Management of accidental hypothermia: an established extracorporeal membrane oxygenation centre experience

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Abstract

Introduction: Data on management of severe accidental hypothermia published from an established high-volume extracorporeal membrane oxygenation centre are scarce.

Methods: A total of 28 patients with intravesical temperature lower than 28°C on admission were either treated with veno-arterial extracorporeal membrane oxygenation or rewarmed conservatively.

Results: A total of 10 patients rewarmed on veno-arterial extracorporeal membrane oxygenation (age: 37 ± 12.6 years) and 18 conservatively (age: 55.2 ± 11.2 years) were collected over a course of 5 years. The dominant cause was alcohol intoxication with exposure to cold (39%), 12 patients were resuscitated prior to admission. The admission temperature in the extracorporeal membrane oxygenation group (23.8 ± 2.6°C) was lower than in the non–extracorporeal membrane oxygenation group (26.0 ± 1.5°C, p=0.01). The peripheral percutaneous veno-arterial extracorporeal membrane oxygenation was always cannulated in malignant arrhythmias causing refractory cardiac arrest. The typical extracorporeal membrane oxygenation blood flow was 3-4L/minute and sweep gas flow 2L/minute, the median extracorporeal membrane oxygenation duration was 48.3 (28.1-86.7) hours. The median rates of rewarming did not differ (0.41 (0.35-0.7)°C/hour in extracorporeal membrane oxygenation and 0.77 (0.54-0.98)°C/hour in non–extracorporeal membrane oxygenation, p=0.46) as well as the admission arterial lactate, pH and potassium. Their development was not different between the groups except for higher pH between the third and ninth hour of rewarming in the extracorporeal membrane oxygenation group. The hospital mortality was 10% in the extracorporeal membrane oxygenation group and 11.1% in the non–extracorporeal membrane oxygenation group with the median last Glasgow Coma Scale 15 and Cerebral Performance Score 1.

Conclusion: Veno-arterial extracorporeal membrane oxygenation for severe hypothermia shows promising outcome data collected in an extracorporeal membrane oxygenation/extracorporeal cardiopulmonary resuscitation centre located in a European urban area. Except for presence of refractory cardiac arrest, the established hypothermia-related prognostic indicators did not differ between patients in need for extracorporeal membrane oxygenation and those rewarmed without extracorporeal membrane oxygenation.

Keywords

extracorporeal life support; extracorporeal membrane oxygenation; veno-arterial extracorporeal membrane oxygenation; accidental hypothermia; severe hypothermia; cardiac arrest; acute heart failure

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Introduction

The extracorporeal life support (ECLS) is gaining popularity and is recognized as a potential life-saving tool in cardiogenic shock and in selected population of patients suffering cardiac arrest.1,2 Among them, a special subpopulation of patients exposed to severe accidental hypothermia may benefit from the veno-arterial extracorporeal membrane oxygenation (VA-ECMO) in a form of a bridge to recovery, that is, controlled rewarming and restoration of haemodynamic stability. Whole body hypothermia offers a unique time window for a better final Cerebral Performance Score (CPS) in severely under-perfused brain suffering from low cardiac output or cardiac arrest.3–5 The concept is not new and had been explored with an extracorporeal circuit known from cardiac surgery already before the renaissance of the ECLS 10 years ago. The experience with rewarming and resuscitation had been particularly taken from mountain emergencies and avalanche victims.6–8 Recent developments and achievements in the field of the ECLS led to a spread of cases treated with VA-ECMO, which is reflected in the current available case reports9–12 and case series.5,8,13–16 These reports focus particularly on the circumstances of an accident and the outcome, less is known about a specific VA-ECMO setting and actual course of the therapy.

