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Clinical paper

Cost-utility of extracorporeal cardiopulmonary resuscitation in patients with cardiac arrest

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Abstract

Background: Extracorporeal cardiopulmonary resuscitation (ECPR) is a resource-intensive tool that provides haemodynamic and respiratory support in patients who have suffered cardiac arrest. In this study, we investigated the cost-utility of ECPR (cost/QALY) in cardiac arrest patients treated at our institution.

Methods: We performed a retrospective review of patients who received ECPR following cardiac arrest between 2012 and 2018. All medical care-associated charges with ECPR and subsequent hospital admission were recorded. The quality-of-life of survivors was assessed with the Health Utilities Index Mark II. The cost-utility of ECPR was calculated with cost and quality-of-life data.

Results: ECPR was used in 32 patients (15/32 in-hospital, 47%) with a median age of 55.0 years (IQR 46.3–63.3 years), 59% male and 66% African American. The median duration of ECPR support was 2.1 days (IQR 0.9–3.8 days). Survival to hospital discharge was 16%. The median score of the Health Utilities Index Mark II at discharge for the survivors was 0.44 (IQR 0.32–0.52). The median operating cost for patients undergoing ECMO was $125,683 per patient (IQR $49,751–$206,341 per patient). The calculated cost-utility for ECPR was $56,156/QALY gained.

Conclusions: The calculated cost-utility is within the threshold considered cost-effective in the United States (<$150,000/QALY gained). These results are comparable to the cost-effectiveness of heart transplantation for end-stage heart failure. Larger studies are needed to assess the cost-utility of ECPR and to identify whether other factors, such as patient characteristics, affect the cost-utility benefit.

Keywords: Extracorporeal cardiopulmonary resuscitation, Advanced cardiac life support, Extracorporeal membrane oxygenation, Cardiac arrest, Cost, Cost-utility

Abbreviations: ECPR, extracorporeal cardiopulmonary resuscitation; VA ECMO, veno-arterial extracorporeal membrane oxygenation; ROSC, return of spontaneous circulation; QALY, quality-adjusted life year; HUI, Health Utilities Index.

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https://doi.org/10.1016/j.resuscitation.2019.01.027
Received 9 January 2019; Accepted 23 January 2019
0300-9572/

Introduction

Extracorporeal cardiopulmonary resuscitation (ECPR) refers to the use of veno-arterial (VA) extracorporeal membrane oxygenation (ECMO) for cardiac arrest refractory to traditional CPR. This life-saving tool provides haemodynamic and oxygenation support and serves as a bridge to definitive therapy or recovery.[1,2] ECPR may allow time for recuperation from the underlying aetiology that resulted in cardiac arrest or it may stabilize the patient to allow for corrective interventions, such as coronary revascularization in cases of ischaemia. In instances of irrecoverable damage to the heart, ECPR serves as a bridge to cardiac transplantation or implantation of a left ventricular assist device.

Recent advances in technology and promising outcomes have led to rapid adoption of ECPR at many centers.[3–9] Yet, ECPR is known to be resource-demanding and is perceived to be associated with a high cost burden. Recent calls for health care systems to use evidence-based practice and to factor costs into clinical decision-making are pervasive.[10–12] Given increasing pressure to curtail costs, determining the value of ECPR is critical.

The primary objective of our study was to assess the costs of ECPR and subsequent in-hospital treatment of adult cardiac arrest patients. A recent systematic review of the majority of studies evaluating ECPR costs have been performed in pediatric and neonatal populations, and these studies have large variations in the reported in-hospital costs.[13] To our knowledge, there are no analyses of the cost-utility of percutaneous ECMO for ECPR in cardiac arrest.

