ECPR for Out-of-Hospital Cardiac Arrest: New opportunities for increasing survival and organ donation

Brian Grunau MD MHSc
Emergency Physician, St. Paul’s Hospital
Clinical Assistant Professor, UBC Department of Emergency Medicine
Scientist, Centre for Health Evaluation & Outcomes Sciences
Early Resuscitation Pioneers
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• In-kind support from PhysioControl, Inc.

Non-Industry Support

• St. Paul’s Hospital Foundation
• Providence Healthcare Research Institute
Overall Survival
~15%
Current Management of Out-of-Hospital Cardiac Arrest

- Out-of Hospital Arrest
- Paramedics attempt resuscitation at the scene of the arrest
- Return of a Pulse?

Yes (~50%)
Transport to hospital

No (~50%)
Declare Dead after 30 minutes of CPR.
Transport to morgue.
Objectives

• An introduction to ECPR for OHCA

• Describe the Vancouver experience using ECPR for OHCA

• Describe national and international projects in this field, highlighting the intersection between resuscitation and organ donation
• Extracorporeal Cardiopulmonary Resuscitation (“ECMO-CPR”, aka “ECPR”)
  • Emergent ECMO or ECLS for Refractory CARDIAC ARREST (not post-arrest cardiogenic shock)

• ECPR for out-of-hospital cardiac arrest
  • Cardiac arrest in the community, brought to hospital with ongoing CPR, cannulated with ongoing CPR
Who inspires this discussion?

• 23 year old healthy woman, 3 mo post partum
• Witnessed PEA arrest in Richmond
• By ambulance to SPH; ECPR at ~100 minutes
• Dx: post-partum cardiomyopathy
• ECMO -> LVAD
• Discharged from hospital neurologically intact
• LVAD removed at 5 months
• This picture was taken a few years later, and she just celebrated her 8th year anniversary
<table>
<thead>
<tr>
<th>Country</th>
<th>n</th>
<th>Survival (%)</th>
<th>Neurologically Intact Survival (%)</th>
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<tbody>
<tr>
<td>Japan</td>
<td>1282</td>
<td>29</td>
<td></td>
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<tr>
<td>[Morimura. Resuscitation 82 (2011) 10–14)]</td>
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<td>Tawian</td>
<td>31</td>
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<td>26</td>
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<tr>
<td>Germany</td>
<td>26</td>
<td>15</td>
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<td>Germany</td>
<td>28</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>Australia (CHEER)</td>
<td>9</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Paris</td>
<td>51</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>[Le Guen. Critical Care 2011,15:R29]</td>
<td></td>
<td></td>
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<tr>
<td>Belgium</td>
<td>14</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>
Early CPR by bystanders or EMS

Young Patients

No major co-morbidities
Interpreting ECPR Studies: Time to ECPR Implantation

Wang et al. Resuscitation 2014 Sep;85(9):1219-24
THE HOPE:

• Achieve incremental gains in survival with ECPR
A ECPR Service for OHCA

• Planning at SPH began early 2014

• Stakeholders: Emergency Department, CV surgery, Perfusion services, Cardiac Anesthesiology, Critical Care, Interventional Cardiology

• Phases:
  2. Senior Leadership Approval: June 2015
  3. Protocol Implementation and Training
  5. Integration of pre-hospital services (July, 2016)
• Single provincial ambulance service
• Tiered response:
  • Municipal fire departments
  • Basic Life Support paramedic
  • Advanced Life Support Paramedic

Population: ~5 million
The Vancouver ECPR Protocol for Out-of-Hospital Cardiac Arrest

**Objective:** To Improve the likelihood of neurologically intact survival of patients in the community with sudden unexpected cardiac arrest

**ECPR Service Goal:** 9-1-1 call to ECPR flows <60-70 minutes
911 call

Paramedics Arrive and Start Resuscitation

Patient remains pulseless after a min. of 3 cycles
Paramedics have started ACLS efforts
Paramedics Arrive and Start Resuscitation