Current methods of rewarming are based on recommendations and guidelines established by the Swiss Hypothermia Scale.3,13,15 Besides body temperature less than 28°C, an attention is to be paid particularly to the reduced consciousness, systolic blood pressure less than 90 mmHg and ventricular arrhythmias.3,4,15,17 If any of these factors are present in a severe hypothermia case the patient should be referred to the nearest hospital with an ECLS availability. VA-ECMO implementation is recommended in severe hypothermia patients (i.e. body temperature <28°C, Swiss Hypothermia Scale III-IV) and haemodynamic instability defined as ventricular arrhythmias or cardiac arrest.3,4,15,17 A decision whether to activate the ECLS centre or to take a patient to the nearest hospital might be challenging in a cold exposure with maintained airway and palpable bradycardia (sinus, junctional rhythm or atrial fibrillation with slow ventricular response). A problem may arise if bradycardia converts to a malignant arrhythmia during patient’s handling and transport. Presence of severe hypothermia significantly limits a chance for cardioversion, either electric or pharmacologically potentiated.3,4

The authors present a retrospective case series of patients with severe accidental hypothermia where patients treated with VA-ECMO were compared to other patients that were not treated with ECMO but warmed by traditional methods including warmed mattress, warm air and blankets. The parameters of VA-ECMO and their course are shown in detail depicting a mechanism which triggered the ECMO insertion and those who despite haemodynamic instability avoided the ECLS therapy. There are two small case series comparing two severely hypothermic groups treated with VA-ECMO and without VA-ECMO. One is from a single accident in Denmark19 and another one is an observational Japanese study from 2009 with a delayed time to surgical cannulation and rather unsatisfactory outcome data.14

There are few data to support how services may be established and hence many unanswered questions. The study submitted from an established high-volume ECMO centre where absolute majority of patients are cannulated percutaneously on admission could help the physicians to better understanding of the role of ECLS in the therapy of severe accidental hypothermia.

Methods

A retrospective, single ECMO centre, case series compared severely hypothermic patients rewarmed on VA-ECMO (n = 10) with hypothermic patients rewarmed using warmed mattress in combination with forced warm air blanket (n = 18). Only patients with intravascular temperature equal or lower than 28°C on admission to hospital were included. All of them fulfilled the Swiss Hypothermia Scale III-IV.3,13,15

The ECMO centre in Prague General University Hospital treats 50–100 ECMO patients annually since 2009. The ECLS patients have been reported into the Extracorporeal Life Support Organization (ELSO) database, 80% of all emergency ECMO cannulations are performed percutaneously by the intensive care or interventional cardiology teams. The centre also provides extracorporeal cardiopulmonary resuscitation (E-CPR) service for the Prague metropolitan area and currently enrols patients into the study on out-of-hospital cardiac arrest (OHCA) treated with VA-ECMO.20

The study qualified as a retrospective evaluation of cases prospectively recorded into our ECMO and intensive care unit (ICU) database. As such, it did not require a review by the University Hospital Ethical Board. The data recorded included demographics, data related to the course of ECMO, haemodynamic and laboratory data. All patients with mild to moderate accidental hypothermia were excluded regardless of their haemodynamic status.

The illness severity scores, courses of temperature and speed of rewarming (= 36 – admission temperature/hours to achieve 36°C) were compared between the ECMO group and the non-ECMO group as well as the haemodynamic parameters associated with restoration of body temperature. The ECMO times, configurations, settings and durations were recorded. The courses of the
reported major prognostic markers like core body temperature, pH, arterial lactate and serum potassium\textsuperscript{17,21–23} were compared between the ECMO and non-ECMO group at time points given by median time to achieving normothermia (36.0°C) using Student’s t-test or Mann–Whitney U test as appropriate. The biochemical, haematology parameters and outcome data were compared between the groups. Student’s t-test was applied for comparisons of data with normal distribution and the Mann–Whitney U test for the non-parametric data.

**Results**

In total, 47 patients with various degrees of accidental hypothermia and haemodynamic instability were admitted to our institution over a 5-year period (since 1 November 2013 till present). A total of 28 of those 47 were severely hypothermic (core body temperature <28°C), 19 patients with moderate to mild hypothermia on admission were excluded from the study. No patient with a core body temperature lower than 28°C admitted over the indicated 5 years was excluded from the study.