Methods

Data collection and assumptions

This single-center, retrospective registry review identified patients by inclusion in an investigational registry of all patients undergoing ECPR at our institution. All cases of ECPR between June 1, 2012 and January 31, 2018 were included. With the approval of the hospital institutional review board, data was collected from both the electronic medical record and from a database of hospital charges and costs. Adult patients suffering either in-hospital or out-of-hospital cardiac arrests were included. ECPR was defined as the initiation of percutaneous VA ECMO following cardiac arrest. All patients reached some degree of return to spontaneous circulation prior to initiation of ECPR, however subsequently had recurrent episodes of cardiac arrest that were unremitting to traditional CPR. Exclusion criteria included the absence of charge or cost data. The primary outcome was cost-utility, which calculates the cost per quality-adjusted life-ear (QALY) saved. Costs are reported in 2018 US dollars.

Costs of hospitalization from the time of institution of ECMO to hospital discharge were obtained and calculated as total operating charges, a sum of both direct and indirect (or overhead) costs. Direct costs are expenses that provide and charge for patient care, including all chargeable items, non-physician personnel time, and physician charges. The type of ECPR pump, CARDIOHELP (Maquet, Wayne, NJ, USA) or CentriMag™ Pump (Thoratec, Pleasanton, CA, USA), was also collected for each patient. The costs at other hospitals and the cost of transportation were not included.

The Health Utilities Index Mark II (HUI-2) was used to evaluate quality of life and make comparisons between ECPR and other health interventions.[14] The HUI-2 is a questionnaire composed of 15 items that is used to derive a utility function score and categorize health status. Scores range from death (score of 0.00) to full health (score of 1.00). The HUI-2 has been shown to have reasonable reliability and has been applied to a number of other disease states, primarily in the pediatric population.[15] For our study, the investigators assigned questionnaire responses to each survivor via review of physical and occupational therapy documentation on the electronic medical record regarding functional status at the time of discharge.

This study was limited to patients receiving ECPR. For simplicity in modeling, we assume that mortality would be 100% had the patients not been placed on VA ECMO. The costs and life-years saved were therefore calculated from the time of institution of VA ECMO. Life expectancy was assumed to be 78.6 years, according to recent data from the National Center for Health Statistics System for 2016.[16]

Sensitivity analysis

For cost-utility analysis, we assessed the sensitivity of our model by varying hospital mortality and functional status. We varied the hospital mortality for ECPR in cardiac arrest patients from 16% to 30% given recent evidence of varying survival rates at hospital discharge.[17] A range of 0.24–0.84 was also applied to the health utility score to account for the possibility that a patient's health status may improve in later years of life.

Results

ECPR was instituted in 32 patients (Table 1). The mean and median age was 52.5 (±16.3) and 55.0 years (IQR 46.3–63.3 years), respectively. The aetiology of cardiac arrest prompting ECPR were variable, including myocardial infarction (n = 11), massive pulmonary embolism (n = 5), post-surgery complications for various reasons including post-TAVR (n = 1), post-ASD repair (n = 1), and air embolus (n = 1), post-viral cardiomyopathy (n = 2), amniotic fluid embolus (n = 1), fat emboli syndrome (n = 1), anomalous origin of the left main coronary artery (n = 1), acute chest syndrome (n = 1), acute

Table 1 – Patient demographics of all subjects receiving ECPR after cardiopulmonary arrest.

Number of patients	32
Average age, years (std dev)	52.5 (16.3)
Male, no. (%)	19 (59%)
African American, no. (%)	21 (66%)
Cause of arrest, cardiogenic shock secondary to	
Myocardial Infarction, no. (%)	11 (34%)
Surgical Complication*, no. (%)	3 (9%)
Pulmonary Emboli, no. (%)	5 (16%)
Other**, no. (%)	13 (41%)
Type of arrest	
Ventricular Tachycardia/Fibrillation, no. (%)	19 (59%)
Pulseless Electrical Activity/Asystole, no. (%)	13 (41%)
Location of arrest	
In-hospital, no. (%)	15 (47%)
Out-of-hospital, no. (%)	17 (53%)
1-Year Survival, no. (%)	5 (16%)

*post TAVR, post ASD repair, and air embolus during surgery. **viral cardiomyopathy, amniotic fluid embolus, fat emboli, non-ischaemic cardiomyopathy, idiopathic pericardial effusion, acute decompensated heart failure, acute chest syndrome and unknown etiologies.

decompensating heart failure (n = 3), idiopathic acute pericardial effusion (n = 1) as well as unknown causes (n = 3).

