department; MTV-CPR, mechanical, team-focused, video-reviewed CPR; and ROSC, return of spontaneous circulation.

and training was provided on the basis of the findings from our video review sessions.

2. Team-focused CPR

We created a standardized team for every cardiac arrest resuscitation in our ED: 3 providers (1 attending physician, 2 resident physicians and/or physicians

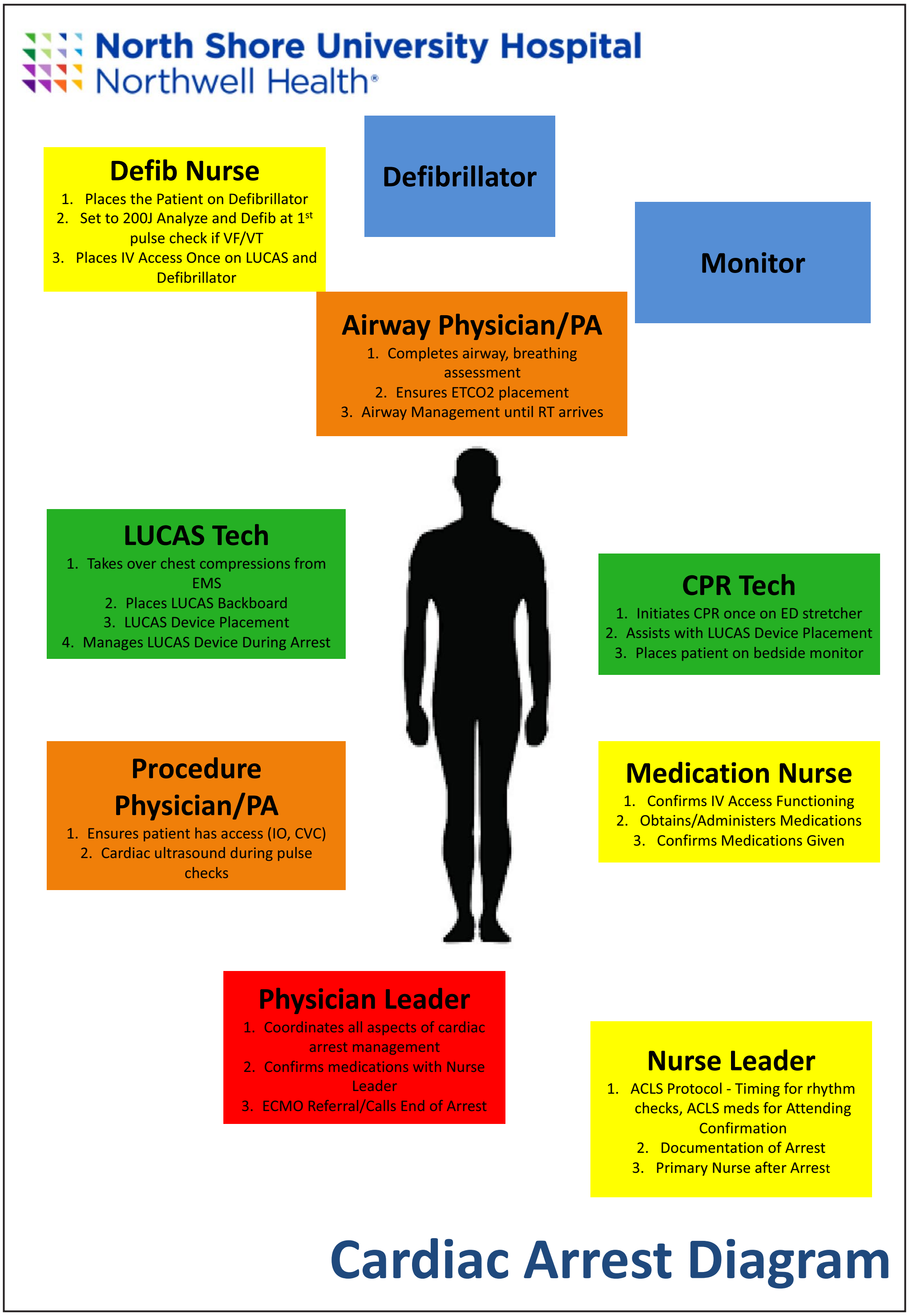

Figure 2. Team-focused mechanical cardiac arrest diagram.
ACLS indicates Advanced Cardiovascular Life Support; CPR, cardiopulmonary resuscitation; CVC, central venous catheter; ECMO, extracorporeal membrane oxygenation; $ETCO_2$, end-tidal carbon dioxide; IO, intraosseus; IV, intravenous; LUCAS, Lund University Cardiopulmonary Assist System; and VF/VT, ventricular fibrillation/ventricular tachycardia.