The intravesical temperature on admission was 25.2 ± 2.2°C, 10 patients had to be treated with VA-ECMO for refractory cardiac arrest and other 18 were rewarmed without ECMO. The circumstances of hypothermic accidents were alcohol intoxication (n = 11), drowning (n = 5), suicidal intoxication (n = 4), pneumonia (n = 4), status epilepticus (n = 1), stroke (n = 1), insulin-dependent diabetes with ketoacidotic hyperoncotic coma (n = 1) and hypoxic cardiac arrest (n = 1). Of the 28 included subjects, 9 were classified as being homeless. The anthropometric and demographic data are shown in Table 1. The admission APACHE II scores and Sequential Organ Failure Assessment (SOFA) scores of the ECMO patients on Day 1 were significantly higher than in the non-ECMO group. The admission core body temperature in the ECMO group was significantly lower than the non-ECMO group (Table 1).

The haemodynamic assessment during retrieval, transport to hospital and on admission was crucial for further course. Patients were retrieved in bradycardia (n = 20), ventricular fibrillation (VF, n = 8) and asystole (n = 4). Of those 12 who underwent CPR on Site 4 were defibrillated with median duration of VF 16.8 (8.4-30) minute, and two were resuscitated from asystole. All six subjects successfully achieving return of spontaneous circulation (ROSC) arrived bradycardic to hospital and were included in the non-ECMO group. Other four patients in VF and two in asystole were brought to hospital under ongoing CPR, and ECMO was cannulated on admission. Four patients presenting with bradycardia on site developed VF during transport to hospital or shortly after admission. They underwent an emergency ECMO cannulation. Eight of 10 patients of the ECMO group had VF at the time of cannulation, and the other two had asystole. All patients in the non-ECMO group were bradycardic (Table 2).

The admission laboratory data are presented in Table 3. The reported pH values are temperature corrected alpha-stat values. There were no significant differences between the groups except for lower haemoglobin level, prolonged international normalized ratio (INR) and activated partial thromboplastin time (APTT) in the ECMO group. These specimens were taken at patient’s admission with already launched VA-ECMO.

### Table 1. The anthropometric data, APACHE II, SOFA and admission core body temperature in the ECMO and non-ECMO groups, all means ± SD.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ECMO group (n = 10)</th>
<th>Non-ECMO group (n = 18)</th>
<th>Level of significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>37 ± 12.6</td>
<td>55.2 ± 11.2</td>
<td>p = 0.48</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168 ± 10.8</td>
<td>171 ± 8.8</td>
<td>p = 0.57</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>68 ± 14.2</td>
<td>70.4 ± 17.7</td>
<td>p = 0.69</td>
</tr>
<tr>
<td>BMI</td>
<td>24.2 ± 4.2</td>
<td>23.9 ± 4.5</td>
<td>p = 0.81</td>
</tr>
<tr>
<td>BSA</td>
<td>1.76 ± 0.22</td>
<td>1.82 ± 0.3</td>
<td>p = 0.61</td>
</tr>
<tr>
<td>APACHE II</td>
<td>42.8 ± 2.4</td>
<td>28.2 ± 5.6</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>SOFA Day 1</td>
<td>12.4 ± 1</td>
<td>10.2 ± 3.2</td>
<td>p = 0.04</td>
</tr>
<tr>
<td>Admission core body temperature (°C)</td>
<td>23.8 ± 2.6</td>
<td>26.0 ± 1.5</td>
<td>p = 0.01</td>
</tr>
</tbody>
</table>

BMI: body mass index; BSA: bovine serum albumin; ECMO: extracorporeal membrane oxygenation; SOFA: Sequential Organ Failure Assessment

*Unpaired t-test.