The mean and median duration of ECPR support was 2.8 (±2.4) and 2.1 days (IQR 0.9–3.8 days), respectively. 69% (22/32) patients underwent ECPR via CARDIOHELP System (Maquet, Wayne, NJ, USA) whereas 22% (7/32) were supported on the CentriMag™ Pump (Thoratec, Pleasanton, CA, USA). Data regarding type of device was unavailable for three patients. The mean and median duration of hospital stay was 11.5 (±13.9) and 4.3 days (IQR 2.1–19.3 days), respectively. Survival to hospital discharge was 16%. Three of the five survivors were discharged home with home health services, one survivor was discharged to subacute rehabilitation and one survivor was discharged to acute rehabilitation. Survival to 1 year for the entire cohort was 16% with 27 patients not surviving to hospital discharge. All of these deaths occurred while subjects were still receiving VA ECMO support or within 72 h of de-cannulation. The most common cause of death (n = 11) was myocardial infarction.

Hospital costs

The mean and median operating cost for patients undergoing ECPR was $156,263 and $125,683 per patient (IQR $49,751–$206,341 per patient, see Table 2), respectively. Operating costs ranged from $9,245 to $942,681. There was significant variation in cost even among survivors, ranging from $139,581 to $336,698. Patients supported with the CARDIOHELP system had a median operating cost of $75,793 (IQR $49,350–$154,505 per patient). Patients supported with CentriMag™ Pump had a median operating cost of $220,721 (IQR $195,622–$238,551). Additionally, out-of-hospital cardiac arrests reported a median operating cost of $69,731 (IQR $45,655–$120,532, n = 17) whereas in-hospital cardiac arrests reported a median operating costs of $176,703 (IQR $133,264–$277,436). The median cost per 24 h of ECPR support was $60,937 (IQR $24,122–$100,044).

Health Utilities Analysis

The mean score of the HUI-II at discharge for the survivors was 0.44 (IQR 0.32–0.52). Three of five patients had severe impairment and disability (utility <0.5) at the time of hospital discharge.

Cost-utility analysis

The calculated cost-utility for ECPR in this population was $56,156/QALY saved. Sensitivity analysis is shown in Fig. 1. Using the utility score calculated, but varying the in-hospital survival for ECPR between 16 % and 30%, resulted in a range of cost-utility ratios from $29,950 to $56,156 per QALY saved. Assuming a hospital survival of 16% but varying the utility scores from 0.24 to 0.84 resulted in a range in calculated cost-utility from $29,323 to $103,520 per QALY.

Table 2 – Hospital costs for ECPR.

Median length of stay (days)	4.3
Median duration of ECMO (days)	2.1
Median direct cost (USD)	$68,936.88
Average direct cost (USD)	$91,505.85
Median indirect cost (USD)	$52,386.48
Average indirect cost (USD)	$64,757.51
Median operating cost (USD)	$1,25,683.00
Average operating cost (USD)	$1,56,263.36
Median payer charges (USD)	$6,50,111.21
Average payer charges (USD)	$7,71,594.59
Cost per QALY saved (USD)	$56,156.40

QALY, quality-adjusted life-year; USD, United States dollars.

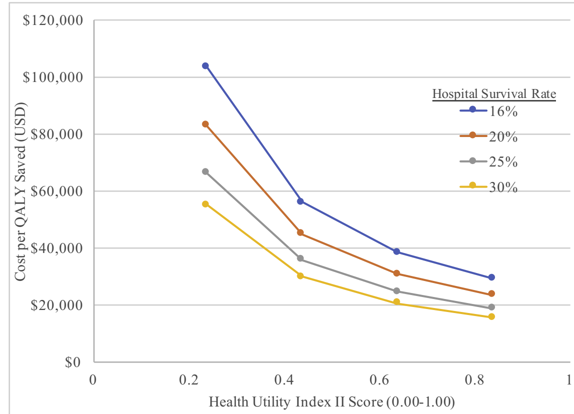

Fig. 1 – Sensitivity analysis of cost-utility for extracorporeal cardiopulmonary resuscitation varying the survival rate and health utility score.
QALY, quality-adjusted life-year; USD, United States Dollar.

