A comprehensive regional clinical and educational ECPR protocol decreases time to ECMO in patients with refractory out-of-hospital cardiac arrest

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ABSTRACT

Objective: Extracorporeal membrane oxygenation within CPR (ECPR) may improve survival for refractory out-of-hospital cardiac arrest (OHCA). We developed a prehospital, emergency department (ED), and hospital-based clinical and educational protocol to improve the key variable of time-to-ECPR (TTE).

Methods: In a single urban health region we involved key prehospital, clinical, and administrative stakeholders over a 2-year period, to develop a regional ECPR program with destination to a single urban tertiary care hospital. We developed clear and reproducible inclusion criteria and processes, including measures of program efficiency. We conducted seminars and teaching modules to paramedics and hospital-based clinicians including monthly simulator sessions, and performed detailed reviews of each treated case in the form of report cards. In this before-and-after study we compared patients with ECPR attempted prior to, and after, protocol implementation. The primary outcome was TTE, defined as the time of initial professional CPR to establishment of extracorporeal circulation. We compared the median TTE for patients in the two groups using the Wilcoxon signed rank test.

Results: Four patients were identified prior to the protocol and managed in an ad hoc basis; for nine patients the protocol was utilized. Overall favourable neurological outcomes among ECPR-treated patients were 27%. The median TTE was 136 minutes (IQR 98 - 196) in the pre-protocol group, and 60 minutes (IQR 49 - 81) minutes in the protocol group ($p = 0.0165$).

Conclusion: An organized clinical and educational protocol to initiate ECPR for patients with OHCA is feasible and significantly reduces the key benchmark of time-to-ECPR flows.

RÉSUMÉ

Objectif: L'oxygénation par circulation extracorporelle (OCEC) en cours de réanimation cardiorespiratoire (RCR) peut améliorer la survie dans les cas d'arrêt cardiaque extrahospitalier (ACEH) réfractaire. Aussi avons-nous élaboré un protocole clinique et éducatif reposant sur le milieu préhospitalier, le service des urgences et le milieu hospitalier afin d'améliorer la principale variable temporelle liée à la RCR + OCEC.

Méthode: Des représentants importants des milieux préhospitalier, clinique et administratif ont travaillé, sur une période de deux ans, à l'élaboration d'un programme de RCR + OCEC dans une région sanitaire urbaine en vue du transport de malades vers un seul centre hospitalier de soins tertiaires, situé en ville. Ont été établis des critères d'inclusion et des processus précis et reproductibles, y compris des mesures d'efficacité du programme. Nous avons tenu des séminaires, préparé des modules d'enseignement à l'intention des ambulanciers paramédicaux et des cliniciens hospitaliers, organisé des séances mensuelles de formation par simulation, et procédé, sous forme de fiche, à l'examen détaillé de chacun des cas traités. Dans cette étude de type avant-après, il y a eu comparaison des patients soumis à des tentatives de RCR + OCEC avant et après la mise en œuvre du protocole. Le principal critère d'évaluation consistait en la mesure du temps écoulé avant la RCR + OCEC, défini comme le temps passé depuis le début des manœuvres de RCR par des professionnels jusqu'à l'établissement de la circulation extracorporelle. Nous avons comparé le temps médian écoulé avant la RCR + OCEC dans les deux groupes de patients à l'aide du test de Wilcoxon pour observations appariées.

Résultats: Quatre patients ont été retenus avant la mise en œuvre du protocole et pris en considération de façon

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CJEM 2017;19(6):424-433 DOI 10.1017/cem.2017.376

ponctuelle, tandis que neuf autres patients ont été soumis au protocole. La proportion de résultats neurologiques favorables chez les patients traités par la RCR + OCEC a atteint, dans l'ensemble, 27 %. Le temps médian écoulé avant la RCR + OCEC était de 136 minutes (écart interquartile [EIQ] : 98-196) dans le groupe antérieur à la mise en œuvre du protocole et de 60 minutes (EIQ : 49 - 81) dans le groupe soumis au protocole (p = 0,0165).

Conclusion: Les résultats de l'étude montrent qu'il est possible d'élaborer un protocole clinique et éducatif sur la pratique de la RCR + OCEC chez les patients victimes d'un ACEH, et que celui-ci permet de réduire considérablement la principale valeur de référence liée au temps écoulé avant la RCR + OCEC.