911 call

- Patient remains pulseless after a minimum of 3 cycles of CPR by a professional
- No major co-morbidities (CHF, COPD/significant lung disease, dialysis, liver failure, malignancy) or pre-existing major neurological deficits
- No history or evidence of recent recreational drug use

YES to all boxes

Either:
- Rectal or oral temperature < 32 °C
- Signs of life (movement or gasping) at time of protocol activation

YES

NO

Witnessed arrest (seen or heard)
- One of the following:
  - Initial rhythm shockable
  - Initial rhythm PEA AND had bystander CPR or was an EMS-witnessed arrest
  - Pupils ≤ 5 mm at time of protocol activation
- Cause of arrest is either:
  - No obvious cause
  - Overdose of cardiac toxins (beta-blocker, beta-blocker, Psych med, digoxin)

ETCO2 > 10 mmHg at time of protocol activation
- Time from Paramedic Dispatch to SPH arrival < 50 min

YES to all boxes
911 call

Paramedics Arrive and Start Resuscitation

Patient remains pulseless after a min. of 3 cycles and ALS Paramedics have started ACLS efforts

Decision to activate protocol if patient meets criteria
- Apply Lucas Device
- Pre-hospital activation of ECPR Protocol and transport
911 call

Paramedics Arrive and Start Resuscitation

Patient remains pulseless after a min. of 3 cycles and ALS Paramedics have started ACLS efforts

Decision to activate protocol if patient meets criteria
• Apply Lucas Device
• Pre-hospital activation of ECPR Protocol and transport

Code ECPR activated:
• Page: CV surgeon, Interventional Cardiology, and Perfusion
• ED prepares for patient
PREPARATION

• Move central fence between Resus 1 and 2 approximately one meter to create more space (see red markings on floor).
• Move bed towards the center of the room (see red flr markings).
• Get appropriate paperwork out for charting.
• Complete ECPR Preparation Checklist.

• Get LUCAS out of case and ready for use.
• Set up regional oximetry ensuring RN1 can visualize screen.
• Ensure monitor is turned on with defibrillation pads attached to monitor.
• Place ultrasound next to patient’s right arm.

• Get epinephrine out of medication cart.
• Draw up 5000 units of heparin and label appropriately.
• Help EP2 set up central line table (see below).
• Spike two bags of cold saline.
• Ensure IO device within reach if needed.
• Help EP1 set up the CV Surgeon table (see below).
• Get any materials needed from outside the room.
• Place ECPR table at the foot of the bed.
• Cover with sterile drape and place 60ml catheter tip syringe (filled with sterile saline), two large piles of 4x4 gauze, and two sterile gowns on top of the sterile drape. Cover with a second sterile drape. All materials are in CV Surgeon box on ECMO table.

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• Place electric CPR device on the bed.
• Cover with sterile drape and place 60ml catheter tip syringe (filled with sterile saline), two large piles of 4x4 gauze, and two sterile gowns on top of the sterile drape. Cover with a second sterile drape. All materials are in CV Surgeon box on ECMO table.

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RESUSCITATION ROLE

• Responsible for documenting the code.
• Ensures ACLS algorithm is being followed.
• Control noise level in room and perform crowd control.
• Sees the big picture in the room.

• Place patient on LUCAS device if not already on LUCAS. Troubleshoot as necessary.
• Place patient on regional oximetry device.
• Place patient on monitor and put defibrillation pads on patient.
• Assist EP2 with US-guided vascular cannulation as necessary.

• Ensure pre-hospital IVs are patent with IV fluids running. Attach to cool NS.
• Start another IV if necessary.
• Draw up and give medications as needed throughout code.

• Help transfer patient onto hospital stretcher.
• Expose patient and place in hospital gown.
• Help with IV access if necessary.
• Gather additional equipment and assist as needed.
• Set up arterial line when needed.

• Team Leader
• Take report from EHS.
• Airway management
• Communicate with CV Surgeon.
• May need to perform US visualization of cannulae after insertion

• Sterilizes groin, places double groin drape, and place single lumen central lines x 2 (one venous and one arterial).
• Draws blood from central line to be sent to lab.
• Helps CV surgeon prn with cannulation.

