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The Use of Mechanical Cardiopulmonary Resuscitation May Be Associated With Improved Outcomes Over Manual Cardiopulmonary Resuscitation During Inhospital Cardiac Arrests

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Objectives: We aimed to investigate the impact of mechanical cardiopulmonary resuscitation devices over manual cardiopulmonary resuscitation on outcomes from inhospital cardiac arrests.

Design: Restrospective review.

Setting: Single academic medical center.

Participants: Data were collected on all patients who suffered cardiac arrest from December 2015 to November 2019.

Main Outcomes and Measures: Primary end point was return of spontaneous circulation. Secondary end points included survival to discharge and survival to discharge with favorable neurologic outcomes.

Results: About 104 patients were included in the study: 59 patients received mechanical cardiopulmonary resuscitation and 45 patients received manual cardiopulmonary resuscitation during the enrollment period. Return of spontaneous circulation rate was 83% in the mechanical cardiopulmonary resuscitation group versus 48.8% in the manual group ($p = 0.009$). Survival-to-discharge rate was 32.2% in the mechanical cardiopulmonary resuscitation group versus 11.1% in those who received manual cardiopulmonary resuscitation ($p = 0.02$). Of the patients who survived to discharge and received mechanical cardiopulmonary resuscitation, 100% ($n = 19$) had a favorable neurologic outcome versus 40% (two out of five) of patients who survived and received manual cardiopulmonary resuscitation ($p = 0.005$).

Conclusions: Our findings demonstrate a significant association of improved outcomes with mechanical cardiopulmonary resuscitation over manual cardiopulmonary resuscitation during inhospital cardiac arrests. Mechanical cardiopulmonary resuscitation may improve rates of return of spontaneous circulation, survival to discharge, and favorable neurologic outcomes.

Key Words: advanced cardiac life support; cardiac arrest, sudden; cardiopulmonary resuscitation; inhospital cardiac arrest

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Trends in survival from inhospital cardiac arrest (IHCA) have increased overtime (1, 2). However, there is still significant morbidity and mortality associated with IHCAs with survival rates between 15% and 20% (1, 3, 4). Patients who suffer from ICHA have a high mortality rate even after discharge with studies reporting mortality rates up to 31% 90 days after discharge (5). Furthermore, patients may have long-term disability with only 29% returning to work and up to 95% having cognitive dysfunction 2 years after the event (6).

The use of mechanical cardiopulmonary resuscitation (CPR) devices has been extensively studied over the past 2 decades in the out-of-hospital sector as a possible method for increasing survival (7–10). Multiple systematic reviews have been completed on out-of-hospital cardiac arrests, which have demonstrated that outcomes are similar between mechanical CPR and manual CPR (11–13). One meta-analysis reported a possible increase in survival to discharge, but an increase in adverse events/injury with mechanical CPR (14). However, there is still a paucity of data for the use of mechanical

CPR during IHCAs. To the best of our knowledge, there are only two studies that have investigated mechanical CPR in the inhospital setting. One was a small feasibility study performed in 1978 with only 50 patients (15) and the other was performed with patients in the emergency department (ED) using a load distributing band chest compression device (16). Finally, the International Liaison Committee on Resuscitation has provided a weak recommendation against the routine use of mechanical CPR based on moderate quality of evidence in their 2015 update to Advanced Life support (17).

Due to this, we chose to perform an observational investigation to assess the potential association between the use of mechanical CPR devices during IHCAs on the rates of return of spontaneous circulation (ROSC), survival to discharge, and neurologically intact outcomes. Our hypothesis was that, for patients suffering IHCA, mechanical compression devices would be associated with improved rates of ROSC and inhospital survival compared with manual compression.

MATERIALS AND METHODS

Design, Setting, and Population

This retrospective review was performed at a single academic medical center in Cambridge, MA. All adult patients (> 18 yr old) who suffered from an IHCA at our facility between December 2015 and February 2019 were considered for inclusion. Patients were excluded from the analysis if it was unclear whether manual CPR or mechanical CPR was performed during the event or if there was poor documentation of the resuscitation record. Patients who arrived to the ED in cardiac arrest or suffered from a cardiac arrest in the ED were excluded as well.