Keywords: extracorporeal membrane oxygenation, heart arrest, cardiopulmonary resuscitation

INTRODUCTION

North American emergency medical services (EMS) attend to 134 cases of out-of-hospital cardiac arrest (OHCA) per 100,000 adult citizens annually,[1,2] with survival ranging from 3%-16%.[1,2] Emerging data have suggested that extracorporeal cardiopulmonary resuscitation (ECPR), a form of veno-arterial extracorporeal membrane oxygenation (ECMO) implanted during cardiac arrest, may improve survival in certain patients with refractory OHCA.[3-6]

Several centres have described ECPR experiences; although inclusion criteria—chiefly, younger patients with both rapid arrest recognition and initiation of cardiopulmonary resuscitation (CPR)—have been similar, outcomes have varied.[4-12] Positive outcomes appear to be strongly correlated with the time from arrest-to-ECPR initiation: survival is rare if this number exceeds 75 minutes.[4,5,7-12] In ECPR studies comparing in-hospital arrests with OHCAs, patients in the latter group—despite often demonstrating better prognostic characteristics such as a younger age and higher proportion of shockable rhythms—demonstrate significantly worse outcomes than their hospitalized counterparts,[7,8] likely in part because of the substantial increase in the time to ECPR initiation.

While the community is the most likely place for a sudden unexpected cardiac arrest in a previously healthy patient, the ideal ECPR candidate, there are logistical challenges in optimizing arrest-to-ECPR intervals for out-of-hospital patients with refractory arrest. At our institution, we recognized that in the small number of OHCAs that were treated with ECPR, the times required to initiate ECMO were prolonged. Further, as our prehospital system prioritizes on-scene resuscitation, with patients in refractory arrest uncommonly transported to the hospital, few could be considered for this therapy. For this reason, we developed a formal regional clinical ECPR protocol for OHCAs, the first of its kind in Canada, to improve the access and efficiency of ECPR initiation. The protocol included prehospital and hospital integration for early identification and transport of ECPR candidates, with rapid ECPR initiation upon hospital arrival for those who remained in refractory arrest. To achieve this, we instituted an intensive educational and quality improvement program, involving all members of the ECPR initiation team from each phase of care, to optimize time metrics. The primary goal of the ECPR service was to achieve expedited initiation of ECPR for appropriate patients; the aim of this study was to measure the change in times to ECPR initiation after protocol implementation.

METHODS

Study design and setting

This study was an observational before-and-after design examining the performance of a clinical protocol, which took place in a single health region including the cities of Vancouver and North Vancouver and the district municipalities of North Vancouver and West Vancouver, in the province of British Columbia (BC). The total land area is approximately 380 km^2 and contains a population of approximately 800,000 (73% between the ages of 15 and 65)[13] and four emergency departments (ED). The study hospital is St Paul's Hospital, a regional cardiac referral centre, which includes 24-hour access to cardiothoracic surgical services and cardiac catheterization, as well as cardiac transplant and ventricular assist device programs. The cardiovascular surgery program has provided ECPR services at St. Paul's Hospital since 2000 on a case-by-case basis, but with no formal protocol prior to the protocol described in this manuscript.[14] The ED treats approximately 85,000 patients annually.

https://doi.org/10.1017/cem.2017.376

This study protocol was submitted to and reviewed by the University of British Columbia (UBC)/Providence Healthcare Research Ethics Board but was deemed exempt from the requirements for researcher ethics approval both in accordance with UBC Policy and the provisions of the Tri-Council Policy because it was a classified as a quality improvement project.

Prehospital care

In BC, coordinated EMS is provided by municipal fire departments (FD) and the provincial Ambulance Service (BCAS). FD first responders are trained in basic life support (BLS)[15] including automated external defibrillators (AED). There are approximately 20 BLS[15] paramedic teams and four advanced life support (ALS)[17] paramedic teams on-duty at any given time; the latter attend to approximately 98% of OHCAs.[18] BCAS policy requires that all patients treated by EMS must undergo resuscitative efforts for at least 30 minutes prior to termination unless contrary to family wishes or a "do not resuscitate" order is identified.[19] Transport of patients who do not regain a pulse (ROSC) in the prehospital setting is rare.[18]

