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Peer-Reviewed Review Article

Modeling Hospital-Wide Extracorporeal Cardiopulmonary Resuscitation: Pros and Cons

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Abstract

Background

We aimed to analyze the potential benefits of implementing a hospital-wide extracorporeal cardiopulmonary resuscitation (ECPR) protocol.

Methods

We analyzed in-hospital cardiac arrests in a large, academic hospital for two consecutive years. For this model, we assumed that ECPR would be started in all adults, with no upper age limit, who have a full code status. We excluded codes lasting <15 minutes, arrests with asystole as an initial rhythm, and patients with hemorrhagic shock or who coded due to new stroke (contraindications for anticoagulation). We calculated how many extra lives could be saved per year if ECPR was initiated during each code meeting these criteria.

Results

During two consecutive years, a total of 710 in-hospital cardiac arrests occurred. We excluded 91 codes due to bleeding or new stroke, 96 cases with asystole as an initial rhythm, and 206 codes lasting less than 15 minutes. In the remaining 317 codes, ECPR could have been used. In 229 cases out of 317, patients survived conventional CPR, so ECPR would be futile.

Out of remaining 88 codes, only 38 (3.5%) were due to reversible cardiac or non-cardiac emergencies and resulted in death. They could have favorable outcomes if ECPR was used. Using the Extracorporeal Life Support Organization data, survival to discharge after ECPR is about 30%. So, we estimate that 13 patients (1.2%) could have been saved in 2 years, or ~7 patients per year. Considering 317 veno-arterial extracorporeal membrane oxygenation (VA ECMO) initiations, the ratio would be 24.4 VA ECMO initiations per one life saved.

Conclusion

An implementation of a hospital-wide ECPR could change outcomes from unfavorable to favorable in 1.2% of patients, at the cost of initiation of 24.4 VA ECMO initiations per one life saved.

Keywords: extracorporeal membrane oxygenation, extracorporeal cardiopulmonary resuscitation, cardiac arrest

Background

The public health burden of cardiac arrests in US is high and has been reported to be about 292,000 per year among adults and rising (1). The survival rate for patients who have an in-hospital arrest is variable and reported to be around 25% (2). These numbers reflect an improvement from past records and have been possible because of the introduction of efficient cardiopulmonary resuscitation (CPR) techniques and drugs along with the introduction of new technology, such as mechanical circulatory and ventilatory support.

Extracorporeal CPR (ECPR), or CPR assisted by veno-arterial extracorporeal membrane oxygenation (VA ECMO) implanted during active resuscitation effort, has been reported to have better survival outcomes when compared to conventional CPR in recent studies (3-5). The mechanical CPR, Hypothermia, ECMO and Early Reperfusion (CHEER) Trial demonstrated a survival rate as high as 54% when used in conjunction to a hypothermia protocol (6).

ECMO is used to support circulation as well as oxygenation in a patient who has had an arrest. According to the 2019 update of American College of Cardiology/American Heart Association (ACC/AHA) guidelines, the use of ECPR can be considered in selected patients as rescue therapy when conventional CPR efforts are failing in settings in which it can be expeditiously implemented and supported by skilled providers (7).

The foreknowledge of the potentially reversible causes is not always possible; thus, when a patient codes in a hospital, CPR is initiated, and a search is undertaken simultaneously for a cause of the arrest. If, after 10-15 minutes of conventional CPR, return of spontaneous circulation (ROSC) is not achieved, alternative options, such as mechanical support, are considered. When ECPR is used, it needs to be deployed swiftly to achieve favorable outcome. Even when used promptly, only about 30% patients will survive till discharge (8).

One of the key differences between conventional CPR and ECPR is resource intensity. ECPR is a resource intensive tool and requires a trained cannulator within a stipulated time period and incurs significant costs. Thus, ECPR should be used judiciously and in a selective group of patients.

This study was designed to estimate the number of lives that could have been saved if ECPR was used for in-hospital cardiac arrests at a single center. This was a retrospective study with hypothetical modeling as a randomized clinical trial would be potentially unethical as it would involve withholding a life-saving intervention for one cohort.

Methods

This was a retrospective study in a university tertiary care hospital. The study was approved by the local institutional review board.

Data were collected by reviewing all handwritten code sheets for two consecutive years (2017 and 2018). Code sheets are logged and maintained for each code that occurs in the hospital.