Our institution's resuscitation team is composed of an intensivist, resident physicians, two nurses, a respiratory therapist, an anesthesia provider (to aide in airway management), and a nursing supervisor. Our nursing supervisor is used as a recorder to complete the documentation of the resuscitation, and this helps ensure there is accuracy of the resuscitation record. The cardiac arrests in our institution require completion of an internal quality and safety report. Due to this, we can ensure all events were collected during the enrollment period and there were no "missed events."

All mechanical CPR was delivered by the same model of device. During the enrollment period, there was no pattern to the delivery of mechanical CPR or surrounding the decision to use mechanical CPR. Mechanical CPR is always available and is brought to every resuscitation at our institution. There are contraindications to mechanical CPR including body habitus (too small or too large), pregnancy, and status post recent sternotomy. However, it appears the decision to use mechanical CPR is largely based on provider preference at our institution.

Formal institutional review board approval was obtained for medical record review. A waiver of informed consent was granted, as this was a retrospective chart review and assessed as low risk (IRB protocol number 023-2018).

Data Collection

We reviewed patient's medical records to collect demographics including the length of the event, initial rhythm, and location where the event occurred (i.e., critical care unit, telemetry unit, nontelemetry unit, step down unit, or others). We reviewed patient's medical records and clinical notes to collect information including suspected cause of the event as documented by the overseeing provider, survival to discharge, and survival to discharge with a favorable neurologic outcome. Resuscitation event records were reviewed to collect information regarding initial rhythm, the type of CPR that was delivered (manual or mechanical CPR), and whether ROSC was obtained.

Measures and Outcomes

Our primary outcome was ROSC that was classified as a palpable pulse for at least 2 consecutive minutes. A palpable pulse for 2 minutes was decided to be the end point for ROSC (rather than 20 min, which is the Utstein definition of survival from an event) as we were limited to determining ROSC based on resuscitation records, which can have differing levels of documentation. Secondary outcomes included survival to discharge and survival to discharge with a favorable neurologic outcome. Survival with a favorable neurologic outcome was classified as a Cerebral Performance Category scales of 1 (**Table 1**).

Statistical Analysis

Summary statistics including means with SD or median with interquartile ranges are provided, as appropriate. Categorical or discrete data are summarized with frequencies and percentages. Chi-square/Fisher exact test was performed for univariate data to determine the association between CPR method, ROSC, and survival to discharge. A multivariable logistic regression model was created to assess the possibility for potential confounding variables. Our primary and secondary outcomes were the dependent variable. Candidate variables were manually screened for association with the outcome of interest (**Supplemental Table 1**, http://links.lww.com/CCX/A414). If there was evidence suggestive of univariate association ($p < 0.2$), the candidate variable was manually carried forward for multivariable modeling. Once entered into the multivariable model, if the confounder variable is no longer associated with outcome, it was removed from the model The

TABLE 1. Cerebral Performance Category Scale

CPC Scale	
CPC 1	Good cerebral performance: conscious, alert, and able to work might have mild neurologic or psychologic deficit.
CPC 2	Moderate cerebral disability: conscious and sufficient cerebral function for independent activities of daily life. Able to work in sheltered environment.
CPC 3	Severe cerebral disability: conscious and dependent on others for daily support because of impaired brain function. Ranges from ambulatory state to severe dementia or paralysis.
CPC 4	Coma or vegetative state: any degree of coma without the presence of all brain death criteria. Unawareness, even if appears awake (vegetative state) without interaction with environment, and may have spontaneous eye opening and sleep/wake cycles. Cerebral unresponsiveness.
CPC 5	Brain death: apnea, areflexia, EEG silent, etc.

CPC = Cerebral Performance Category.

candidate variables included were age, location at time of the arrest, initial rhythm, suspected cause of the arrest, length of the event, and presence of the following past medical history; and coronary artery disease, chronic kidney disease, congestive heart failure, diabetes mellitus, atrial fibrillation, hypertension, chronic obstructive pulmonary disease, hyperlipidemia, cancer, venous thromboembolism, cerebrovascular attack, pulmonary fibrosis, or cardiomyopathy.