Development of hospital-based care protocols

In January 2014, discussions commenced regarding the establishment of a regional ECPR service for OHCA based at St. Paul's Hospital. It was acknowledged that ECPR services were already being utilized for OHCA, but quite infrequently and on an ad hoc basis, that there was no established eligibility criterion and that ECMO initiation times were prolonged. A committee was created involving administrative and clinical representatives from the health authority's senior leadership team, emergency medicine, cardiac surgery, perfusion services, cardiac anesthesiology, interventional cardiology, and critical care. The feasibility, potential benefits, resource utilization, and costs of such a formal program for OHCA ECPR application were discussed, and analyses were developed and published.[20,21] The committee endorsed the proposal, which was approved by the hospital administration in June 2015. Over the next six months, a formal OHCA ECPR hospital-based protocol was developed that commenced in January 2016. The stated overall vision was to improve the proportion of neurologically intact survivors among young previously healthy victims of sudden unexpected OHCA, through rapid identification of appropriate candidates and initiation of ECPR in the ED for a short duration of intensive therapy. The key goal metric of the protocol was time-to-ECMO (TTE) flows within 75 minutes, but preferably within 60 minutes, of initial professional resuscitative efforts. The inclusion and exclusion criterion are described in Figure 1. All required equipment and materials for ECPR initiation, including an ECMO unit, were acquired and housed in the ED resuscitation bay.

Activate *Code-ECPR* for those in refractory cardiac arrest if following criteria are met:

Inclusion Criteria (meets all of the following):

- Age ≤ 65 yr
- Witnessed Arrest (by bystander or EMS)
- Early CPR (bystander initiated OR time from 911 call to EMS CPR < 10 min)
- Cause of arrest is one of the following:
  - No obvious non-cardiac cause
  - Overdose of cardiac toxin (including beta-blockers, calcium channel blockers, tricyclic antidepressants, or digoxin), or
  - Hypothermia (with T < 32°C)*

Exclusion Criteria (meets any of the following):

- Any other cause of cardiac arrest
- Inappropriate for ICU admission
- Pre-Existing major organ system failure (incl. CHF, COPD, dialysis-dependent, liver failure, major neurological deficits)
- Active malignancy
- EMS arrival > 40 minutes from initial professional resuscitation

*Hypothermia-related arrests may be eligible for ECPR even if other inclusion criteria are not met, provided the patient is appropriate for ICU admission.

Figure 1. ECPR Criteria.

Development of novel prehospital ECPR protocol

In June 2015, discussions began with the senior leadership at BCAS. As arrests typically run for 30 minutes without transport to the hospital for those who did not achieve ROSC,[19,21] this new protocol required a major change. The prehospital phase of the protocol was developed, along with a training program for paramedics in the region, and was based on a six-step Kern approach.[22] One Lucas mechanical chest compression device (Physio-Control, Inc., Lund, Sweden) was acquired for each ALS team. The training package was sent to all paramedics: 1) a manual outlining the ECPR protocol; 2) a manual describing the operation of the Lucas device; 3) video instructions for the Lucas device; and 4) hypothetical case examples of potential ECPR patients. In addition, all ALS paramedics underwent: 1) standardized in-person training of the protocol and operation of the Lucas chest compression device; and 2) a test to confirm competency. A Lucas-compatible mannequin was placed in each ALS station for interval training. Pocket cards detailing the inclusion and exclusion criteria, as well as the prehospital portion of the protocol, were given to each paramedic.

