

# Use of extracorporeal life support for active rewarming in a hypothermic, nonarrested patient with multiple trauma

Daniel K. Ting MD, Douglas J.A. Brown MD

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**A** 53-year-old man was driving in the winter when he was involved in a single-vehicle collision in the early morning hours (around 4:30). The vehicle travelled down a six-metre embankment and struck several large trees. The man was not wearing a seatbelt and was ejected through the windshield, ending up pinned under a tree. The ambient temperature was about  $-20^{\circ}\text{C}$ .

Loggers found the patient at 6:30 am with a decreased level of consciousness. While extrication efforts were underway, the ambulance service was notified and arrived on scene at 9 am.

The initial assessment by the paramedics documented a Glasgow Coma Scale score of 8, a heart rate of 42, and a blood pressure of 61/43. They placed a tibial intraosseous line and intubated the patient under direct laryngoscopy. They measured an esophageal temperature of  $23.5^{\circ}\text{C}$ . The patient was transported via air ambulance under full spinal precautions to the regional trauma and extracorporeal life support centre. Paramedics began passive rewarming techniques and also infused a litre of warmed normal saline. Prehospital notification was sent to cardiac surgery, anesthesia and intensive care.

At 11:15 am, the patient arrived at the emergency department and was assessed concurrently by the trauma team leader, cardiac surgeon, anesthesiologist and intensivist. Vital signs included a Glasgow Coma Scale score of 2T, a heart rate of 61, a blood pressure of 60/39 and an esophageal temperature of  $24.9^{\circ}\text{C}$ . Primary and secondary surveys did not show any life-threatening injuries. Extended focused assessment with sonography for trauma was negative for pneumothorax, hemothorax, abdominal free fluid or pericardial effusion. Continuous cardiac monitoring showed intermittent premature ventricular complexes, but no other cardiac arrhythmias. Initial laboratory investigations showed a hemoglobin of 130 g/L (normal range 135–169 g/L), a lactate of 8.5 mmol/L (normal range 0.7–2.1 mmol/L) and a serum potassium of 3 mmol/L (normal range 3.4–4.5 mmol/L). Results of arterial blood gas were pH 7.06, partial pressure of carbon dioxide 53 and partial pressure of oxygen 428 on 100% oxygen. The patient's ethanol level was 50 mmol/L (he had a history of alcoholic liver cirrhosis). While in the emergency department, the patient received a second litre of warmed normal saline. The

## KEY POINTS

- Extracorporeal life support can be used both for cardiopulmonary support and to rewarm patients who have had multiple trauma, either during surgical or endovascular procedures, or after major bleeding has been excluded.
- Extracorporeal life support is resource intensive and invasive; in nonarrested patients with severe hypothermia, there are no consensus criteria to guide its use, but current evidence suggests that patients who are unstable, comorbid or older are likely to benefit.
- The decision to begin extracorporeal life support in these patients must be weighed carefully against the risks of complications arising from the treatment.
- More study is required to determine optimal protocols and who may best benefit.

team decided to proceed directly to the hybrid operating room (which contains advanced imaging modalities within the surgical theatre) to facilitate further imaging, resuscitation and primary rewarming using veno-arterial extracorporeal life support.

In the hybrid operating room, an intraoperative chest radiograph, pelvis radiograph and a computed tomography scan of the patient's head were negative for acute injury. Systolic blood pressures remained below 80 mm Hg and core temperature at  $25.9^{\circ}\text{C}$ . The cardiac surgeon inserted a 25-Fr venous and 19-Fr arterial cannula into the right femoral area and started extracorporeal life support at 12:25 pm. The extracorporeal life support circuit was programmed to have flow rates of 4.5 to 5 L/min, a temperature gradient of  $1-2^{\circ}\text{C}$ , and a fraction of inspired oxygen of 100%. The team decided to avoid using heparin, as the patient had sufficient physiologic fibrinolysis from hypothermia and trauma. The patient was rewarmed to  $36.5^{\circ}\text{C}$  over two hours ( $5.3^{\circ}\text{C}/\text{h}$ ) and was then weaned and decannulated. Intravenous infusions of norepinephrine (0.02 to 0.12  $\mu\text{g}/\text{kg}/\text{min}$ ) and vasopressin (0.06 units/min) were used during extracorporeal life support. No substantial arrhythmias occurred. Four units of crystalloid and three units of packed red blood cells were transfused to support intravascular volume.

The patient was transferred in stable condition on vasopressor support to the intensive care unit (ICU) for care and full trauma workup. He remained in the ICU for 11 days, and was discharged from hospital 33 days after admission. His trauma workup showed a C4–C5 ligamentous injury that required neurosurgical stabilization and severe frostbite to his right hand, which eventually necessitated partial amputation of all digits. The patient had a full neurologic recovery. He declined referral for treatment of his alcohol disorder.