We were concerned that length of the event could have a large impact on both the primary and secondary outcomes. Resuscitation time bias has been studied and is a unique challenge to researchers as time is a unique predictor of outcomes including survival (18). Due to this, we performed subgroup analyses by events in which the length of the event lasted greater than 10 minutes and greater than 20 minutes.

All analyses were performed using the SAS Software (version 9.4; SAS Institute, Cary, NC) and were assumed to be two-sided with an alpha of 0.05.

RESULTS

During the period of January 2016 to February 2019, there were 110 events which occurred. Six events were excluded from the analysis as they had poor documentation, or it was not clear which method of CPR was used. A total of 104 patients were included in the final analysis, with 59 events using mechanical CPR and 45 events where manual CPR was provided. In both groups, the most common initial rhythm was pulseless electrical activity or asystole: 83.3% in the mechanical group and 84.4% in the manual group, respectively (Table 2). The most common suspected cause was respiratory failure in both groups, 28.3% in the mechanical group versus 31.1% in the manual group, followed by an unknown cause, a cardiac cause, sepsis, or other including pulmonary embolism, myocardial infarction, seizure, prolonged QT interval, and hemorrhage (Table 2). The most common location the event occurred was in the critical care unit for both groups: 71.7% in the mechanical group versus 64.4% in the manual group. A total of 75 patients achieved ROSC (71.4%), 24 patients survived to discharge (23.1%), and 21 patients survived to discharge with a favorable neurologic outcome (20.2%).

For the primary outcome, we found the use of mechanical CPR was associated with an increase in the rates of ROSC. Of the 59 patients who received mechanical CPR, 49 achieved ROSC (83%) versus 22 of the 45 patients who received manual CPR achieving ROSC (48.8%, $p = 0.009$) (**Fig. 1**). In multivariable-adjusted analysis, mechanical CPR remained associated with increased rates of ROSC over manual CPR ($p = 0.001$). In a subgroup analysis including only events that lasted greater than 10 minutes, the use of mechanical CPR was still associated with an increase in ROSC ($p = 0.007$). An analysis including only events lasting longer than 20 minutes demonstrated an increase in the rates of ROSC with mechanical CPR as well ($p = 0.04$).

For the secondary outcome of survival to discharge, we found that the use of mechanical CPR was associated with an increase in survival: 19 of the 59 patients (32.2%) who received mechanical CPR survived to discharge versus five of the 45 patients who received manual CPR (11.1%, $p = 0.02$) (**Fig. 2**). A multivariate analysis demonstrated that the use of mechanical CPR was still associated with an increase in survival to discharge ($p = 0.02$). In an analysis including only patients who suffered events lasting at least 10 minutes, we found that six of the 18 patients who received mechanical CPR survived to discharged (33.3%) versus one of 26 patients who received manual CPR (3.8%, $p = 0.04$). Finally, an analysis including patients who suffered cardiac arrests lasting longer than 20 minutes two out of nine patients who received mechanical CPR survived to discharge (22.2%) compared with one out of 13 patients who received manual CPR (7.6%, $p = 0.5$).

For the outcome of survival with a favorable neurologic impairment, we found that of the 24 patients who survived to discharge, a total of 21 patients survived with favorable neurologic outcomes. We found that all 19 patients who received mechanical CPR and survived to discharge had a favorable neurologic outcome (100%) versus two out of five patients who received manual CPR and survived to discharge with a favorable neurologic outcome (40%, $p = 0.005$). In multivariate analysis, the use of mechanical CPR showed an increased trend in survival with a favorable neurologic outcome ($p = 0.06$). Finally, all

TABLE 2. Demographics and Patient Characteristics.

Patient Characteristics	Mechanical CPR	Manual CPR
Number of patients	59	45
Age, median (SD)	73.5 (±13.3)	71 (±15.2)
Male sex, *n* (%)	41 (68.3%)	32 (71.1%)
Location, *n* (%)		
ICU	43 (71.7%)	29 (64.4%)
Telemetry	12 (20%)	11 (24.4%)
Nontelemetry	3 (5%)	3 (6.7%)
Other location (electrophysiology lab, dialysis, etc.)	2 (3.3%)	2 (4.4%)
Initial Rhythm, *n* (%)		
Ventricular tachycardia/ventricular fibrillation	10 (16.7%)	7 (15.6%)
Pulseless electrical activity/asystole	50 83.3%)	38 (84.4%)
Suspected cause, *n* (%)		
Respiratory failure	17 (28.3%)	14 (31.1%)
Unknown	15 (25%)	11 (24.4%)
Cardiac	13 (21.7)	7 (15.6%)
Sepsis	4 (6.7%)	3 (6.7%)
Other (pulmonary embolism, myocardial infarction, etc.)	11 (18.3)	10 (22.2%)
Return of spontaneous circulation, *n* (%)	49 (83%)	22 (48.8%)
Survival to discharge, *n* (%)	19 (32.2%)	5 (11.1%)
Survival with favorable neurologic outcome, *n* (%)	19 (100%)	2 (40%)