The data points collected from the code sheets included age, sex, date, time and duration of code, survival of code, history of multiple codes, and initial rhythm (ventricular tachycardia, ventricular fibrillation, asystole, sinus, atrial flutter/fibrillation, other).

Electronic medical records were used to collect the date of admission and discharge, history of arrest at home prior to arrival, cause of arrest (sepsis, medical accident, ischemic or hemorrhagic stroke, bleeding, cardiac or medical emergency), survival of hospital stay, utilization of ECMO, and contraindications to anticoagulation (ischemic or hemorrhagic stroke and bleeding) or ECMO use (initial asystole, contraindication to anticoagulation or code <15 mins). Medical accidents included arrests during manipulation of feeding tubes, ventilators or tracheostomy tubes, dialysis catheters, accidental interruptions of the airways during suction, etc.

All adult patients who underwent CPR for in-hospital cardiac arrest, with no upper age limit, were screened.

We excluded the following categories: age<18 years, pregnant, “do not resuscitate” status, arrest occurred out of hospital, respiratory codes (defined as intubation only with no chest compressions), and codes when family stopped resuscitation efforts while the code was in progress.

The following limitations were applied in potential use of ECPR as these would amount to wasteful use of resources:

1. Code duration less than 15 minutes (putting patient on ECMO in under 15 minutes is not feasible)
2. Contraindications to anticoagulation (we excluded bleeding and stroke, both ischemic and hemorrhagic, as etiology of the code).
3. Asystole as initial rhythm

The survival rate estimated from the Extracorporeal Life Support Organization (ELSO) registry (8) of 30% was used to estimate the number of lives that could have been saved every year by applying ECPR to all patients were compared to selective group.

Results

During 2017 and 2018, a total of 1244 codes were recorded, and the management and outcomes were documented on code sheets. We excluded 534 codes for the following reasons: 202 arrests occurred out of hospital, but resuscitation continued on arrival; 160 arrests were respiratory in nature and required intubation but no chest compressions; family stopped the efforts in 59 cases; 99 arrests were in patients younger than 18 years of age; and 54 more arrests were excluded for less frequent reasons like accidentally starting CPR on a patient with "do not resuscitate" status. Our final sample consisted of 710 in-hospital cardiac arrests (Figure 1).

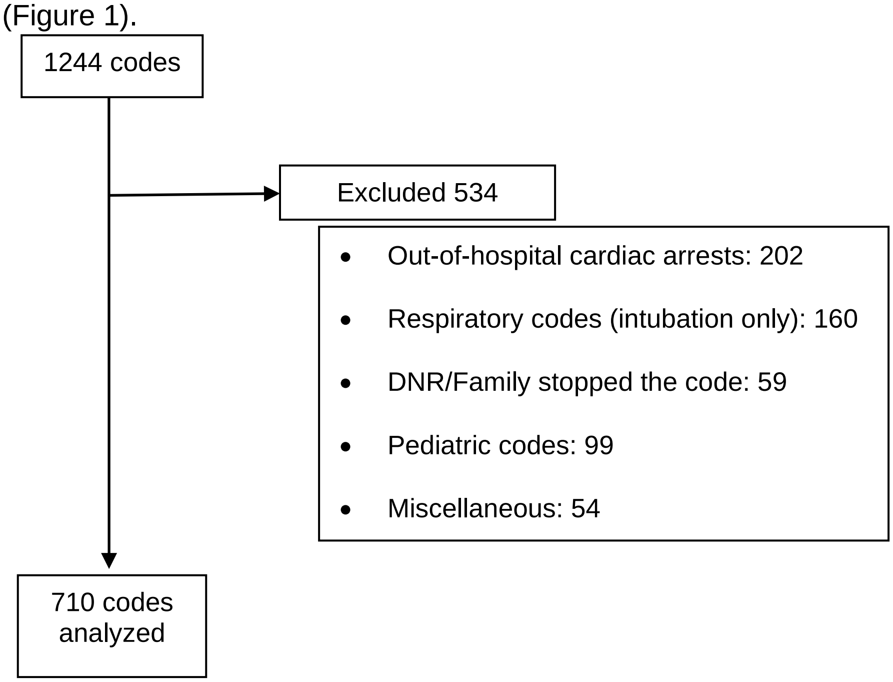

Figure 1. *Flowchart: patient selection*

The mean age of this population was 59+/- 14.5 years. The arrests occurred in males in 444 cases (62.5%) and in females in 266 cases (37.4%). The mean duration of the code was 22.8 +/-19 minutes.