The median time from emergency alert to running VA-ECMO was 72 (63-109.8) minute, time from admission to hospital to running VA-ECMO was 27.6 (14-42.6) minute, that is, including those four with delayed onset VF in hospital. All patients had peripheral
femoro-femoral VA-ECMO. Nine cannulations were percutaneous by an intensivist (n = 5) or interventional cardiologist (n = 4). Besides those nine adult patients, there was one 12-year-old patient cannulated in the cath lab surgically. The mean size of the venous cannula was $23.7 \pm 3.5$ (range: 17-29) F and arterial cannula was $19.3 \pm 2.7$ (range 15-23) F, all patients were routinely inserted antegrade 7 or 6 F sheath into the femoral superficial artery to secure a distal leg perfusion. The devices used were A.L.ONE ECMO oxygenator (Eurosets S.r.l., Italy) with Rotaflow pump (Maquet Cardiopulmonary GmbH, Germany) (n = 5), PLS set (Maquet Cardiopulmonary GmbH, Germany) (n = 3), HLS 5.0 set (Maquet Cardiopulmonary GmbH, Germany) (n = 1) and HILITE 7,000 LT oxygenator (Medos Medizintechnik AG, Germany) with Rotaflow pump (Maquet Cardiopulmonary GmbH, Germany) (n = 1). Patients were anticoagulated with unfractionated heparin to maintain the median APTT of 59.6 (48-73) seconds, the median dose of heparin was 5.3 (0.9-6.4) IU/kg/hour. The median platelet count on ECMO was 100 (64-149) $10^3/\mu$L. Three of the ECMO group suffered bleeding complications (haemothorax post-CPR, nasopharyngeal bleeding, bleeding after surgical cannulation and one bleeding around percutaneously inserted arterial cannula). There were median of 0.5 (0-2) units/24 hours of packed red cells, median 0 (0-2) units/24 hours of fresh frozen plasma and 0.5 (0-2) units/24 hours of platelets administered during the rewarming on VA-ECMO. The course of major ECMO parameters (blood flow $Q_b$, sweep gas flow [SGF] and fraction of sweep oxygen $FsO_2$) throughout the median time to normothermia (36.0°C) are shown in Figure 1. The typical $Q_b$ was between 3-4 L/minute and SGF hovering around 2 L/minute, the median ECMO duration was 48.3 (28.1-86.7) hours until decannulation.

### Table 2. Speed of rewarming and major haemodynamic data in the ECMO and non-ECMO groups.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ECMO group (n = 10)</th>
<th>Non-ECMO group (n = 18)</th>
<th>Level of significance****</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of rewarming to 36.0°C (°C/hour)</td>
<td>0.41 (0.35-0.7)</td>
<td>0.77 (0.54-0.98)</td>
<td>p = 0.46</td>
</tr>
<tr>
<td>Time to 36.0°C (hour)</td>
<td>26.5 (16-31)</td>
<td>13 (10-19)</td>
<td>p = 0.07</td>
</tr>
<tr>
<td>Duration of ventricular fibrillation (minute)</td>
<td>99 (76.8-205.2)</td>
<td>N/A*</td>
<td>N/A</td>
</tr>
<tr>
<td>Heart rate on admission (beats/minutes)</td>
<td>N/A***</td>
<td>43 (33-65)</td>
<td>N/A</td>
</tr>
<tr>
<td>MAP at start (mmHg)</td>
<td>67.5 (62-73)***</td>
<td>84.5 (65-96)</td>
<td>p = 0.45</td>
</tr>
<tr>
<td>Noradrenaline dosage ($\mu$g/kg/minute)</td>
<td>0.23 (0.1-0.5)</td>
<td>0.08 (0-0.2)</td>
<td>p = 1.0</td>
</tr>
</tbody>
</table>

ECMO: extracorporeal membrane oxygenation; MAP: mean atrial pressure.

*Four of 18 defibrillated to palpable pulse prior to admission, other 2 of those 18 received successful ECC for asystole (10 and 8 min) during retrieval and transport; **Four in refractory VF and two in asystole, another four of those 10 had bradyarrhythmia 20-40/minute prior to transport to hospital, and all four popped to refractory VF during admission; ***On VA-ECMO; ****Mann–Whitney U test. All medians and interquartile ranges.