assistants); 3 nurses (1 nurse leader responsible for running the Advanced Cardiovascular Life Support algorithm, 1 medication administration nurse, and 1 intravenous access nurse); and 2 ED technicians (1 to focus on CPR, and 1 to focus on the MCCD). We placed posters with a diagram of roles and responsibilities in our 4 resuscitation rooms. In May 2018, we organized a performance improvement session with a multidisciplinary group of nurses, technicians, EMS providers, resident physicians, and attending physicians to systematically examine and improve upon our cardiac arrest resuscitation processes from what we learned during early video review sessions. This process was facilitated by the Performance Improvement Team from our health system and used Lean Six Sigma principles to design a swimlanes diagram process map to identify all the roles and responsibilities in a cardiac arrest resuscitation team. Then a priority payoff matrix was generated to identify high-benefit, low-effort actionable items. From this session we revised our team-focused approach to mechanical CPR with more clearly defined tasks for each team member (Figure 2), and we updated our cardiac arrest packets with stickers that are handed out to each team member to identify their role and responsibilities. The major changes from this session were the requirement for 2 ED technicians to perform coordinated CPR and MCCD placement on each patient with cardiac arrest and to wait until the first or second pause in chest compressions for pulse checks to attempt MCCD placement. Since 2 ED technicians were required for MCCD placement, we reassigned the role of attaching patients to the defibrillator to the nurse whose previous role was obtaining intravenous access since almost every patient already had an intravenous or intraosseus access in place on arrival at the ED. In July and August 2018, several in situ simulations using all the necessary members of the cardiac arrest team were held to teach our new intervention and to identify additional challenges not initially identified during the performance improvement session. Educational follow-up sessions were provided on several occasions to remind the ED team about roles.

3. Video review program

   All 4 resuscitation rooms in our ED are equipped with video review technology. All OHCAs are brought into 1 of these 4 resuscitation rooms. Patients who go into cardiac arrest in another area of our ED are brought to 1 of these 4 resuscitation rooms when possible. The cardiac arrest team is notified about an incoming cardiac arrest or an in-ED cardiac arrest to prepare, and video recording is initiated. All videos are stored on a secured server and deleted automatically after 28 days. The goal of this video review process was to identify opportunities for improvement and education, as well as to track and improve cardiac arrest process and outcome measures. Importantly, the tone of these video review sessions was intended to be collaborative and improvement focused, rather than being judgmental or critical of individuals or the team. We meet biweekly with a multidisciplinary team of ED nurses, technicians, attending and resident physicians, medical students, research staff, and EMS providers to review the videos. During these video review sessions, we discuss the varying aspects of the resuscitation, including preparation, EMS-to-ED transitions, chest compression quality, rhythm analysis and defibrillation, MCCD placement, airway management, and team communication. The input of all video review attendees is taken into account when scorecards are filled out to evaluate the cardiac arrest resuscitation (Figure 3). These scorecards were not initially sent to resuscitation team members during the study period but were collected for quality improvement purposes and potential educational projects in the future. Since the beginning of the video review program, our team has provided individualized feedback to providers on both areas for improvement and well-run resuscitations. Additionally, a bimonthly cardiac arrest lessons learned email was sent to all ED staff to disseminate common issues identified during cardiac arrest resuscitations. Occasionally, we identify difficulties with uncommon procedures (such as pericardiocentesis and transvenous pacing), and we educated the physicians on these procedures when we noted deficiencies.

Outcomes

The primary outcome for our study was ROSC, and the secondary outcomes were survival to admission and survival to discharge. Prehospital ROSC was not considered ROSC for this study because the patients had not yet received the MTV-CPR intervention in the ED. Since the beginning of our video review program, we have been tracking important process measures in cardiac arrest management: time-to-bed transfer, time-to-rhythm analysis, time-to-MCCD placement, interruptions in chest compressions including the reason for the interruption (pulse check, ultrasound, defibrillation, MCCD placement), and chest compression fraction.

Statistical Analysis

Descriptive statistics were used to describe the study sample. Means and standard deviations are reported for normally distributed continuous variables, whereas medians and interquartile ranges are

Room: Critical ____

Code ACLS

Date of Cardiac Arrest Activation:

ED Attending:

Resident/PA(s):	**Total # ED residents/PAs:**
Nurse(s):	**Total # ED nurses:**
ED Tech(s):	**Total # ED Techs:**
Date of Video Review:	**Total # Involved in Care:**