CPR = cardiopulmonary resuscitation.

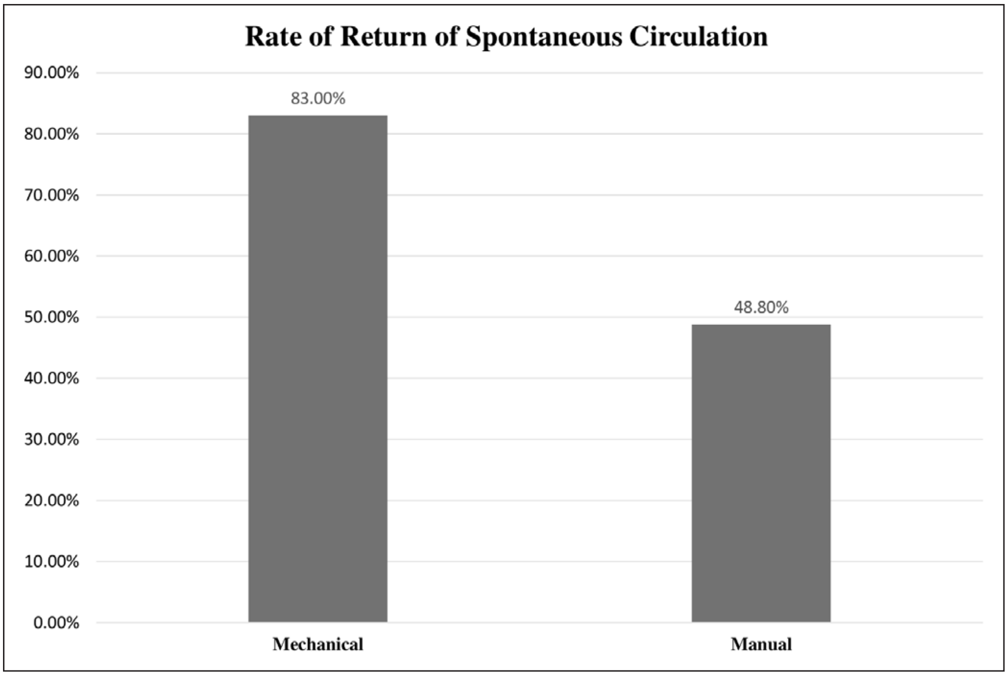

Figure 1. Bar chart demonstrating differences in the rates of return of spontaneous circulation for patients who received mechanical vs manual cardiopulmonary resuscitation.