• Take over airway management on patient arrival.
• Ventilate with 100% oxygen through established ETT or using BVM if patient is not intubated.
• Attach ETCO2 monitoring. Inform RN1 of values when initiating ETCO2 monitoring and prn.
Preparation (prior to patient arrival)

Sterile set-up with US, central line x 2

ED ECMO Machine

Team Leader

Surgical Table: sterile equipment ready
Paramedics Arrive and Start Resuscitation

Patient remains pulseless after a min. of 3 cycles and ALS Paramedics have started ACLS efforts

Decision to activate protocol if patient meets criteria
• Apply Lucas Device
• Pre-hospital activation of ECPR Protocol and transport

Patient Arrives in ED; Resuscitation Continues
Prepare for ECMO

Code ECPR activated:
• Page: CV surgeon, Interventional Cardiology, and Perfusion
• ED prepares for patient

GOALS
- 911-to-ECPR time ≤ 60 min
- Door-to-ECPR time ≤ 30 min
Paramedics Arrive and Start Resuscitation

Patient remains pulseless after a min. of 3 cycles and ALS Paramedics have started ACLS efforts

Decision to activate protocol if patient meets criteria
• Apply Lucas Device
• Pre-hospital activation of ECPR Protocol and transport

Patient Arrives in ED; Resuscitation Continues
• Prepare for ECMO

Code ECPR activated:
• Page: CV surgeon, Interventional Cardiology, and Perfusion
• ED prepares for patient

Cardiology/Perfusion/CV Surgeon arrival

ECMO initiated

GOALS
• 911-to-ECPR time ≤ 60 min
• Door-to-ECPR time ≤ 30 min
Ballistic Gel Pelvis

Department Store Mannequins
### The St. Paul's Hospital ECPR Service for Out-Of-Hospital Cardiac Arrest

**Objective:** To improve the survival of patients in the community with sudden unexpected cardiac arrest.

**ECPR Service Goal:** EMS-Arrival time (or last arrest) to ECPR flows <60-75 minutes

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#### Case Details

**Patient Characteristics**

<table>
<thead>
<tr>
<th>Patient MRN</th>
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<table>
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<tr>
<th>Age</th>
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<tbody>
<tr>
<td></td>
<td>52</td>
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<table>
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<tr>
<th>Date of arrest</th>
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<tr>
<td></td>
<td>14 January 2016</td>
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<table>
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<tr>
<th>Initial arrest rhythm</th>
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<tr>
<td></td>
<td>PEA-VF</td>
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<table>
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<tr>
<th>Bystander CPR</th>
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<tbody>
<tr>
<td></td>
<td>No</td>
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<table>
<thead>
<tr>
<th>Arrest witnessed</th>
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<tr>
<td></td>
<td>No</td>
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<tr>
<th>ROSC Re-arrest?</th>
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<tr>
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<td>Yes/Yes</td>
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<th>Presumed cause of arrest</th>
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<td>Hypothermia</td>
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**Preparation**

- Was the protocol initiated pre-hospital? **No** – see analysis
- Were all ED pre-patient arrival tasks completed? **No** – see analysis
- Did the activation fit criteria? **Yes**
- EMS on-scene arrival time to ED notification (goal < 15 min) **No** – see analysis

**Time Intervals**

<table>
<thead>
<tr>
<th>EMS on-scene arrival to ECMO flow (goal &lt; 60-75 min)</th>
<th><strong>57 minutes</strong></th>
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<tbody>
<tr>
<td>EMS on-scene arrival time to ED arrival (goal &lt; 30 min)</td>
<td><strong>6 min</strong></td>
</tr>
<tr>
<td>Patient arrival to cannulation time (goal &lt; 15 min)</td>
<td><strong>36 minutes</strong></td>
</tr>
<tr>
<td>CV surgeon page to arrival time (goal &lt; 30 min)</td>
<td><strong>33 minutes</strong></td>
</tr>
<tr>
<td>Door to ECMO time (goal &lt; 30 min)</td>
<td><strong>32 minutes</strong></td>
</tr>
<tr>
<td>ECMO flow to cath lab (goal &lt; 60 min)</td>
<td><strong>N/A</strong></td>
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<tr>
<td>Time family provided updated</td>
<td><strong>23:25</strong></td>
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**ED Physician (s)**