### Table 3. Selected admission laboratory data, all means ± SD.

<table>
<thead>
<tr>
<th>Parameter (arterial sample on admission)</th>
<th>ECMO group (n = 10)</th>
<th>Non-ECMO group (n = 18)</th>
<th>Level of significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>lactate (mmol/L)</td>
<td>8.22 ± 5.54</td>
<td>6.22 ± 5.2</td>
<td>p = 0.35</td>
</tr>
<tr>
<td>pH</td>
<td>7.11 ± 0.15</td>
<td>7.12 ± 0.19</td>
<td>p = 0.81</td>
</tr>
<tr>
<td>BE (mmol/L)</td>
<td>−10 ± 6.4</td>
<td>−13.1 ± 10.2</td>
<td>p = 0.39</td>
</tr>
<tr>
<td>PaO2 (kPa)</td>
<td>30.1 ± 27</td>
<td>33.8 ± 21.9</td>
<td>p = 0.70</td>
</tr>
<tr>
<td>PaCO2 (kPa)</td>
<td>7.6 ± 3.0</td>
<td>6.2 ± 2.0</td>
<td>p = 0.17</td>
</tr>
<tr>
<td>aHCO3− (mmol/L)</td>
<td>17.9 ± 5.4</td>
<td>16.0 ± 7.5</td>
<td>p = 0.51</td>
</tr>
<tr>
<td>K+ (mmol/L)</td>
<td>3.2 ± 0.8</td>
<td>3.7 ± 1.1</td>
<td>p = 0.18</td>
</tr>
<tr>
<td>Na+ (mmol/L)</td>
<td>138 ± 6.1</td>
<td>135 ± 7.8</td>
<td>p = 0.33</td>
</tr>
<tr>
<td>Hb (g/L)</td>
<td>105 ± 40</td>
<td>130 ± 21</td>
<td>p = 0.04</td>
</tr>
<tr>
<td>INR</td>
<td>1.92 ± 0.64</td>
<td>1.32 ± 0.32</td>
<td>p = 0.003</td>
</tr>
<tr>
<td>APTT (s)</td>
<td>114 ± 60</td>
<td>46 ± 13</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

INR: international normalized ratio; APTT: activated partial thromboplastin time; ECMO: extracorporeal membrane oxygenation.

*Unpaired t-test. The reported pH are temperature corrected alpha-stat values.
The median speed of rewarming was 0.41 (0.35-0.7)°C/hour and median time to achieve 36.0°C from admission was 26.5 (16-31) hours. For major haemodynamic data see Table 2.

**Non-ECMO group**

The non-ECMO patients were admitted bradycardic with the median palpable pulse of 43 (33-65)/minute. A total of 13 had slow sinus rhythm, three slow junctional rhythm and two atrial fibrillation with slow ventricular response. While on vasopressor support (Table 2), they underwent rewarming using warmed mattress (Blanketrol, Cincinnati Sub-Zero, USA, or Gaymar, Gaymar Ind, USA) in combination with forced warm air blanket (Bair Hugger, 3M, USA). The median speed of rewarming 0.77 (0.54-0.98)°C/hour was not different to the patients rewarmed on VA-ECMO (p = 0.46). The time to reach normothermia (36.0°C) 13 (10-19) hours was not different compared to the patients of the ECMO group (p = 0.07). The median APTT in the non-ECMO patients of 42 (36-47) second was significantly lower (p < 0.001) than in the ECMO group. While only three (17%) of those 18 rewarmed conservatively received an anticoagulation in the form of unfractionated heparin (5.1 (3.3-6.2) IU/kg hour). The median platelet count was 189 (109-265) 10^3/μL, which is significantly higher (p < 0.001) than in the ECMO group. Only one patient of the non-ECMO group suffered from a bleeding diathesis (haemoptysis post-drowning). One patient received one unit of packed red cells, and four patients were administered three units of fresh frozen plasma.