Based on the etiology of the cardiac arrests, we categorized the cases into the following groups: cardiac emergencies (such as electric storm in a patient with known cardiomyopathy or acute myocardial infarction); medical emergencies (e.g. aspiration, hyperkalemia, etc); arrests in patients with known chronic disease with poor prognosis (known multiple myeloma, metastatic cancer, anoxic brain injury after prior arrest); cardiac arrest in a septic patient, hemorrhagic shock, acute stroke (ischemic or hemorrhagic); and medical accidents. The latter group accounted for only 3.2% of arrests, but it was distinctly different from any other group, so we separated these codes from the rest. They represented codes resulting from accidental fault of equipment, e.g. disconnection of the endotracheal tube from the ventilator during turning the patient in bed. These codes were always witnessed, etiology was clear, and resuscitation resulted in a ROSC in 96% of the cases (Table 1). Interestingly, survival to discharge was only 56.5% even in this population (Figure 2).

Table 1: Distribution of codes by etiology of cardiac arrest

Cause	**Total**		**Survived code**		**Discharged alive**	
Cardiac emergency	249	35.1%	199	79.9%	99	39.8%
Medical emergency	54	7.5%	43	81.1%	31	58.5%
Terminal illness	129	18.2%	95	73.6%	13	10.1%
Bleeding	43	6.1%	27	62.8%	10	23.3%
CVA	48	6.8%	39	81.3%	14	29.2%
Sepsis	164	23.1%	118	72.0%	19	11.6%
Medical accident	23	3.2%	22	95.7%	13	56.5%
Total	710	100	543	76.5%	199	28.0%

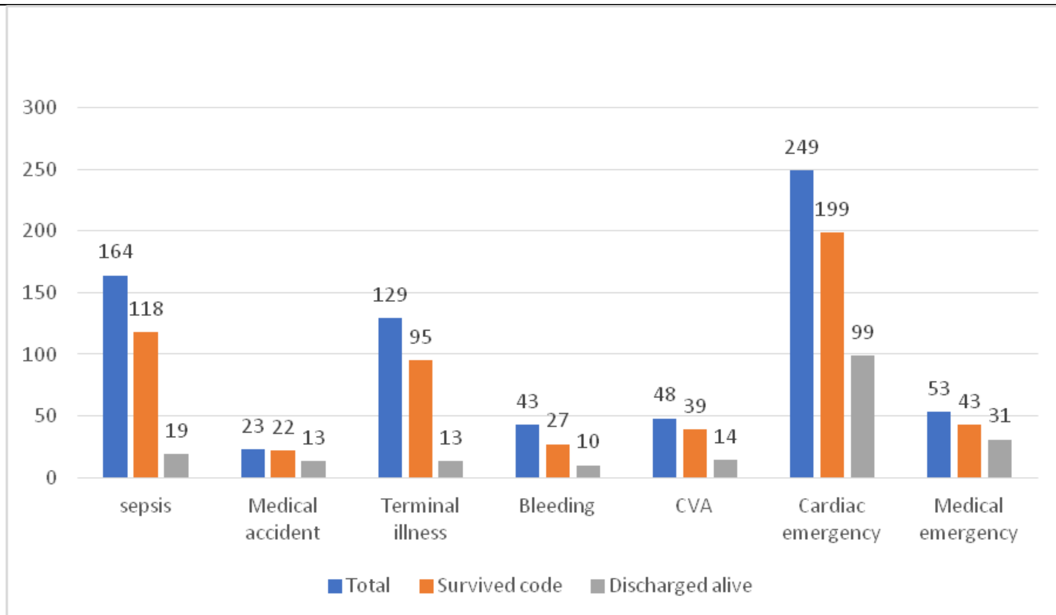

Figure 2. *Survival to return of spontaneous circulation and to discharge based on the etiology of cardiac arrest.*

Despite high code survival rates, even in patients with known terminal illness, survival to discharge was very low in this category (10.1%) and in sepsis (11.6%).

Modeling potential use of ECPR, we applied our prespecified criteria.