https://doi.org/10.1017/cem.2017.376

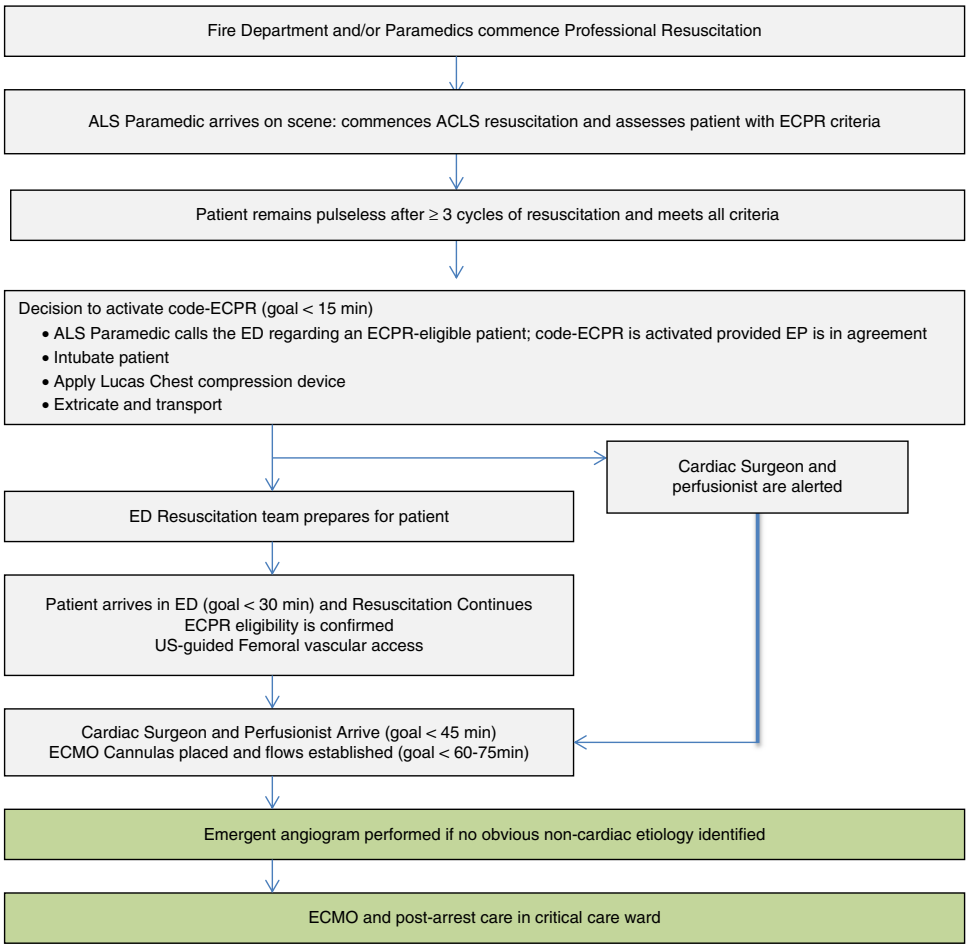

Figure 2. ECPR Protocol Scheme.

The protocol is shown in Figure 2. For all patients meeting the criteria, the ALS paramedic called the on-duty St. Paul's emergency physician (EP). The criteria were reviewed, and if candidacy was confirmed, the EP activated "code-ECPR." Paramedics intubated the patient (if not already performed), applied the Lucas compression device, extricated, and then transported the patient to St. Paul's Hospital with ongoing ACLS resuscitation.

ED and hospital-based protocol

Upon receiving a call from an ALS paramedic, the EP completed a standardized form to ensure the patient was appropriately included; if so, the EP initiated "code-ECPR." The ED unit clerk notified the on-call cardiovascular surgeon and perfusionist (in-hospital from 6:00 a.m. to 6:00 p.m., and within 30 minutes of the hospital at other times), as well as cardiac anesthesiology, intensive care, the cardiac surgery intensive care unit (ICU) nurse leader, and the hospital clinical coordinator. The ED team, consisting of two EPs, four nurses, and one respiratory therapist, assembled in the resuscitation bay prior to patient arrival, and various duties were assigned (Online Appendix 1). Upon patient arrival, the patient was again assessed using the eligibility criteria. One EP began placing single-bore 16-gauge catheters in the artery and vein using US guidance. In addition, a bedside US was performed to assess for reversible OHCA causes. Upon arrival, the cardiovascular surgeon assumed leadership of cannulation, inserting the ECMO cannulas with the EPs assisting and using a bedside US to assist with wire placement. ECMO flows were then commenced. Unless an obvious noncardiac cause was identified, an emergent coronary angiogram was performed. Online Appendix 2 details the strategy for ongoing ECMO management. All patients for whom withdrawal of

https://doi.org/10.1017/cem.2017.376

life-sustaining therapies was planned were considered for donation.

Medical and nursing education

Beginning in June 2015, we organized monthly stakeholder meetings to create a curriculum that was open to feedback and continuous iterative improvements. We sent monthly electronic messages to all ED staff regarding the protocol and invited contributions. At monthly departmental and educational rounds, various committee members gave ten-minute sessions relating to various protocol aspects.