**Prognostic and outcome data**

The courses of recognized hypothermia-related major prognostic parameters like temperature, arterial lactate level, pH and plasmatic potassium were compared between the ECMO and non-ECMO group over initial 36 hours of rewarming (Figure 2). Except for the lower admission temperature in the ECMO patients (p = 0.01) and their significantly higher pH achieved between the third to ninth hour (p = 0.004-0.06), the other comparisons did not show any statistically significant difference (Figure 2).

The median ICU and hospital lengths of stay (LOS) were not different between the groups. The hospital mortality was 10% in the ECMO group and 11.1% in the non-ECMO group (Table 4). The patient declared dead on ECMO became organ donor with harvesting of four organs. The survivors presented excellent neurologic outcome with predominant Glasgow Coma Scale (GCS) 15 and CPS 1. The 3-month mortality data are difficult to conclude due to two patients in each group being discharged in the recent weeks and a significant loss in follow-up of the non-ECMO patients (Table 4).

**Discussion**

This retrospective observational study depicts a management of severe hypothermia in the established ECLS and E-CPR centre located in the centre of a European urban area. The retrieval of the victims was provided by the metropolitan emergency medical service which applies a rendezvous algorithm, where doctors are called to every unstable collapsing patient. The concept of care for a cardiovascular collapse with highly unstable or cardiac arrest patients is to refer them to an ECMO centre instead of establishing ECMO in the field, that is, patient to ECMO rather than bringing ECMO to a patient. Short accident-to-ECMO times have influenced our results also in the care of a severe accidental hypothermia. The rates of rewarming were similarly slow in both groups and slower than published elsewhere. We speculate that the slower rate of rewarming might be associated with a better neurological outcome. Patients on ECMO were slightly more hypothermic on admission, in cardiac arrest and with a similar rate of rewarming achieved faster pH rise between the third and ninth hour compared to the non-ECMO group (Figure 2).

The study on severe accidental hypothermia performed in the urban setting shows typically alcohol intoxication with exposure to cold. This together with other presentations like suicidal intoxications and pneumonias may produce better final CPS than asphyxia-associated hypothermia similar to an avalanche victim.
Moreover, the established pathway for retrieval is also facilitating better outcomes than, for example, in remote Alpine or Scandinavian regions.7–9,17,21

Table 4. The median ICU and hospital lengths of stay (LOS), last Glasgow Coma Score, Cerebral Performance Score, ICU, hospital and 3-month mortality.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ECMO group (n = 10)</th>
<th>Non-ECMO group (n = 18)</th>
<th>Level of significancea</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS ICU (days)</td>
<td>6 (6-11)</td>
<td>4.5 (2-8)</td>
<td>p = 1.0</td>
</tr>
<tr>
<td>LOS hospital (days)</td>
<td>10.5 (6-16)</td>
<td>12.5 (10-16)</td>
<td>p = 1.0</td>
</tr>
<tr>
<td>Last GCS (3-15)</td>
<td>15 (15-15)</td>
<td>15 (15-15)</td>
<td>p = 0.84</td>
</tr>
<tr>
<td>Last CPS (1-5)</td>
<td>1 (1-1)</td>
<td>1 (1-2)</td>
<td>p = 0.80</td>
</tr>
<tr>
<td>ICU mortality</td>
<td>1/10 (10%)</td>
<td>1/18 (5.6%)</td>
<td>ns</td>
</tr>
<tr>
<td>Hospital mortality</td>
<td>1/10 (10%)</td>
<td>2/18 (11.1%)</td>
<td>ns</td>
</tr>
<tr>
<td>3-month mortality</td>
<td>1/8***</td>
<td>2/11****</td>
<td>ns</td>
</tr>
</tbody>
</table>

ECMO: extracorporeal membrane oxygenation; LOS: length of stay; GCS: Glasgow Coma Scale; CPS: Cerebral Performance Score; ICU: intensive care unit.