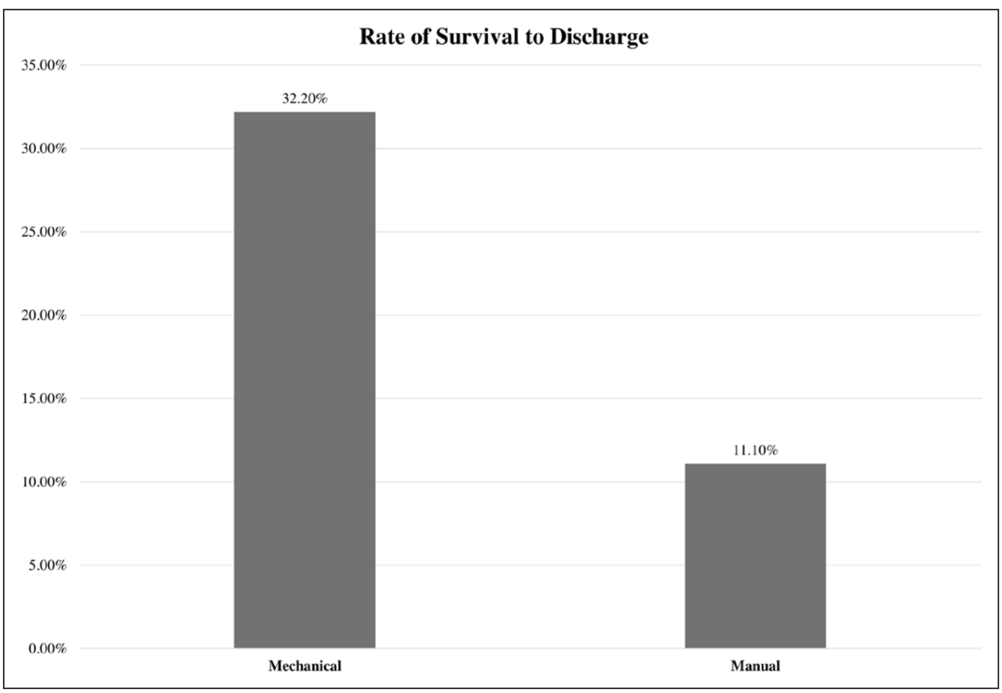

Figure 2. Bar chart demonstrating differences in the rates of survival to discharge for patients who received mechanical vs manual cardiopulmonary resuscitation.

three patients who had survived to discharge with a poor neurologic outcome received manual CPR.

DISCUSSION

Our single-center retrospective investigation of cardiac arrests in the inhospital setting demonstrates that there is a significant association with the use of mechanical CPR and improved rates of ROSC, survival to discharge, and survival with favorable neurologic outcomes. These results remained robust after multivariate modeling to control for confounding variables.

Although the use of mechanical CPR has been studied extensively, there is a paucity of evidence for the use of mechanical CPR devices in the inhospital setting. Proponents of mechanical CPR advocate for these devices as they offer continuous CPR with minimal interruptions, there is no possibility for CPR fatigue during a resuscitation, and healthcare workers can be freed up to complete other tasks. However, there have been few studies to demonstrate a meaningful increase in outcomes. Multiple systematic reviews have demonstrated that mechanical CPR is noninferior to manual CPR and may even be associated with a worse neurologic outcome (12–14). These investigations were almost entirely based on resuscitations in the out-of-hospital setting or in EDs. To the best of our knowledge, there are no recent studies to investigate the impact of mechanical CPR in the inhospital setting.

This investigation is the first to demonstrate an improvement in outcomes from IHCA with mechanical CPR. Due to the observational nature of this study, we are unable to determine causation. However, we believe there are a couple of reasons that mechanical CPR may be associated with improved outcomes, including less pauses/interruptions in CPR (which has been associated with worse outcomes), as mechanical CPR provides continuous, high-quality compressions and reduced rescuer fatigue. Additionally, the use of mechanical CPR allows healthcare providers to focus on other critical aspects of the resuscitative effort.

There are also potential adverse effects with the use of mechanical CPR. These include the time to device application, the device being applied incorrectly, potential solid organ injury including liver laceration, diaphragmatic injury, damage to inferior vena cavan, and more. Finally, it is possible there is incomplete recoil of the chest with mechanical CPR. Granted, some of these adverse effects can be mitigated with proper training. However, there are case reports of patients succumbing to solid organ injury after a successful resuscitation with mechanical CPR

(19). Additionally, mechanical CPR devices vary in their structure and design and certain devices use a suction cup to ensure that complete chest recoil is obtained.

Our investigation has limitations, including our small sample size and single center design. Additionally, the retrospective design of our study is a limitation as we reviewed records that were documented during chaotic events, and thus, there could be inaccuracies in documentation. We attempted to mitigate this by excluding poorly documented records. Another limitation is that we were unable to collect data on why patients received mechanical versus manual CPR during the resuscitation. A mechanical CPR device is brought to every resuscitation at our institution. However, mechanical CPR is not always used. It is possible that body habitus or other potential contraindications to the use of a mechanical CPR device may play a roll. However, we were unable to collect any data on the decision-making on the use of mechanical CPR or manual CPR. We believe the decision to use mechanical CPR is most likely based on provider preferences, which could certainly affect our results. Future investigations should include larger multicenter trials to validate our study results.