Cardiac Arrest Video-Recording Activation Performance Metrics	Criteria Met?		
Preparation	**Yes**	**No**	**Unable or N/A**
☐ Resuscitation equipment (Glidescope, Ultrasound, and LUCAS prepared)			
☐ Team roles were assigned			
Circulation	**Yes**	**No**	**Unable or N/A**
☐ High quality chest compressions performed on EMS stretcher			
☐ Pads attached and AED analyzed within first two minutes on ED stretcher, early defibrillation if indicated			
☐ Placed on LUCAS with minimal interruption in chest compressions or appropriate decision not to use LUCAS b/c patient size			
☐ Timely IV/IO access			
☐ Placed on continuous $ETCO_2$ monitoring if intubated			
☐ Early Ultrasound use for PEA, Asystole			
Airway and Breathing	**Yes**	**No**	**Unable or N/A**
☐ Appropriate BVM; early confirmation of EMS ET tube; or intubated with minimal interruptions in chest compressions or ventilations			
☐ Appropriate ventilation rate and bag squeeze			
ACLS	**Yes**	**No**	**Unable or N/A**
☐ Appropriate timing and selection of medications			
☐ Appropriate timing/performance of CPR cycle, pulse check, rhythm determination			
☐ Chest compressions delays <10 seconds			
Communication	**Yes**	**No**	**Unable or N/A**
☐ Clear team communication (Closed Loop)			
☐ Team member clearly summarizes findings and plan			

Figure 3. Cardiac arrest video review scorecard.
ACLS indicates Advanced Cardiovascular Life Support; AED, automated external defibrillator; BVM, bag-valve-mask; CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, emergency medical services; ET, endotracheal; $ETCO_2$, end-tidal carbon dioxide; IO, intraosseous; IV, intravenous; LUCAS, Lund University Cardiopulmonary Assist System; PA, physician assistant; and PEA, pulseless electrical activity.

reported for nonnormally distributed continuous variables. Frequencies and proportions are reported for categorical variables. The study sample was stratified into 2 groups: (1) patients who were resuscitated before the intervention (January 2017 to December 2017) and (2) patients who were resuscitated after the intervention (January 2018 to July 2019). Differences in demographic and clinical characteristics between patients who were resuscitated before and after the MTV-CPR intervention were assessed using bivariate tests appropriate for the distribution of the data. Differences in the proportions of patients achieving ROSC, survival to hospital admission, and survival to hospital discharge before and after the intervention were assessed using chi-square tests. A Cochran-Mantel-Haenszel stratified analysis was conducted to determine whether the proportion of patients achieving ROSC before and after our MTV-CPR intervention remained significant after adjusting for location of the cardiac arrest (OHCA versus in-hospital cardiac arrest). Separate multivariable logistic regression models were constructed using data available in both the pre- and postintervention periods to estimate the relative odds of each of our outcome measures, while controlling for relevant variables. Variables hypothesized to be associated with our outcome measures based on prior literature, clinical importance, and statistical significance in bivariate analyses (P<0.20) were included in our initial multivariable regression models. Variables were then individually eliminated from the model, starting with the variable with the largest P value; all variables that were statistically significant at the P<0.05 level in the model were retained. Regardless of statistical significance, age and sex were adjusted for in all models. Adjusted odds ratios and 95% confidence intervals are reported for each outcome measure. Hosmer–Lemeshow goodness-of-fit tests were used to assess model fit of the logistic regression models. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

There were 284 patients with cardiac arrest who were brought to our hospital or had a cardiac arrest in the ED during the study period. We do not have data on the total number of patients who suffered an OHCA in our catchment area; therefore, all patients who had termination of resuscitation in the field were excluded. Thirty-one patients had sustained ROSC with EMS (10 in the preintervention group and 21 in the postintervention group), did not rearrest with EMS or in the ED, and were excluded from analysis. Five patients (1 in the preintervention group and 4 in the postintervention group) received E-CPR from the ED and were excluded from analysis (Figure 1). A total of 248 patients with cardiac arrest were included in our analysis, 97 patients before and 151 patients after the MTV-CPR intervention. The median age was 80 years, and was not significantly older in the preintervention period (83 years) than the postintervention period (79 years). Seventy-four percent of patients were OHCA, and shockable rhythms accounted for 15% of the population. Despite the lack of randomization, the groups appear similar with respect to patient demographics, cardiac arrest location, initial rhythm, and time from EMS dispatch to ED arrival. Bystander or first responder defibrillation was higher in the preintervention group. Although not statistically significant, witnessed arrest was slightly higher in the preintervention group. Independent living status was better identified in the intervention period (Table 1).