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<tr>
<td>Drs. K. Lindsey, B. Gunnar</td>
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**ED Nurses**

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<tr>
<td>CRN – Laurie Fraser</td>
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**CV Surgeons (s)**

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<td>Drs. C. Cheung</td>
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**Perfusionist (s)**

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<tr>
<td>Jonathan</td>
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**Social Worker**

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<td>Asian Anuyot</td>
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**Interventional Cardiologist**

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<td>N/A</td>
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**Intensivist(s)**

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<tr>
<td>Drs. A. Boyd, G. Grant</td>
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**Areas for Improvement**

- Correct pre-hospital notification
- Decreased time for EP vascular access
- Prolonged door-to-ECMO time largely due to no pre-hospital code-ECPR activation
- UC confusion over the correct perfusion tubing # after hours – conflicting information present
- Debriefing for staff involved – any opportunity for using the FAST-PAGE approach to debriefing?
- What is the right number of appropriate staff required during an ECPR case? – Crowd control that is professional and constructive, and reduces chance of patient harm
- Role clarification and role identification
- Further development on the best location of care for patient successfully weaned from ECMO

---

**What Went Well?**

- Rapid SCRRS identification of potential ECPR patient and expedited transport to SPH
- When CV Surgery arrived venous and arterial access had been secured and a sterile field was in place
- EMS arrival to ECMO flow goal achieved

  "ED physician Dr. Lindsey was the team leader who confidently re-formed the team"

  "Incredible opportunity for learning from the perfusionists – both were actively interacting with the nurses and incredibly supportive in providing education"

  "I was proud and amazed that we got a perfusing rhythm – I was proud of being part of this team"
A comprehensive regional clinical and educational ECPR protocol decreases time to ECMO in patients with refractory out-of-hospital cardiac arrest

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

<table>
<thead>
<tr>
<th></th>
<th>Pre-Protocol n=4</th>
<th>Protocol n=9</th>
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<tr>
<td></td>
<td>n or median (%)</td>
<td>n or IQR</td>
</tr>
<tr>
<td>Time to ECMO flows (minutes)</td>
<td>136 (98 - 196)</td>
<td>60 (49 - 81)</td>
</tr>
<tr>
<td>Door to ECMO flows (minutes)</td>
<td>104 (53 – 138)</td>
<td>28 (20 - 45)</td>
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HIGH-FIVING A SHARK

Nothing you ever do will be as awesome as
The next 14 patients...

• Only one survivor (7.1%)
• One organ donor (7.1%)

• ECMO Duration (median, IQR): 1.02 days (0.30 – 2.77)
Objective: Patient vs Organs?

1 ORGAN DONOR CAN SAVE 8 LIVES!!
Extracorporeal membrane oxygenation (ECMO) assisted cardiopulmonary resuscitation or uncontrolled donation after the circulatory determination of death following out-of-hospital refractory cardiac arrest—An ethical analysis of an unresolved clinical dilemma

Anne L. Dalle Ave\textsuperscript{a,b,*}, David M. Shaw\textsuperscript{c}, Dale Gardiner\textsuperscript{d}