CONCLUSIONS

Our findings suggest that the use of mechanical CPR is associated with increases in ROSC, survival to discharge, and survival with a favorable neurologic outcome. Our results demonstrate the use of mechanical CPR may be beneficial to improving outcomes from IHCA.

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REFERENCES

1. Radeschi G, Mina A, Berta G, et al; Piedmont IHCA Registry Initiative: Incidence and outcome of in-hospital cardiac arrest in Italy: A multicentre observational study in the Piedmont region. *Resuscitation* 2017; 119:48–55
2. Girotra S, Nallamothu BK, Spertus JA, et al; American Heart Association Get With the Guidelines–Resuscitation Investigators: Trends in survival after in-hospital cardiac arrest. *N Engl J Med* 2012; 367:1912–1920
3. Nolan JP, Soar J, Smith GB, et al; National Cardiac Arrest Audit: Incidence and outcome of in-hospital cardiac arrest in the United Kingdom National Cardiac Arrest Audit. *Resuscitation* 2014; 85:987–992
4. Sandroni C, Nolan J, Cavallaro F, et al: In-hospital cardiac arrest: Incidence, prognosis and possible measures to improve survival. *Intensive Care Med* 2007; 33:237–245
5. Lundgren-Nilsson A, Rosén H, Hofgren C, et al: The first year after successful cardiac resuscitation: Function, activity, participation and quality of life. *Resuscitation* 2005; 66:285–289
6. Hofgren C, Lundgren-Nilsson A, Esbjörnsson E, et al: Two years after cardiac arrest; cognitive status, ADL function and living situation. *Brain Inj* 2008; 22:972–978
7. Esibov A, Banville I, Chapman FW, et al: Mechanical chest compressions improved aspects of CPR in the LINC trial. *Resuscitation* 2015; 91:116–121
8. Stapleton R: Comparing CPR during ambulance transport. Manual vs. mechanical methods. *JEMS* 1991; 16:63–64
9. Dickinson ET, Verdile VP, Schneider RM, et al: Effectiveness of mechanical versus manual chest compressions in out-of-hospital cardiac arrest resuscitation: A pilot study. *Am J Emerg Med* 1998; 16:289–292
10. Casner M, Andersen D, Isaacs SM: The impact of a new CPR assist device on rate of return of spontaneous circulation in out-of-hospital cardiac arrest. *Prehosp Emerg Care* 2005; 9:61–67
11. Bonnes JL, Brouwer MA, Navarese EP, et al: Manual cardiopulmonary resuscitation versus CPR including a mechanical chest compression device in out-of-hospital cardiac arrest: A comprehensive meta-analysis from randomized and observational studies. *Ann Emerg Med* 2016; 67:349–360.e3
12. Ong ME, Mackey KE, Zhang ZC, et al: Mechanical CPR devices compared to manual CPR during out-of-hospital cardiac arrest and ambulance transport: A systematic review. *Scand J Trauma Resusc Emerg Med* 2012; 20:39
13. Li H, Wang D, Yu Y, et al: Mechanical versus manual chest compressions for cardiac arrest: A systematic review and meta-analysis. *Scand J Trauma Resusc Emerg Med* 2016; 24:10
14. Wang PL, Brooks SC: Mechanical versus manual chest compressions for cardiac arrest. *Cochrane Database Syst Rev* 2018; 8:CD007260
15. Taylor GJ, Rubin R, Tucker M, et al: External cardiac compression. A randomized comparison of mechanical and manual techniques. *JAMA* 1978; 240:644–646
16. Hock Ong ME, Fook-Chong S, Annathurai A, et al: 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
17. Andersen LW, Grossestreuer AV, Donnino MW: "Resuscitation time bias"-a unique challenge for observational cardiac arrest research. *Resuscitation* 2018; 125:79–82
18. Soar J, Andersen LW, et al: Part 4: Advanced life support. *Resuscitation* 2015; 95:71–120
19. Deras P, Manzanera J, Millet I, et al: Fatal pancreatic injury due to trauma after successful cardiopulmonary resuscitation with automatic mechanical chest compression. *Anesthesiology* 2014; 120:1038–1041