Discussion

The challenge of all cost-utility analyses is determining which threshold value ($-per-QALY) is representative of cost-effectiveness. The literature has traditionally suggested $50,000-per-QALY as a reasonable threshold since as early as 1982.[18] However, recent evidence has challenged this limit and suggested a much higher cut-off for value (closer to $150,000-per-QALY).[19,20]

Our analysis indicates that the use of ECPR costs $56,156 per QALY saved, which falls within contemporary thresholds of cost-effectiveness. Moreover, the sensitivity analysis produced a possible cost-utility range of $15,639–$103,520 per QALY saved. Therefore, assuming the least favorable scenario – significantly lower hospital mortality and reported health utility than was observed in our cohort– the cost-utility of ECPR remains $103,520 per QALY gained, which falls within the threshold of $150,000-per-QALY. This cost-effectiveness is similar to reported measures for dialysis ($72,476/QALY), kidney transplantation ($39, 939–$80,486/QALY), and orthotopic heart transplantation (<$100,000/QALY).[21,22] This overlap of cost-effectiveness may provide further evidence to the claim of general acceptability.

The independent variables that influence cost-utility in our analysis are survival rate, quality of life following ECPR, and contributors to total operating costs. Examining each variable in turn may provide further insight into mechanisms to improve cost-effectiveness. In terms of survival, a recent systematic review sought to describe typical rates of survival following ECPR, but significant heterogeneity and small sample sizes limit interpretation.[17] In one analysis, Beyea et al. reported an 8.3–41.6% survival to discharge with a good neurologic outcome for patients treated with ECPR in a cohort study.[23] Additional survival analyses have reported other clinical variables that were strongly associated with mortality, including the presence of ongoing CPR at the time of ECMO initiation, arrest to cannulation time, initial shockable rhythm, and age.[24–26] In addition, multiple risk scores integrating biomarkers, pH, and laboratory values have been created to predict hospital mortality with high reliability.[27,28]

Typically, the same measures that are associated with better survival are also associated with improved quality of life, and in particular, neurological outcome. The duration of cardiac arrest to ECMO, specifically an estimate of 40 minutes, has been significantly associated with good neurological outcomes.[29] In terms of cost, the type of ECMO device (i.e. CARDIOHELP vs CENTRIMAG) has considerable differences in hardware and disposable costs for the range of devices avaialbe.[30] Other measures impacting costs include whether cardiac arrest occurred in-hospital or out-of-hospital. Larger studies are needed to assess the cost-utility of ECPR and to identify whether other factors, such as patient characteristics and type of cannulae in addition to the aforementioned contributors, affect the cost-utility benefit.

A number of limitations to this study must be acknowledged. First, costs were only assessed at our institution. Therefore, the costs associated at secondary institutions or transportation were not included and cannot be assessed in relation to its impact on cost analysis. Similarly, the analysis did not account for medical costs incurred after hospital discharge for survivors (including outpatient follow-up visits, the cost of medications, outpatient imaging tests, or the cost of outpatient supportive healthcare like skilled nursing and long-term acute care), thereby underestimating the global costs of survival after ECPR. Third, we only assessed functional status after institution of ECPR. The HUI assessment does not account for baseline functional status. Analyzing the difference in functional status before and after ECPR would be a more precise measurement of quality of life preserved post-ECPR. Fourth, the reported operating costs were unable to exclude expenses related to other medical devices utilized during hospital stay for some patients, including but not limited to ventricular assist devices and intra-aortic balloon pumps, thus perhaps inflating ECPR costs. However, this contribution is small for the entire data set and is not expected to substantially contribute to the reported costs.

Conclusions

ECPR in the setting of refractory cardiac arrest is cost-effective at our institution. The use of ECPR costs $56,156 per QALY saved. Larger, multicenter studies are required to assess the generalizable cost-utility of ECPR.

Conflicts of interest statement

There are no conflicts of interest to disclose.

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