## Discussion

The choice of rewarming treatments for hypothermic patients varies from centre to centre and from physician to physician.<sup>1,2</sup> There is not sufficient available literature to guide management of hypothermic patients, as studies are mostly retrospective in nature and limited by small patient numbers. Physiologic studies in humans are generally restricted from cooling below 35°C for ethical reasons, and there are no good animal models.<sup>3</sup>

Expert opinion suggests using active external and minimally invasive rewarming methods for patients who are stable, and using extracorporeal life support for patients in cardiac arrest.<sup>4,5</sup> Nonarrested patients with severe hypothermia are at risk of cardiac arrest and therefore may benefit from transport to a centre capable of providing extracorporeal life support, rather than the closest emergency department.<sup>4,5</sup>

For nonarrested patients with severe hypothermia, it is unknown which patients may benefit from extracorporeal life support rewarming and which patients will rewarm safely with the use of minimally invasive techniques. Morita and colleagues<sup>6</sup> conducted a historical before and after trial that included 68 nonarrested patients with core temperatures less than 28°C. They found a 30% absolute reduction in mortality after the implementation of protocols based on extracorporeal life support for this population compared with conventional rewarming methods. Röggla and colleagues<sup>7</sup> carried out a retrospective cohort study in an urban setting that identified 36 hypothermia patients with core temperatures less than 28°C who were rewarmed using conventional methods; patients had an in-hospital mortality of 42%, which increased to 65% for the subgroup with systolic blood pressures less than 70 mm Hg. They showed an 8% rate of in-hospital cardiac arrest during conventional rewarming and attributed death to comorbid illness for 13 of the 15 fatalities. In contrast, younger populations with fewer comorbidities may rewarm safely with minimally invasive techniques. Wanschler and colleagues<sup>8</sup> reported a case series in which three young nonarrested patients had core temperatures of less than or equal to 28°C and were rewarmed with conventional techniques without complications. Furthermore, Steele and colleagues<sup>9</sup> prospectively studied 16 adult patients with temperatures lower than 32°C who were all safely rewarmed noninvasively.

In severe hypothermia, minimally invasive rewarming techniques take a median of 10 hours.<sup>7</sup> During this time, patients are at risk of hypothermic complications such as arrhythmia, coagulopathy and multi-organ failure.<sup>5</sup> Extracorporeal life support

rewarming is more rapid and provides cardiorespiratory support that ameliorates the poor organ perfusion associated with severe hypothermia, but it is an invasive, resource-intensive procedure with an approximate 1.2% risk of death or limb amputation.<sup>10</sup> In 2016, the International Commission for Mountain Emergency Medicine endorsed a review that proposed five potential criteria for extracorporeal life support in nonarrested hypothermic patients<sup>5</sup> (Box 1), but other experts support different criteria, including a core temperature below 28°C<sup>10</sup> and comorbid illness that impairs tolerance for hypothermic multi-organ dysfunction.<sup>11</sup>

The clinician has limited existing evidence to guide management of patients with both hypothermia and trauma. Hypothermia in trauma is independently associated with a threefold increase in mortality,<sup>12,13</sup> and survival may be particularly poor with mechanisms involving water submersion.<sup>4</sup> Any hemorrhage is worsened by coagulopathy, which develops below 34°C and is not measured by standard assays.<sup>3</sup> Furthermore, lactic acidosis and hypoperfusion secondary to hypovolemic shock are all poorly tolerated in trauma and contribute to patient harm.<sup>5</sup> For these reasons, multiple trauma may be a comorbidity that prevents patients from being able to tolerate the multi-organ dysfunction associated with their hypothermia safely.

Before the development of heparin-free protocols, the use of extracorporeal life support in patients with trauma was limited. More recently, patients with trauma who have refractory hypoxemia or hypotension are being managed with extracorporeal life support while undergoing damage control through surgical or endovascular treatments.<sup>13</sup> In such patients, the presence or absence of intracranial hemorrhage as well as the exclusion of terminal illness may be pivotal to determining the risk versus benefit of extracorporeal life support.

Patients with severe hypothermia in addition to their trauma, such as the case presented, pose unique decision-making challenges. Generally, such patients have a substantial traumatic mechanism, are immobile or unable to seek care for a prolonged period, have a decreased level of consciousness and are hypotensive. By the very nature of surviving long enough to become severely hypothermic, many of these patients have declared that they do not have hemorrhagic injuries that require urgent intervention, despite their hypotension and mechanism. Accurate core temperature measurement showing mild hypothermia can help rule out hypothermia as the cause of a decreased level of consciousness, but

### Box 1: Selected proposed criteria for extracorporeal life support rewarming in severe hypothermia\*

- Failure to improve with external active and minimally invasive rewarming methods
- Life-threatening arrhythmia
- Hypotension (systolic blood pressure < 90 mm Hg)
- Respiratory failure
- Refractory acidosis

\*As endorsed by the International Commission for Mountain Emergency Medicine.<sup>5</sup>

below about 29°C, hypothermia usually causes neurologic impairment and can mask traumatic brain injury or comorbid illness.<sup>5</sup> For trauma management, the Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach should be prioritized, including temperature management and surgical or endovascular control of hemorrhage as required. Transfer to the closest appropriate trauma centre is usually indicated, regardless of core temperature.<sup>4</sup>