As shown in Table 2, the proportion of patients achieving ROSC improved from 26% before our MTV-CPR intervention to 41% after our MTV-CPR intervention (P=0.014). These findings were consistent for both OHCA (21.9% preintervention versus 33.9% postintervention) and patients with in-hospital cardiac arrest (37.5% preintervention versus 58.5% postintervention) and demonstrated a significant improvement in ROSC in the postintervention period after adjusting for cardiac arrest location using the Cochran-Mantel-Haenszel test (P=0.019). There was a nonsignificant increase in the proportion of patients surviving to admission before and after our MTV-CPR intervention (20%–26%; P=0.257). Similarly, there was a nonsignificant increase in the proportion of patients surviving to hospital discharge before and after our MTV-CPR intervention (3%–7%; P=0.163). After controlling for relevant covariates (Table 3), multivariable regression analysis demonstrated that the odds of ROSC remained higher in the intervention period (odds ratio, 2.11; 95% CI, 1.14–3.89), but there was no significant increase in the odds of survival to admission (odds ratio, 1.29; 95% CI, 0.65–2.54) or survival to discharge (odds ratio, 2.58; 95% CI, 0.66–10.10).

During the MTV-CPR intervention period, video review data were available for 94 patients, and we analyzed several available cardiac arrest process measures. Time from EMS to ED bed transfer was a median of 57 seconds and there was a mean interruption in chest compressions secondary to EMS bed transfer of 5 seconds. Time to rhythm analysis was a median of 214 seconds, and the median interruption time secondary to each defibrillation attempt was 20 seconds. Median compression fraction was 88%. Finally, median interruption in chest compressions secondary to successful MCCD placement was 50 seconds.

DISCUSSION

Our study demonstrated an improvement in ROSC with the use of a 3-component MTV-CPR intervention bundle. This bundle includes the use of mechanical CPR in the ED, but multiple larger studies have failed to find a benefit to mechanical CPR. The LUCAS in Cardiac Arrest (LINC)[12] and pre-hospital randomised assessment of a mechanical compression device in

Table 1. Characteristics of the Study Sample Stratified by Time Period

Variable	Total Sample (n=248)	Before (n=97)	After (n=151)	*P* Value
Age, y				0.286
Median (IQR)	80 (66–89)	83 (67–90)	79 (65–88)	
Sex				0.868
Male, n (%)	139 (56.1)	55 (56.7)	84 (55.6)	
Female, n (%)	109 (44.0)	42 (43.3)	67 (44.4)	
Race				0.192
White, n (%)	159 (64.1)	67 (69.1)	92 (60.9)	
Nonwhite, n (%)	89 (35.9)	30 (30.9)	59 (39.1)	
Ethnicity				0.942
Hispanic or Latino, n (%)	15 (6.1)	6 (6.2)	9 (6.0)	
Not Hispanic or Latino, n (%)	233 (94.0)	91 (93.8)	142 (94.0)	
Cardiac arrest location				0.674
Out-of-hospital, n (%)	183 (73.8)	73 (75.3)	110 (72.9)	
In-hospital, n (%)	65 (26.2)	24 (24.7)	41 (27.2)	
First cardiac rhythm				0.764
Asystole, n (%)	110 (44.4)	45 (46.4)	65 (43.1)	
Pulseless electrical activity, n (%)	72 (29.0)	25 (25.8)	47 (31.1)	
Ventricular fibrillation/tachycardia, n (%)	37 (14.9)	14 (14.4)	23 (15.2)	
Unknown/not documented, n (%)	29 (11.7)	13 (13.4)	16 (10.6)	
Cardiac arrest witnessed by				0.402
Bystander, n (%)	64 (25.8)	30 (30.9)	34 (22.5)	
EMS, n (%)	25 (10.1)	11 (11.3)	14 (9.3)	
ED staff, n (%)	65 (26.2)	24 (24.7)	41 (27.2)	
Unwitnessed, n (%)	76 (30.7)	24 (24.7)	52 (34.4)	
Unknown, n (%)	18 (7.3)	8 (8.3)	10 (6.6)	
CPR initiated by				0.871
Bystander, n (%)	43 (17.3)	16 (16.5)	27 (17.9)	
EMS/police/fire, n (%)	127 (51.2)	50 (51.6)	77 (51.0)	
ED staff, n (%)	66 (26.6)	25 (25.8)	41 (27.2)	
Unknown, n (%)	12 (4.8)	6 (6.2)	6 (4.0)	
First defibrillation by				0.032
Bystander or first responder, n (%)	16 (6.5)	10 (10.3)	6 (4.0)	
EMS, n (%)	39 (15.7)	16 (16.5)	23 (15.2)	
ED staff, n (%)	18 (7.3)	4 (4.1)	14 (9.3)	
Not defibrillated, n (%)	109 (44.0)	35 (36.1	74 (49.0)	
Unknown/not documented, n (%)	66 (26.6)	32 (33.0	34 (22.5)	
Independent living				0.003
Yes, n (%)	107 (43.2)	36 (37.1)	71 (47.0)	
No, n (%)	85 (34.3)	28 (28.9)	57 (37.8)	
Unknown, n (%)	56 (22.6)	33 (34.0)	23 (15.2)	
EMS dispatch to ED arrival time				0.640
Median min (IQR)	41 (33–52)	43 (31–53)	41 (34–52)	