*Mann–Whitney U test; **plus two alive and less than 3 months after admission; ***plus two alive and less than 3 months after admission, five lost in follow-up.

Moreover, the established pathway for retrieval is also facilitating better outcomes than, for example, in remote Alpine or Scandinavian regions.7–9,17,21

Our ICU and hospital mortalities of severely hypothermic patients are lower than published results on rather different case series where longer times to ECMO/
rewarming, more frequently asphyxiated patients and almost exclusively surgical approach to cannulation produced worse outcome data. Dead patients may also become organ donors when the harvesting is ideally performed on ECMO (brain dead or non–heart beating donor protocols) which shortens the period of warm ischaemia. The service is organized in co-operation with the national transplant team as part of the e-CPR service.

The study tests proposed prognostic factors judged also in relation to an ECMO indication like pH, lactate, potassium level, temperature and rhythm. Except for admission temperature, haemodynamic status and heart rhythm, the published indicators did not differ between a patient indicated to ECMO and a patient that could still be managed conservatively. Of the 28 included patients, 12 were resuscitated on their way to hospital, yet only 6 of those were ultimately placed on VA-ECMO, and 6 were successfully managed conservatively. A potential for a malignant arrhythmia has always been a concern in this cohort of the critically ill. Two of those 18 patients in the non-ECMO group had their femoral vein and femoral artery cannulated with 8F sheaths on admission in order to proceed immediately with ECMO cannulation when cardiac output would have been lost. The approach of a very cautious handling and stand-by ECMO has also an implication for triage of a severely hypothermic critically ill. If not admitted through a cath lab with an ECLS availability, they should bypass an emergency department straight to the ICU where an ECMO cannulation and perfusionists are available 24/7.

A ‘restrictive approach’ to invasive procedures in severely hypothermic patients emphasizes a need for training in haemodynamics and ECMO for the intensive care and cardiology teams. The application of non-invasive monitoring with echocardiography is feasible with regards to potential triggers of malignant arrhythmia when an invasive monitoring is applied. The diagnostic approach, 24/7 opportunity for ECMO cannulation by the intensive care team and a stand-by primed ECMO circuit allowed to rationalize the approach to VA-ECMO rewarming only to those who could not be managed and thus rewarmed without an ECLS. A ‘restrictive approach’ to the ECMO in hypothermic patients may also have an impact on utilization of the ICU resources and costs of care which has become an issue. Nine of those 28 included were from Prague homeless community with an outstanding CPS in a case series of patients with severe hypothermia retrieved in a European urban area and treated in an established ECLS and E-CPR centre. Besides mildly lower temperature in the ECMO patients and a presence of refractory cardiac arrest, the prognostic indicators published on previous case series and meta-analysis did not differ between patients in need of ECLS and those treated conservatively. The rewarming requires a short duration of the VA-ECMO with decreasing blood flow and lower SGF. These are related to an early afterload effect on the heart recovering from hypothermia and hypothermia-related low CO2 production.

The study is limited by the small number of patients preventing to draw any firm conclusions on a long-term outcome. In addition, a retrospective nature of the study made on prospectively collected data set calls for a prospective collection of data from various established ECLS centres, ideally those reporting patients to the ELSO database.

Conclusion

The study demonstrates a promising hospital survival of 89% with an outstanding CPS in a case series of patients with severe hypothermia retrieved in a European urban area and treated in an established ECLS and E-CPR centre. Besides mildly lower temperature in the ECMO patients and a presence of refractory cardiac arrest, the prognostic indicators published on previous case series and meta-analysis did not differ between patients in need of ECLS and those treated conservatively. The rewarming requires a short duration of the VA-ECMO with decreasing blood flow and lower SGF. These are related to an early afterload effect on the heart recovering from hypothermia and hypothermia-related low CO2 production.

Declaration of Conflicting Interests

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