We organized ECPR simulations involving prehospital and ED providers monthly since October 2015 and included ALS prehospital notification, code-ECPR activation, ED preparation and delegation of roles, paramedic arrival (with a mannequin on an EMS stretcher and ongoing mechanical chest compressions) and transfer of care, ED ACLS resuscitation, and US visualization of femoral vessels with US-guided catheterization. New medical supplies were used in each simulation to enhance verisimilitude. We used an adapted mannequin with a custom-made ballistic gel over a tubing insert to cannulate and place ECMO cannulas. At the conclusion of each session, a debriefing session was held, and the simulation director and program leaders provided feedback. Simulations were recorded for further analysis.

Quality improvement model

The Model for Improvement Framework of Deming's System of Profound Knowledge was utilized to achieve and sustain the primary outcome.[23] Real-time data were measured using run charts, with additional analysis to examine any particular cause variation noted.[23] We attempted to interview all participants after the ECPR activations, including all involved physicians and surgeons, nurses, perfusionists, and respiratory therapists.

Report cards

A designated quality and safety team was constructed to perform a standardized, detailed review of all "code-ECPR" activations that included interviews of participants, a synopsis of the event, calculation of time intervals, areas of success, and areas for improvement. We assembled template report cards (see Online Appendix 3) and sent them to all stakeholders and all ED staff members.

Selection of participants and analysis groups

This study included consecutive patients with nontraumatic refractory OHCA who had ECPR initiation attempted in the ED. Patients were excluded if sustained ROSC was achieved prior to ECPR initiation attempt.[24] We dichotomized patients based on whether they were treated prior to or after protocol implementation. We included patients who were treated up to two years prior to and within the first seven months of the commencement of the ECPR protocol.

Outcome measures and variable definitions

The primary outcome was the TTE, defined as the time of first professional resuscitative efforts to the commencement of ECMO flows. All cases were included in the analysis, regardless of whether adequate ECMO flows were achieved. In addition, we described the outcomes of the ECPR-treated patients at hospital discharge: 1) favourable neurologic outcomes defined as a cerebral performance category 1–2; and 2) survival.[25]

Data collection

All prehospital data including commencement of first EMS CPR, patient characteristics, Utstein variables,[25] and treatments were recorded on standardized BCAS template charting (in use since prior to the pre-protocol period). Perfusion services have used a standard template form for all ECMO initiations since before the pre-protocol time period; this template includes data entry for the time ECMO flows were first initiated. We collected data from these sources onto a standardized Excel spreadsheet, which was used to populate the ECPR report cards (Online Appendix 3). The overall number of OHCAs in the region was determined using the BC Resuscitation Outcomes Consortium OHCA Registry.[26]

Data analysis

We used Microsoft Excel 2008 (Microsoft Corp, Redmond, WA, USA) and R version 3.2.4 with the "exactRankTests" package (Foundation for Statistical Computing, Vienna, Austria) for data entry and analysis. QI Macros for Excel 2013 (KnowWare

https://doi.org/10.1017/cem.2017.376

International, USA) and statistical process control charts were used for quality improvement monitoring. We compared the median TTE for patients in the two groups using the Wilcoxon signed-rank test.

RESULTS

Characteristics of study subjects

The overall number of adult nontraumatic EMS-treated OHCAs in the region prior to and after the protocol implementation was 953 and 353, respectively. There were four and nine ECPR cases attempted prior to and after protocol commencement, respectively. The median age was 44 (IQR 35-58); two (15%) were female, and 62% had initial shockable cardiac rhythms (Table 1).

Main results

Patient characteristics are shown in Table 1. Of the pre-protocol patients, all had adequate ECMO flows established, and one (25%) survived (Table 2). One patient in the pre-protocol phase was transported to a different ED within the region and then transferred with ongoing CPR to St. Paul's hospital for ECPR initiation. After protocol implementation, ECPR was attempted in nine patients (all transported directly to St. Paul's), seven of whom had adequate ECMO flows established and two of whom survived. Of the two patients who could not have adequate ECMO flows established (thus precluding ECPR treatment), both were found to have aortic dissection on autopsy. All survivors had favourable neurological outcomes at hospital discharge. Two patients, both in the protocol group, were determined to be organ donation candidates; for one, an appropriate recipient was identified, and organs were donated (two kidneys, pancreas, and liver).