P-values derived from Wilcoxon rank-sum test for age and chi-square or Fisher's exact tests where appropriate for all other categorical variables. ED indicates emergency department; EMS, emergency medical services; IQR, interquartile range; and MTV-CPR, mechanical, team-focused, video-reviewed cardiopulmonary resuscitation.

cardiac arrest (PARAMEDIC)[13] randomized controlled trials failed to demonstrate an improvement in survival with mechanical CPR using a LUCAS over manual CPR for OHCA. ASPIRE,[14] another prehospital randomized controlled trial, demonstrated worse neurologically intact survival with the AutoPulse Resuscitation System (ZOLL Circulation, San Jose, CA). The Survey of Survivors After Out of Hospital Cardiac Arrest in

Table 2. Outcomes of Cardiac Arrest Resuscitation by Time Period

Outcomes	Before MTV-CPR (n=97)	After MTV-CPR (n=151)	*P* Value
ROSC achieved, n (%)	25 (25.8)	62 (41.1)	0.014*
OHCA, n (%)	16 (21.9)	38 (34.6)	0.016†
IHCA, n (%)	9 (37.5)	24 (58.5)	
Survival to admission, n (%)	19 (19.6)	39 (25.8)	0.257*
Survival to discharge, n (%)	3 (3.1)	11 (7.3)	0.163*

IHCA indicates in-hospital cardiac arrest; MTV-CPR, mechanical, team-focused, video-reviewed cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; and ROSC, return of spontaneous circulation.

**P* value derived from chi-square test.

†*P* value derived from Cochran-Mantel-Haenszel test for general association.

Kanto Area (SOS KANTO),[15] a prior multicenter observational study from Japan, demonstrated decreased likelihood of ROSC and survival to hospital discharge when mechanical CPR was used in the ED compared with manual CPR. One reason mechanical CPR has not been demonstrated to improve outcomes may be the interruptions in chest compressions that are required to place the MCCD. Prior video review studies have demonstrated prolonged interruptions in chest compressions when mechanical CPR is used.[19,20] Our study also identified prolonged interruptions in chest compressions, a median of 50 seconds, secondary to MCCD placement. Levy et al[21] demonstrated that a quality improvement program reduced interruptions in chest compressions secondary to initial MCCD placement from 21 to 7 seconds in the prehospital setting. In addition, Hock Ong et al[22,23] demonstrated improved neurologically intact survival with mechanical CPR using the AutoPulse in the ED after focused team training. Video review allows us to provide personalized feedback to our ED technicians who are placing the MCCD on patients, to maximize their likelihood of success. Additionally, video review has contributed to modifications in our team-focused approach to mechanical CPR. We are now delaying attempts to place the MCCD until optimally prepared on the first or second pulse check once the patient is on the ED stretcher. We are in the process of a focused quality improvement initiative for MCCD placement and plan to evaluate if our MTV-CPR intervention can decrease interruptions in chest compressions secondary to MCCD placement.

The Minnesota Resuscitation Consortium uses a LUCAS MCCD to transport patients directly to the cardiac catheterization for ECMO in their prehospital refractory ventricular fibrillation/ventricular tachycardia algorithm, which has demonstrated 48% neurologically intact survival in those patients successfully placed on ECMO.[18] We decided to begin using mechanical CPR before implementing a similar E-CPR strategy that allows patients with refractory cardiac arrest to be transported from the ED to the cardiac catherization suite for ECMO placement. This E-CPR strategy started on October 1, 2018. Five patients (1 before and 4 after MTV-CPR) were excluded from this analysis because they received E-CPR, which requires admission to the hospital in our program and was the likely cause of the patients' survival to admission rather than our MTV-CPR intervention.