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Inclusion criteria for E-CPR comparing with uDCDD protocols.</th>
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</thead>
<tbody>
<tr>
<td><strong>E-CPR</strong>\textsuperscript{10–13,20–22,23}</td>
<td><strong>uDCDD France</strong>\textsuperscript{17,31}</td>
</tr>
<tr>
<td>• Witnessed CA</td>
<td>• Witnessed CA</td>
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<tr>
<td>• CPR &gt;10–30 min</td>
<td>• ACLS &gt;30 min without ROSC</td>
</tr>
<tr>
<td>• No-flow &lt;5–10 min or signs of life during CPR</td>
<td>• No-flow &lt;30 min</td>
</tr>
<tr>
<td>• Bystander CPR</td>
<td></td>
</tr>
<tr>
<td>• Age &lt;65–75 years</td>
<td>• Age 18–55 years</td>
</tr>
<tr>
<td>• Lack of severe comorbidities</td>
<td>• Lack of severe comorbidities</td>
</tr>
<tr>
<td>• VF/VT as initial rhythm</td>
<td>• Hypothermia and drug intoxication: consider E-CPR</td>
</tr>
<tr>
<td>• Hypothermia</td>
<td></td>
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<tr>
<td>• Drug intoxication</td>
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</table>

UDDC: uncontrolled donation after circulatory determination of death; E-CPR: ECMO assisted CPR; CA: cardiac arrest; min: minutes; ACLS: advanced cardiac life support; VF: ventricular fibrillation; VT: ventricular tachycardia.
Inclusion: Age 18 – 65
Not asystole
Witnessed arrest
No major bleeding or significant known/suspected co-morbidities
Cardiac Arrest > 30 min
ECMO Team available
An integrated program of extracorporeal membrane oxygenation (ECMO) assisted cardiopulmonary resuscitation and uncontrolled donation after circulatory determination of death in refractory cardiac arrest.

Studied Patients
Refactory cardiac arrest (>30 mins) (N=58)

ECPR (N=18)
- ROSC (N=15)
  - ECMO wean (N=8)
    - Die post ECMO wean (N=2)
  - Die prior ECMO wean (N=7)
    - MOF / SBI (N=6)
    - Brain death (N=1)
- No ROSC (N=3)
  - ECMO wean (N=8)
    - Survive CPC-1 (N=6)
    - Liver recovery and Tx (N=1)
    - Kidney recovery and Tx (N=2)
- uDCDD (N=40)
  - nRP successful (N=33)
    - Kidney recovery (N=62)
    - Liver recovery (N=1)
  - nRP unsuccessful (N=7)
    - Kidney Tx (N=44)

47 organs
In Settings with DCD for OHCA / Presumed Consent

- Failed Conventional Resuscitation
  - Continue Resuscitation ECPR for patient resuscitation
  - Resume Organ Resuscitation ECMO for organ preservation
  - Organ Donation if eligible

Survivor
1. Stable WLST after Brain Death

- 31 yo woman, hx of bulimia, witnessed VF arrest at YVR
- Arrival in ED: 33 minutes
- Door-to-ECMO flows: 14 minutes
- Day 2 CT head: intraparenchymal hemorrhage with herniation
- Brain death
- Donation: liver, kidneys, pancreas
2. Stable WLST: Controlled DCD

• 55 yo male, hx of LAD stent after cardiac arrest
• Found on the ground, last seen approximately 15 minutes prior
• CPR started by co-workers, initial rhythm asystole
• Arrival in ED: 32 min
• Door-to-ECMO: 25 min
• ECMO-to-Cath: 35 min ➔ LAD stent restenosis
• Due to evidence of severe anoxic brain injury and poor cardiac recovery decision made to WLST ➔ donation after cardiac death (pancreas, liver, kidneys)
4. Unstable Unplanned death: Uncontrolled DCD ???

- 41 yo male, Playing squash with friends
- VF Cardiac arrest with bystander CPR
- EMS on-scene arrival to ECMO flows: 64 min
- Emergent cath: LAD lesion, stented
- Day 2, difficult to maintain ECMO flows and MAP, abd distension, groin expansion
- Vascular OR: R groin arterial injury
- Declared dead in OR
5. Neurological Recovery, without cardiac recovery

• 49 year old male, OHCA after cocaine use
• ECPR initiated
• Neurological function returned, but cardiac function did not
• Deemed not a candidate for LVAD/transplant
• “one-way” ECMO wean performed ➔ patient died
Failed Conventional Resuscitation