The median TTE flows prior to protocol implementation was 136 minutes (IQR 98-196 minutes), in comparison to 60 minutes during the protocol period (IQR 49-81 minutes, $p = 0.017$) (Table 2). The difference remained significant after removal of the one patient who was not transported directly to the ECPR-performing institution ($p = 0.027$). A run chart can be seen in Figure 3. The median door-to-ECPR time pre-protocol was 104 minutes (IQR 53-138), and after the protocol implementation, it was 28 minutes (IQR 20-45, $p = 0.011$).

Table 1. Patient characteristics and treatment data of ECPR attempts

	Pre-Protocol	Protocol
	n or median (% or IQR)	n or median (% or IQR)
Number	4	9
Age	38 (32-44)	46 (35-61)
Past Medical History		
None	1 (25)	3 (33)
Coronary artery disease	0	2 (22)
Mental health	1 (25)	2 (22)
Inflammatory bowel disease	1 (25)	1 (11)
COPD	1 (25)	1 (11)
Bystander CPR	3 (75)	6 (67)
Witnessed		
Bystander	2 (50)	6 (67)*
EMS	1 (25)	2 (22)*
Initial rhythm		
VF	3 (75)	5 (55)
PEA	1 (25)	2 (22)
Asystole	0	2 (22)
Etiology of arrest		
Hypothermia	2 (50)	2 (22)
ACS	1 (25)	3 (33)
Unknown	1 (25)	1 (11)
Aortic dissection	-	2 (22)
Electrolyte	-	1 (11)
Time of Resuscitation		
0601-1800	4 (100)	3 (33)
1801-0600	0	7 (77)
Time from first EMS CPR to ED Arrival		
Prehospital Resuscitation (minutes)	43 (26-66)	32 (25-44)
Hospital Duration		
ECMO, days†	0.86 (0.16-4.84)	1.10 (0.57-2.77)
ED/Critical Care, days	3.42 (0.20–8.57)	1.65 (0.17-13.99)
Total Hospital stay, days	3.42 (0.20-8.57)	1.65 (0.18-27.84)
Interventions		
Angiogram	1 (25)	4 (44)
Fasciotomy	1 (25)	1 (11)
CABG	1 (25)	0
Laparotomy	0	1 (11)
Complications		
Compartment syndrome requiring a fasciotomy	1 (25)	1 (11)
Vascular injury	0	1 (11)
Intracranial hemorrhage	0	1 (11)
Liver laceration	0	1 (11)

ACS = acute coronary syndrome; CABG = coronary artery bypass graft; CPR = cardiopulmonary resuscitation; ECMO = extracorporeal membrane oxygenation; EMS = emergency medical systems; PEA = pulseless electrical activity; VF = ventricular fibrillation.
*One protocol period patient who had an unwitnessed arrest was treated with ECPR; he fell out of a boat with companions and then arrested soon afterwards; he was considered a hypothermia-related arrest and thus was not required to meet all criteria; and he was a nonsurvivor.
†Patients for whom adequate ECMO flows were unable to be established were excluded from this statistic.

The median duration of ECMO treatment among survivors and non-survivors (excluding those for whom adequate ECMO flows were not established) was 1.10 days (IQR 1.02-2.77) and 0.86 days (IQR 0.37-3.07 days), respectively. The median duration of the total

https://doi.org/10.1017/cem.2017.376

Table 2. Patient outcomes

	Pre-Protocol	Protocol
	n or median (% or IQR)	n or median (% or IQR)
Time to ECMO flows (minutes)	136 (98-196)	60 (49-81)
Door to ECMO flows (minutes)	104 (53-138)	28 (20-45)
ECPR-treated outcomes at hospital DC		
Survival (n, %)	1/4 (25)	2/7 (29)
Favourable neurological outcome	1/4 (25)	2/7 (29)
Eligible organ donors	0/4 (0)	2/9 (22)

DC = discharge; ECMO = extracorporeal membrane oxygenation; ECPR = extracorporeal membrane oxygenation cardiopulmonary resuscitation.