Team-focused CPR, or high-performance CPR, involves the creation of predefined roles for all team members, with a focus on evidence-based interventions in cardiac arrest, such as minimizing interruptions in chest compressions and early defibrillation, to create a more coordinated approach to cardiac arrest management. A prior prehospital study on the use of team-focused CPR in North Carolina EMS systems demonstrated improved neurologically intact survival with team-focused CPR (8%) versus standard CPR (5%).[6] In addition, a study from the Chicago Fire Department EMS demonstrated improved neurologically intact survival from 12% before to 29% after implementation of a system-wide initiative to improve cardiac arrest care including phone-assisted and community CPR training, high-performance CPR, and simulation training, new postresuscitation and destination protocols, and EMS provider feedback.[7]

We initially created a team-focused approach in January 2018. We then modified our team-focused approach to mechanical CPR based on a performance improvement session we hosted (Figure 2) and implemented this revised approach in July 2018. There are several innovations to our team-focused CPR. First, we assigned a nurse leader to manage the Advanced Cardiovascular Life Support algorithm and communicate all timing for pulse checks. Therefore, the physician leader is liberated to identify and respond to issues with the resuscitation, to obtain additional information and communicate with EMS and families, and to think critically of other potential causes of the arrest

Table 3. Multivariable Logistic Regression Models on Outcomes Associated With MTV-CPR Intervention

Outcomes	Adjusted Odds Ratio	95% CI
ROSC achieved*	2.11	(1.14–3.89)
Survival to admission†	1.29	(0.65–2.54)
Survival to discharge‡	2.58	(0.66–10.10)

MTV-CPR indicates mechanical, team-focused, video-reviewed cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

*Model adjusted for age, sex, initial cardiac rhythm, and witnessed status. Hosmer–Lemeshow goodness-of-fit test *P* value: 0.703.

†Model adjusted for age, sex, initial cardiac rhythm, and witnessed status. Hosmer–Lemeshow goodness-of-fit test *P* value: 0.516.

‡Model adjusted for age, sex, race, and location of cardiac arrest. Hosmer–Lemeshow goodness-of-fit test *P*-value: 0.857.

and options for treatment. Our second innovation was the use of mechanical CPR and the designation of 2 ED technicians to coordinate placement of the patient on the MCCD. Finally, we removed the primary role of intravenous access nurse and assigned this nurse to defibrillator pad placement, moving the intravenous nurse out of the way and allowing our 2 ED technicians to focus on MCCD placement. Ours is the first study we could identify on the use of team-focused CPR in the ED. A team-focused approach to cardiac arrest demonstrates another substantial way EDs can improve outcomes in cardiac arrest and should be considered whether EDs are using mechanical or manual CPR.

This is the first study we could identify demonstrating a temporal improvement in selected clinical outcomes, specifically ROSC, of patients with cardiac arrest with a video review quality improvement program. Video review of cardiac arrest provides the ability to monitor the quality of CPR and quickly identifies multiple areas for improvement in cardiac arrest management. Prior video review data in pediatric cardiac arrest demonstrated appropriate compressions and interruptions, but ventilations were often faster than recommended.[24] Additionally, video review data have been used to identify prolonged interruptions in chest compressions with ultrasound and was used to develop and implement a cardiac arrest sonographic assessment protocol that decreased those interruptions.[25,26] In 1988, Hoyt et al[8] published the first study on video review in trauma demonstrating an improvement in time to definitive care and assignment of team responsibilities. More recently, in 2017, improved compliance with Advanced Trauma Life Support algorithms was demonstrated with implementation of a trauma video review program from 9% at baseline to 92% 1 year later.[9] Video review has demonstrated its benefits to improving process measures; however, there are limited data demonstrating any improvement in outcomes.

Our video review program monitors multiple aspects of a cardiac arrest (Figure 3). This monitoring provides baseline process measures and allows for objective goals for improvement within the ED. Aside from the interruptions in chest compressions with MCCD placement, our video review process identified prolonged interruptions secondary to EMS-to-ED bed transfer and defibrillation. We have multiple ongoing projects to improve these interruption times, which we plan to report on in the near future.

As technology has improved, video recordings are being used throughout our society to improve safety. In the media, this is most notable in the use of video cameras by police officers to record their interactions. Video recording was prevalent at US trauma centers in the 1990s before passage of the Health Insurance Portability and Accountability Act and the Joint Commission and the Centers for Medicare and Medicaid Services requirements for informed consent for video recording in health care in the early 2000s.[27] There are enumerable benefits to video recording in health care for educational and quality improvement purposes, especially with regard to less common and highly stressful resuscitations like cardiac arrest and trauma. There is an urgent need to overcome the obstacles to video recording in hospitals and fears about patient privacy because the potential benefits to patient safety from video recording with focused feedback and education are enormous. If the Joint Commission wants to improve patient safety in emergencies like cardiac arrest and trauma resuscitation, they should consider modifying the restrictions on recording patients and reviewing videos without informed consent in advance so similar video review programs can be created throughout the United States.

