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ELSO 2025 Narrative Guideline on the Use of ECMO for Accidental Hypothermia

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This narrative guideline is intended to provide guidance for hypothermic cardiac arrest, distinguishing their characteristics and clinical considerations from normothermic cardiac arrest.

Background

Accidental hypothermia (AH) can be caused by exposure to cold weather conditions, immersion in water, avalanche burial in snow, or indoors, mostly affecting elderly patients with multiple comorbidities.[1,2] There are three stages of AH.[3] In mild AH core temperatures are 35°C–32°C (95°F–89.6°F) and mental status is normal or mildly impaired. In moderate AH with core temperatures between 32°C–28°C (89.6°F–82.4°F), patients may be unconscious or conscious with altered mental

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Take-home messages

1. There are significant differences between hypothermic and normothermic cardiac arrest.
2. Patients with out-of-hospital hypothermic cardiac arrest have better survival with more favorable neurological outcomes than patients with normothermic out-of-hospital cardiac arrest.
3. Extracorporeal life support (ECLS) criteria established for normothermic patients should not be used for hypothermic patients.
4. Unwitnessed cardiac arrest, asystole, long no-flow and low-flow (cardiopulmonary resuscitation [CPR]) times, age ≥70, and low $EtCO_2$ are not contraindications to ECLS for hypothermic cardiac arrest patients.
5. ECLS rewarming produces satisfactory results in patients in severe hypothermia.

status. In severe AH with core temperatures <28°C (82.4°F), patients are unconscious. Pathophysiologic changes caused by hypothermia affect the cardiovascular system, leading to dysrhythmias, impaired cardiac output, and cardiac arrest (CA).[4–7] There may be significant morbidity and mortality but there may also be favorable outcomes.[8–11] Patients with core temperatures <28°C (82.4°F) without CA can be rewarmed by conventional rewarming methods. In unstable patients, extracorporeal life support (ECLS)—extracorporeal membrane oxygenation (ECMO) or cardiopulmonary bypass—is more effective than conventional means because it provides cardiorespiratory support in addition to rewarming.[3,8,12–17] Extracorporeal membrane oxygenation can also be used to provide post-rewarming cardiorespiratory support if necessary.

Patient selection, outcome prediction, and treatment depend on logistics and planning, including planning for the implementation of ECLS.[18,19] The risk of CA is high in young, healthy patients with core temperatures <28°C (82.4°C), and in elderly patients or patients of any age with comorbidities and core temperatures <30°C (86°F). These patients should be transferred to centers capable of providing ECLS.[20] The ICE-CRASH study showed that treatment with ECMO was significantly associated with improved 28 day survival and favorable neurological outcomes at hospital discharge in patients with CA compared with those who did not receive ECMO (odds ratio [OR]: 0.17, 95% confidence interval [CI]: 0.05–0.58, and OR: 0.22, 95% CI: 0.06–0.81).[21] Indications for ECLS rewarming in severely hypothermic patients with preserved circulation have not been precisely established, and the data on outcomes are conflicting. In one study, ECMO did not improve survival or neurological outcomes and increased treatment duration and frequency of bleeding complications.[21] Two other studies found that patients with severe hypothermia and cardiovascular instability might benefit from extracorporeal rewarming without an increased risk of complications. The survival rate was higher in patients rewarmed with ECLS. The relative risk of death was twice as high in patients rewarmed by less invasive means.[22] Eligibility for ECLS should not be based on core temperature alone or on the stage of hypothermia but also on the condition of the patient.

This expert consensus Extracorporeal Life Support Organization (ELSO) guideline gives recommendations for the use of ECLS for cardiorespiratory support and for rewarming in severe AH.

Preparation and Organization

The chain of survival in AH starts in the prehospital phase (Figure 1).[12,16,23–31] Patients, who are unconscious, have a systolic blood pressure of <90 mm Hg, bradycardia of <40/min, or ventricular arrhythmias are at a high risk of CA.[12,20,25] Cardiac arrest may be triggered by movement of the patient, by airway management, and by other rescue procedures. The onset of hypothermic cardiac arrest (HCA) reduces survival by half.[26] Cautious patient movement may prevent HCA. Early recognition of AH as a possible cause of CA, and provision of high-quality cardiopulmonary resuscitation (CPR) are essential to improve the chance of survival. Mechanical chest compression is advantageous because CPR may be prolonged.[27] Delayed or intermittent CPR is an option in awkward or hazardous locations, when moving a patient in HCA, or if insufficient rescuers