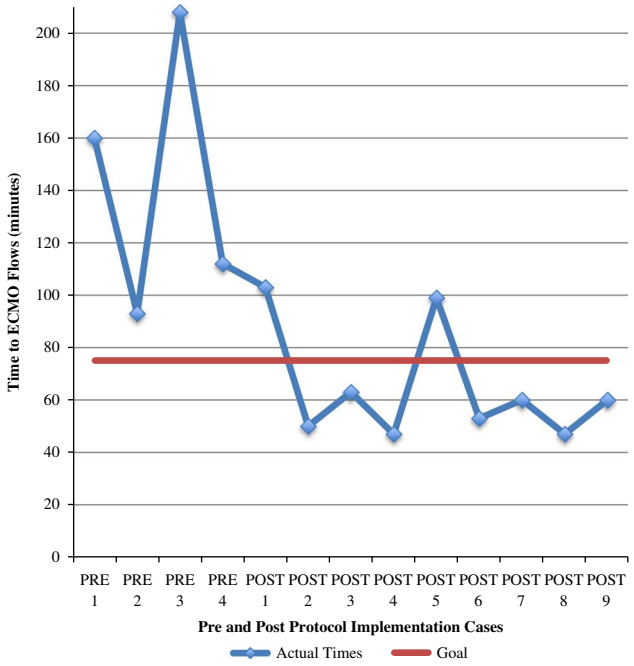

Figure 3. Run-Chart of ECPR Attempts in the Pre- and Post-Protocol time periods demonstrating Time-to-ECMO metrics.

hospital stay for survivors and non-survivors was 9.38 days (IQR 4.25-120.9) and 0.91 days (IQR 0.03-5.78), respectively.

DISCUSSION

We sought to improve outcomes from refractory OHCA in our region, specifically focusing on young victims of sudden unexpected cardiac arrest. We developed and implemented a structured formal multidisciplinary ECPR protocol involving prehospital resuscitation, prehospital-hospital coordination, pre-rehearsed ED management including the establishment of extra-corporeal membrane oxygenation, standardized post-arrest management, and ongoing education; the goal of this protocol was to achieve ECMO initiation in under 75 minutes from first paramedic contact. We found that there was a large decrease in the elapsed resuscitation duration to the establishment of ECMO flows after our protocol implementation. Importantly, during the pre-protocol period, when patients received unstructured care, the median 136-minute TTE exceeded a reasonable time frame that patients might be expected to survive; conversely, the median 60-minute TTE under the organized protocol is more likely to lead to positive outcomes. Our protocol, including the educational aspects and the description of the development process, might assist other hospitals in determining the feasibility of achieving required time metrics to provide ECPR therapy to patients with OHCA.

During the pre-protocol time, few OHCAs were treated with ECPR, likely because of the following: 1) the lack of a formal protocol; 2) the prehospital resuscitation paradigm focused on on-scene resuscitation; and 3) the infrequent intra-arrest patients transported to the hospital were sent to the closest hospital as opposed to one where a protocol would be developed. During this time, ECPR was only considered after failed ED resuscitative efforts that made acceptable TTE metrics virtually impossible, especially during times in which non-ED personnel were not in the hospital. While comparing time metric differences in the pre-hospital and hospital phases of care, it appears the greatest decrease was in the hospital phase. However, an essential component of this hospital-based improvement was prehospital activation of the protocol that allowed critical preparation to occur and mobilization of non-ED personnel to attend the ED—an especially key component as the majority of cases occurred outside of daytime hours in which non-ED personnel were offsite.

We previously reported an estimate of the number of potential ECPR candidates in our region and found that of those with initial shockable rhythms, the outcomes were already excellent, with 87% surviving to admission to a hospital ward.[20] Acknowledging these data, we were cognizant of the risk of worsening this high survival rate while building the protocol. Our examination of time-to-ROSC survival curves determined the optimal transport time to mitigate harm to patients who might have good outcomes with conventional resuscitation.[21]

To achieve the benefit of ACLS therapies both on-scene and during transport, we required that ALS paramedics attend to patients prior to transport for ECPR. This might have delayed hospital transport; however, we believed this would mitigate the risk of worsening baseline outcomes by maintaining all elements of our current conventional treatment algorithm at the scene and during transport. Our reliance on ALS-concentrated decision-making placed the experience with fewer but more experienced personnel, reducing training time and resources. In addition, we made mechanical CPR a prerequisite for transport and thus outfitted each ALS team with a mechanical chest compression device. While there is no evidence that mechanical chest compression devices are superior to manually performed CPR if applied to all OHCAs,[27] these devices have been shown to perform superior CPR quality during ambulance transport.[28,29]