1. We decided not to consider ECPR if there were contraindications for anticoagulation. Therefore, arrests due to hemorrhagic shock (43) and acute stroke, ischemic or hemorrhagic (48), were excluded. This left us with 619 cardiac arrests for potential ECMO utilization.

2. In 206 cases, resuscitation lasted for less than 15 minutes, and ECMO could not be deployed for pure logistical reasons.

3. In 96 cases, initial rhythm was asystole.

After these cases were excluded, there were 317 cases where ECMO would be used. In 229 cases out of 317, patients survived conventional CPR, so ECPR would be futile.

Out of remaining 88 codes, only 38 patients had potentially reversible cardiac or non-cardiac emergencies. 50 patients had a “full code” status, but they had either sepsis/septic shock (28 cases) or known terminal condition (e.g. liver cirrhosis, severe chronic obstructive pulmonary disease with several weeks of ventilator support, metastatic cancer, anoxic brain injury after prior cardiac arrest, etc.) (22 cases), and ECPR would be futile because of the overall poor prognosis.

Therefore, 38 of the 710 cardiac arrests (3.5%) occurred due to potentially reversible conditions and could have favorable outcomes if ECPR was used. Per the ELSO data, survival to discharge after ECPR is about 30% (8). So, 13 patients (1.2%) could be saved in 2 years, or 7 patients per year. Considering the 317 ECMO initiations needed, the ratio would be 24.4 ECMO initiations per one life saved.

Discussion

From the model described, the effort to deploy ECMO for all cases of CPR would result is a very high resource utilization per life saved. The situation is even more complicated if we consider the urgency of decision making. The decision to use ECMO should be made almost immediately because the chance of meaningful survival decreases with each minute of the code. The time required to activate the extracorporeal life support (ECLS) team and start the actual flow of circuit while CPR is being performed needs to be considered. Wengemayer et al. demonstrated survival rate of 67% when CPR duration was shorter than 2 minutes; the rate decreased to 29%, 10%, and 6% after 20-45, 45-60, and over 60 minutes, respectively (9). Haneya et al. showed a 70% chance of survival to discharge when interval from CPR to ECLS was less than 15 minutes and only 50%, 27% and 11% with increasing interval of 15-30 minutes, 30-45 minutes and 45-60 minutes, respectively(10). If ECMO is selectively dispatched for potentially reversible emergencies, the ratio appears to be more favorable.

As reported by one study, 61% of patients survived ECPR and 30% survived to discharge after excluding patients with contraindications for anticoagulation, over 70 years of age; a “Do Not Resuscitate” order, a terminal illness, advanced coronary artery disease, or a previous neurologic deficit (11). Another study reported 58% of patients were successfully weaned from ECMO when it was applied selectively for refractory in-hospital cardiac arrests after excluding patients with terminal malignancies, aortic dissection, severe peripheral arterial disease, severe cardiac failure without indication for heart transplant or severe aortic failure. These exclusions mirror contraindications for the use of ECMO and thereby represent a selective use of ECMO.

Another study included both out of hospital (24%) and in-hospital cardiac arrests (76%); when ECPR was used for refractory cardiac arrests, survival to discharge was 35% irrespective of etiology of the arrest (12). The survival to ICU discharge outcome was reported as only 41% (12). Survival after ECPR was used as the outcome in our study as opposed to survival to ICU discharge; the discharge outcome may be a more reflective outcome. The CHEER trial also demonstrated a better survival rate of 54%; however, this trial included only cardiac arrests due to suspected cardiac etiology and chest compressions commenced within 10 minutes (6).

In our study 24.4 ECMO initiations would have to be done to save one life when ECMO is used selectively.

The urgency and complexity of decision making regarding the use of VA ECMO during CPR brings up a possibility stratifying the code status into “full code ECPR eligible”, “full code no ECPR”, and “do not resuscitate”.

Limitations

This is a retrospective single center study, which may limit applicability of our conclusions to other medical centers.

Conclusion

Our retrospective analysis of in-hospital cardiac arrests highlighted the complexity of implementing hospital-wide ECPR. In our experience, an implementation of hospital-wide ECPR could change outcomes from unfavorable to favorable in 1.2% of patients, at the cost of the initiation of 24.4 VA ECMO procedures per one life saved. Given the high resource requirements and urgency of decision making, an upfront stratification of code status into “full code ECPR eligible” and “full code ECPR ineligible” may facilitate focus on potentially salvageable patients with favorable long-term prognoses.

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