### Diagnosis

Accidental hypothermia is defined as an involuntary drop in core temperature below 35°C.<sup>4</sup> Accidental hypothermia can be subdivided into primary hypothermia, caused by environmental exposure, or secondary hypothermia, caused by impaired thermoregulation. Hypothermia slows metabolism, markedly decreases oxygen consumption, and is neuroprotective, allowing for remarkable cases of survival,<sup>5</sup> but also causes altered level of consciousness, coagulopathy and progressive multi-organ failure. Patient survival with fully intact neurologic recovery has been reported with core temperatures as low as 13.7°C and over six hours of cardiopulmonary resuscitation.<sup>5</sup> Many clinicians now classify and treat hypothermia using the modified staging system: mild (HT I, 35°C to 32°C), moderate (HT II, 32°C to 28°C), severe (HT III, below 28°C) and cardiac arrest (HT IV) (Box 2). The main advantage of this classification is that an accurate core temperature is not needed to triage transport.<sup>4</sup> Given the multidisciplinary nature of hypothermic patient care and the relative infrequency with which providers manage hypothermia, a clinical practice guideline such as the one developed in British Columbia<sup>14</sup> may help improve quality of care.

### Management

In this case, the patient presented with severe hypothermia (core temperature of 23.5°C), likely owing to a combination of primary exposure and secondary hypothermia from trauma and ethanol intoxication. Hypothermia was probably the main contributor to the profound hypotension (61/43) given the 4.5 hours since initial injury and the negative primary and secondary surveys, including the extended focused assessment with sonography for trauma (EFAST) examination; however, the severe mechanism and lack of imaging created uncertainty regarding potential traumatic injuries. The clinicians were faced with a clinical decision to do one of the following: resuscitate and rewarm in the emergency department using minimally invasive techniques or extracorporeal life support; transfer to radiology for trauma imaging before determining patient disposition; or proceed directly to the operating room for extracorporeal life support rewarming with or without trauma laparotomy. With minimally invasive rewarming, the patient would be at risk of ischemic injury from prolonged hypotension and circulatory decompensation from severe hypothermia for many hours. Proceeding directly to extracorporeal life support involved a risk of futility should the patient have already suffered a catastrophic intracranial injury. Whereas it would be ideal to image all patients with multiple trauma fully, the clinicians judged that the patient's need for ongoing resuscitation and the risk of cardiac arrest were a contraindication to imaging in the radiology department, as it is a suboptimal location for resuscitation. In this case, the operating room, where it is possible to diagnose and treat life-threatening pathology simultaneously, was selected as the optimal location for further treatment.

#### Box 2: Staging and treatment of accidental hypothermia<sup>11</sup>

Stage	Clinical signs	Approximate core temperature (°C)	Treatment
Mild (HT I)	Conscious, shivering	32 to 35	<ul style="list-style-type: none"> <li>Warm environment and clothing; warm, sweet drinks; active movement if possible</li> </ul>
Moderate (HT II)	Impaired consciousness, with or without shivering	28 to < 32	<ul style="list-style-type: none"> <li>Active external and minimally invasive rewarming</li> <li>Cardiac and core temperature monitoring</li> <li>Minimize movements, horizontal position, immobilization</li> <li>Full body insulation</li> </ul>
Severe (HT III)	Unconscious, vital signs present	< 28	<ul style="list-style-type: none"> <li>HT II management, plus:               <ul style="list-style-type: none"> <li>Airway management as required</li> <li>Preference to treat in ECLS centre*</li> </ul> </li> </ul>
Cardiac arrest (HT IV)	Unconscious, vital signs absent	< 28 (variable)	<ul style="list-style-type: none"> <li>CPR and up to 3 doses of epinephrine and defibrillation</li> <li>Airway management</li> <li>Transport to ECLS centre</li> <li>Prevent further heat loss (insulation, warm environment, do not apply heat to head)</li> <li>Active external and minimally invasive rewarming during transport (as per HTII)</li> </ul>

Note: CPR = cardiopulmonary resuscitation, ECLS = extracorporeal life support, HT = hypothermia.

\*Refer to Box 1 for proposed ECLS criteria.

It is impossible to know how the patient would have done without extracorporeal life support, but given his low core temperature, he was at high risk for hypothermic cardiac arrest and had a threefold increased chance of death from any traumatic injuries.<sup>12</sup> The patient was later found to have an unstable cervical spine injury which, in the event of a malignant arrhythmia, might have been worsened by cardiopulmonary resuscitation.

## Conclusion

We report the case of a nonarrested patient with severe accidental hypothermia and multiple trauma who had a full neurologic recovery after undergoing extracorporeal life support for primary rewarming. The decision to begin extracorporeal life support in patients like this must be weighed carefully against the risks of complications arising from the treatment. We suggest further research to determine the indications and contraindications for extracorporeal life support in hypothermic patients with multiple trauma.

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**Affiliations:** Department of Emergency Medicine (Ting), University of British Columbia, Kelowna, BC; Department of Emergency Medicine (Brown), University of British Columbia, Vancouver BC

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**Correspondence to:** Daniel Ting, daniel.ting@alumni.ubc.ca