The low volume of ECPR candidates is a threat to developing and maintaining competency in an ECPR protocol for OHCA within prehospital and ED settings. Our educational and simulation program sought to develop and maintain team-based familiarity with the procedure. Volumes may be higher in other settings with less strict inclusion criteria, those with existing outcomes including fewer patients who achieve ROSC, or those with differing population demographics or density.

Although not the primary objective of our efforts, our data indicates that the application of ECPR for OHCA in Canada may result in additional opportunities for organ procurement; this has the potential to benefit additional patients, and the cost-benefit of transplantation might offset the resource-intensive nature of ECPR therapy. In addition, the opportunity to donate, which would not otherwise be possible, may be an important source of consolation to bereaved families. Consistent with any patient with severe brain injury, our program incorporates the consideration of organ donation only after the decision of patient disposition as part of comprehensive end-of-life care. In contrast to OHCA ECMO programs in which ECMO is initiated with the primary purpose of supporting organ function for uncontrolled donation after cardiac death,[30,31] we believe that our donation practice does not represent conflict of interest.

Overall, our proportion of positive outcomes among those treated with ECPR was 27%. These data are consistent with previous reports.[32] Acknowledging the low sample sizes of ECPR-treated cases series, the undifferentiated mix of cardiac arrest patients with varied etiologies and baseline characteristics, and clinician selection bias, confidence in estimates of true effectiveness in terms of survival and comparisons with other sites or between different time periods are difficult to ascertain. The inclusion of non-shockable rhythms in our protocol also likely influenced our outcomes. Whereas those with refractory arrest after initial shockable rhythms might be better candidates, we elected to include patients with initial non-shockable rhythms as we hoped this therapy would be a way to improve the poor prognosis of this group. Overall, we found that non-survivors had modest impacts on resource utilization in terms of ECMO treatment durations and overall hospital stays.

LIMITATIONS

This is a single-region protocol, conducted from a single hospital with extensive experience in cardiovascular emergencies and prior ad hoc ECMO experience, but no previous formal in-hospital ECMO protocol. As such, our protocol, patients, and results might be difficult to replicate. In addition, our prehospital system, with long-standing experience in new protocols,[33-35] might differ from other settings. However, we offer a description of our experience and a template upon which other interested sites might build to accommodate the various demands of their individual EMS, region, EDs, and hospitals. It is possible that eligible patients were not correctly identified and not treated with the protocol. Although the outcomes of this study might be compared with outcomes of similar patients treated with equal durations of attempted conventional resuscitation,[21] this study is unable to make conclusions about ECPR efficacy.

From an analytic standpoint, our small sample size might limit enthusiasm. However, the post-protocol improvement in TTE is so profound that it is difficult to conceive what is because of chance alone. Patients with a 136-minute TTE are unlikely to have meaningful recovery after ECPR treatment[7,9]; the 60-75 minute zone is likely an appropriate benchmark.

CONCLUSIONS

An organized clinical and educational protocol to initiate ECPR for patients with OHCA is feasible and significantly reduces the key benchmark of time-to-flow.

https://doi.org/10.1017/cem.2017.376

Acknowledgements: We would like to acknowledge the contributions of the following to our protocol: Cindy Lawlor, Pat Munro, Sarah Hooper, David Byres, Navreet Johal, Melissa Pearson, Demetrios Sirounis, Jade Munro, Helen Connolley, Tanya Campbell, Marianne Lesage, Laurie Fraser, Robert Schlamp, Jennie Helmer, Booby Lee, Jessica Blackbourn, John Merrett, and the St. Paul's Hospital Senior Leadership Team.

Competing interests: None declared. Funding support was provided by Providence Healthcare Research Institute, St. Paul's Hospital Foundation, Cardiac Services BC; Lucas chest compression devices were provided (on loan) from Physio-Control, Inc., In-Kind Support from BC Emergency Health Services, and In-Kind Support from St. Paul's Hospital.

SUPPLEMENTARY MATERIAL

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