Limitations

This study on our MTV-CPR intervention has several limitations. The sample size for this study is small, and while there were improvements in ROSC, the small sample size increases the likelihood that this improvement is due to chance. Additionally, the small sample size may explain the lack of improvement in survival to admission and survival to discharge. Since we do not have data on the total number of patients who suffered a cardiac arrest in our catchment area, it is possible there was selection bias between the 2 study periods. However, we are not aware of any changes to termination of resuscitation protocols that were made by the EMS agencies bringing patients to our hospital, and our patients baseline characteristics were similar between the 2 study periods (Table 1). Our patient population is older than other cardiac arrest populations in the United States,[28] limiting the generalizability of our study. This may explain the low ROSC rate before ED arrival in OHCA.

This was a single center study of our MTV-CPR cardiac arrest performance improvement program. Since our study took place in a large, academic, tertiary care ED, it is important to evaluate if a similar program at other institutions generates similar results, especially with smaller teams and less resources (our cardiac arrest team consists of 8 members for the initial management phase). Larger, multicenter studies of our MTV-CPR intervention are needed to determine if patient-oriented outcomes improve and are generalizable.

Because there were 3 primary interventions to our bundle, and all were implemented at the same time, it is difficult to distinguish which aspect of our bundle led to the improvement in ROSC. Finally, the Hawthorne effect is a well-described potential source of bias secondary to being observed when initiating a study.[29] It is unclear whether video review uses the Hawthorne effect to provide a sustained improvement in outcomes because the team is being observed or if the improvement is a confounder that will be lost as the department becomes more accustomed to video review of cardiac arrest. We are planning to continue our video review program and will continue to monitor outcomes over time.

CONCLUSIONS

Our MTV-CPR intervention for cardiac arrest management in the ED was associated with an improvement in ROSC but did not result in an improvement in survival to admission or survival to discharge. This study cannot identify if individual components of our bundle led to the observed improvement in ROSC. Additional studies using a similar approach at different hospitals would be important to establish external validity and generalizability.

ARTICLE INFORMATION

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Disclosures

None.

REFERENCES

1. AHA Cardiac Arrest Statistics. Available at: https://cpr.heart.org/AHAECC/CPRAndECC/ResuscitationScience/UCM_477263_AHA-Cardiac-Arrest-Statistics.jsp%5BR=301,L,NC%5D. Accessed April 19, 2019.
2. Cheng A, Nadkarni VM, Mancini MB, Hunt EA, Sinz EH, Merchant RM, Donoghue A, Duff JP, Eppich W, Auerbach M, et al. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American Heart Association. *Circulation*. 2018;138:e82–e122.
3. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression rates during cardiopulmonary resuscitation are suboptimal. *Circulation*. 2005;111:428–434.
4. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, Callaway CW, Bishop D, Vaillancourt C, Davis D, et al. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. *Circulation*. 2009;120:1241–1247.
5. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, et al. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? *Crit Care Med*. 2012;40:1192–1198.
6. Pearson DA, Darrell Nelson R, Monk L, Tyson C, Jollis JG, Granger CB, Corbett C, Garvey L, Runyon MS. Comparison of team-focused CPR vs standard CPR in resuscitation from out-of-hospital cardiac arrest: results from a statewide quality improvement initiative. *Resuscitation*. 2016;105:165–172.
7. Del Rios M, Weber J, Pugach O, Nguyen H, Campbell T, Islam S, Stein Spencer L, Markul E, Bunney EB, Vanden Hoek T. Large urban center improves out-of-hospital cardiac arrest survival. *Resuscitation*. 2019;139:234–240.
8. Hoyt DB, Shackford SR, Fridland PH, Mackersie RC, Hansbrough JF, Wachtel TL, Fortune JB. Video recording trauma resuscitations: an effective teaching technique. *J Trauma Acute Care Surg*. 1988;28:435.
9. Wurster LA, Thakkar RK, Haley KJ, Wheeler KK, Larson J, Stoner M, Gewirtz Y, Holman T, Buckingham D, Groner JI. Standardizing the initial resuscitation of the trauma patient with the Primary Assessment Completion Tool using video review. *J Trauma Acute Care Surg*. 2017;82:1002–1006.
10. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA*. 2005;293:305–310.
11. Wik L, Kramer-Johansen J, Myklebust H, Sørebø H, Svensson L, Fellows B, Steen PA. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. *JAMA*. 2005;293:299–304.
12. Rubertsson S, Lindgren E, Smekal D, Östlund O, Silfverstolpe J, Lichtveld RA, Boomars R, Ahlstedt B, Skoog G, Kastberg R, et al. Mechanical chest compressions and simultaneous defibrillation vs conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest: the LINC randomized trial. *JAMA*. 2014;311:53–61.
13. Perkins GD, Lall R, Quinn T, Deakin CD, Cooke MW, Horton J, Lamb SE, Slowther AM, Woollard M, Carson A, et al. Mechanical versus manual chest compression for out-of-hospital cardiac arrest (PARAMEDIC): a pragmatic, cluster randomised controlled trial. *Lancet*. 2015;385:947–955.
14. Hallstrom A, Rea TD, Sayre MR, Christenson J, Anton AR, Mosesso VN Jr, Van Ottingham L, Olsufka M, Pennington S, White LJ, et al. Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial. *JAMA*. 2006;295:2620–2628.
15. Hayashida K, Tagami T, Fukuda T, Suzuki M, Yonemoto N, Kondo Y, Ogasawara T, Sakurai A, Tahara Y, Nagao K, et al. Mechanical cardiopulmonary resuscitation and hospital survival among adult patients with nontraumatic out-of-hospital cardiac arrest attending the emergency department: a prospective, multicenter, observational study in Japan (SOS-KANTO [Survey of Survivors After Out-of-Hospital Cardiac Arrest in Kanto Area] 2012 Study). *J Am Heart Assoc*. 2017;6:e007420. DOI: 10.1161/JAHA.117.007420.
16. Youngquist ST, Ockerse P, Hartsell S, Stratford C, Taillac P. Mechanical chest compression devices are associated with poor neurological survival in a statewide registry: a propensity score analysis. *Resuscitation*. 2016;106:102–107.
17. Wang PL, Brooks SC. Mechanical versus manual chest compressions for cardiac arrest. *Cochrane Database Syst Rev*. 2018;8:CD007260.
18. Bartos JA, Carlson K, Carlson C, Raveendran G, John R, Aufderheide TP, Yannopoulos D. Surviving refractory out-of-hospital ventricular fibrillation cardiac arrest: critical care and extracorporeal membrane oxygenation management. *Resuscitation*. 2018;132:47–55.
19. Huang EP, Wang HC, Ko PC, Chang AM, Fu CM, Chen JW, Liao YC, Liu HC, Fang YD, Yang CW, et al. Obstacles delaying the prompt deployment of piston-type mechanical cardiopulmonary resuscitation devices during emergency department resuscitation: a video-recording and time-motion study. *Resuscitation*. 2013;84:1208–1213.
20. Wroe PC, Clattenburg EJ, Gardner K, Gelber J, Schultz C, Singh A, Nagdev A. Emergency department use of a mechanical chest compression device frequently causes unanticipated interruptions in cardiopulmonary resuscitation. *Resuscitation*. 2018;133:e3–e4.
21. Levy M, Yost D, Walker RG, Scheunemann E, Mendive SR. A quality improvement initiative to optimize use of a mechanical chest compression device within a high-performance CPR approach to out-of-hospital cardiac arrest resuscitation. *Resuscitation*. 2015;92:32–37.