ECMO-CPR for resuscitation

Survival

Unstable, Death

Decision to withdrawal care

Unstable, Death

Permission to donate

Organ Assessment

Unstable, Death

Organ Donor

Does not survive assessment period; Death

Ineligible, Death
• Opportunities and Barriers for ECPR in Canada
  • May 4, 2016, Toronto, Ontario; met again in 2017
• Chairs:
  • Dr. Sam Shemie
  • Dr. Steve Brooks

• **Canadian ECPR Working Group**: “discuss and initiate a platform for further investigations & research on the topic of whether ECPR should be implemented broadly across Canada”

Brooks et al. CJEM 2018;20(4):507-517
Canadian ECPR Research Network for Out-of-Hospital Cardiac Arrest (CERNO)
cerno.network@gmail.com

Objectives
1. Create a network of Canadian clinical sites with interest in ECPR for OHCA
2. Collectively advance the state of the evidence of ECPR for OHCA, in order to determine the role of this therapy in the Canadian setting

• Projects:
  ✷ Web-based Networking site (complete)
  ✷ Canadian environmental scan of ECPR capacity and barriers to implementation (in progress)
  ✷ Registry of ECPR-treated OHCA’s within CanROC (pending)

Planning Committee: Steve Brooks, Brian Grunau, Sam Shemie, Dave Nagpal, Clay Gillrie, Laura Hornby, Katie Dainty, Sylvia Torrance
A Qualitative Study of Patient and Family Experience of Extracorporeal Cardiopulmonary Resuscitation for Refractory Out-of-Hospital Cardiac Arrest

I. Information Sharing
   • Treatments
   • Prognosis

II. Decision Making Process

III. Organ Donation

IV. Perceived Value of ECPR

V. Opinions of the ECPR Information Pamphlet
Sections:

- The team
- What is a cardiac arrest?
- What is ECMO and ECPR?
- How does ECMO work?
- What has happened to my loved one so far?
- How successful is ECPR?
- What happens now?
- What if my loved one does not survive?
- Is there an option for organ donation?

Thanks to the ECMO Team of the Heart & Vascular Intensive Care Unit at the Hospital of the University of Pennsylvania, for using their “Guide to ECMO Therapy” as a platform.
“Is there an option for Organ Donation?”

• “The CSICU team is not involved in the process of organ donation
• “Each ECPR case: referred to an organ donation specialist, blood tests taken for donation assessment
• “If you would like to speak to someone earlier about organ donation, to receive further information or make your wishes known, we can arrange this for you.”
Scientific Statement on Organ Donation After Out-of-Hospital Cardiac Arrest: Scope of Work Proposal for Public Comments by Public or Lay Providers

• Investigate the incidence of organ donation among OHCA’s
• Strategies to close the gap between actual and potential donation
• Focused category on extracorporeal strategies
• Ethical and cost-effective considerations

Members:
Laurie Morrison  Bob Neumar
Steve Brooks        Gavin XX
Brian Grunau
XX
XX

www.costr.ilcor.org
Hyperinvasive approach to out-of-hospital cardiac arrest using mechanical chest compression device, prehospital intraarrest cooling, extracorporeal life support and early invasive assessment compared to standard of care. A randomized parallel groups comparative study proposal. “Prague OHCA study”

Jan Belohlavek1, Karel Kucera2, Jiri Jarkovsky3, Ondrej Franek4, Milana Pokorna4, Jiri Danda5, Roman Skripovsky5, Vit Kandrnka2, Martin Balik5, Jan kunstyr6, Jan Horak1, Ondrej Smid1, Jaroslav Valasek2, Vratislav Mracek1, Zdenek Schwarz2 and Ales Linhart1

Concluding Remarks: ECPR for OHCA

• Resource intensive and logistically challenging
• Benefits: Survivors, Organ Procurement
• ECPR and Organ Donation Systems – a natural synergy
• Large obstacles to bridge the gap between potential and actual organ donors
• Regional/societal-level evaluation required
Thank you!

Brian.Grunau2@vch.ca