22. Hock Ong ME, Fook-Chong S, Annathurai A, Ang SH, Tiah L, Yong KL, Koh ZX, Yap S, Sultana P. Improved neurologically intact survival with the use of an automated, load-distributing band chest compression device for cardiac arrest presenting to the emergency department. *Crit Care*. 2012;16:R144.
23. Ong ME, Quah JL, Annathurai A, Noor NM, Koh ZX, Tan KB, Pothiawala S, Poh AH, Loy CK, Fook-Chong S. Improving the quality of cardiopulmonary resuscitation by training dedicated cardiac arrest teams incorporating a mechanical load-distributing device at the emergency department. *Resuscitation*. 2013;84:508–514.
24. Donoghue A, Hsieh TC, Myers S, Mak A, Sutton R, Nadkarni V. Videographic assessment of cardiopulmonary resuscitation quality in the pediatric emergency department. *Resuscitation*. 2015;91:19–25.
25. Clattenburg EJ, Wroe P, Brown S, Gardner K, Losonczy L, Singh A, Nagdev A. Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: a prospective cohort study. *Resuscitation*. 2018;122:65–68.
26. Clattenburg EJ, Wroe PC, Gardner K, Schultz C, Gelber J, Singh A, Nagdev A. Implementation of the Cardiac Arrest Sonographic Assessment (CASA) protocol for patients with cardiac arrest is associated with shorter CPR pulse checks. *Resuscitation*. 2018;131: 69–73.
27. Williams KS, Pace C, Milia D, Juern J, Rubin J. Development of a video recording and review process for trauma resuscitation quality and education. *West J Emerg Med*. 2019;20:228–231.
28. Daya MR, Schmicker RH, Zive DM, Rea TD, Nichol G, Buick JE, Brooks S, Christenson J, MacPhee R, Craig A, et al. Out-of-hospital cardiac arrest survival improving over time: results from the Resuscitation Outcomes Consortium (ROC). *Resuscitation*. 2015;91:108–115.
29. Sedgwick P, Greenwood N. Understanding the Hawthorne effect. *BMJ*. 2015;351:h4672.