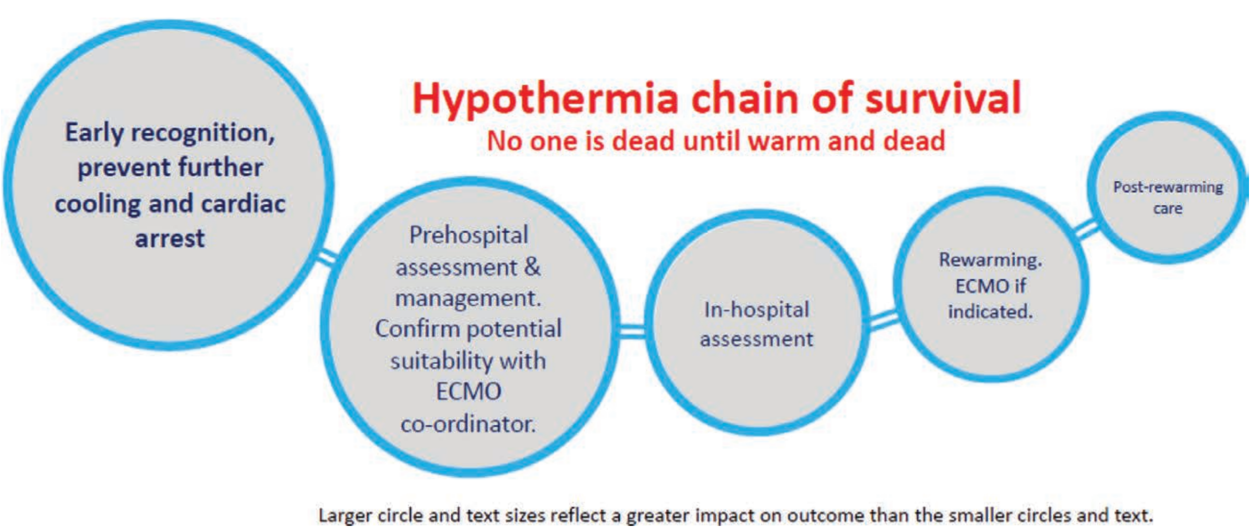

Figure 1. The hypothermia chain of survival. ECMO, extracorporeal membrane oxygenation.

Table 1. Prehospital Stage of Hypothermia Chain of Survival

Stage	Essential Actions	Decision Criteria/Specific Actions	Required Equipment
Early recognition and transport decision	Assess: Is history compatible with hypothermia? Assess clinical findings to identify candidates for ECLS - Decide on the need for hospital transport	Timing and location: Estimated length of time the patient has been exposed: date, time found, location Circumstances: Collapse, submersion, evidence of cooling, witnesses, evidence of attempted suicide, drug use, sudden loss of consciousness Factors affecting cooling rate: Immersion, clothing type, weather conditions. Potential contraindications: History of cardiac arrest before cooling; avalanche without patent airway and >60 min burial; major trauma; prolonged submersion. Core temperature: <30°C Level of consciousness: P or U on AVPU scale Cardiorespiratory status: *In cardiac arrest* Chest compressible *Not in cardiac arrest* Systolic blood pressure <90 mm Hg Bradycardia <40 beats/min Ventricular arrhythmia No absolute contraindication: See Figure 2.	Low-reading thermometers (esophageal or epitympanic) Noninvasive blood pressure Point-of-care glucose ECG Ultrasound
Assessment and management	- Monitoring - Patient care: - Advanced Life Support - Thermal protection	Commence CPR if necessary. Hypothermic cardiac arrest needs prolonged resuscitation. High-quality continuous CPR (preferably mechanical chest compression) are essential. Intermittent CPR is an option for short periods in difficult locations, insufficient rescue staff to maintain continuous CPR, or when moving an arrested patient.	- CPR devices. Mechanical chest compression device. Defibrillator. End-tidal carbon dioxide to confirm endotracheal tube position (but not to decide whether to terminate resuscitation). - Portable monitoring devices. - Insulation, chemical heat pads, intravenous fluid warmer, intravenous glucose
Transport to correct hospital	- Coordination with ECLS Center and Hypothermia Center - Establish transport logistics. - In-transport care - Arrival and handover	- Communicate patient status and ECLS need: cardiac arrest (Y/N); time; delay in CPR after arrest; CPR continuous or intermittent; mechanical chest compression; defibrillation attempted, number of times; ALS drugs; airway management. - Availability of ECLS-capable facility. - Ensure transport method - Distance and transport time to facility - Ongoing care and monitoring - Updates on estimated time of arrival and patient status with receiving facility on the way - Provide comprehensive patient report	- Communication devices

A, Alert; ALS, Advanced Life Support; CPR, cardiopulmonary resuscitation; ECG, electrocardiogram; ECLS, extracorporeal support life support; N, no; P, responds to painful stimulus; P, pain; U, unresponsive; Y, yes; V, responds to verbal stimulus.

are available to perform continuous CPR.[28] Long duration of transport with ongoing CPR should not be a reason to withhold resuscitation.

The receiving hospital should be notified by the emergency medical service (EMS) in collaboration with the ECLS center while the patient is still at the scene. The ECLS center should be available 24/7 to support prehospital teams.[27,29] The prehospital hypothermia, chain of survival illustrates the importance of early recognition of AH with prevention of further cooling, with monitoring, and with transport to the correct hospital for a patient in AH (Table 1).[16,23–32] Early identification of patients in the prehospital phase may be impaired by lack of core temperature thermometers.[33–35]

The ELSO provides a directory of ECLS centers worldwide (https://www.elso.org/membership/centerdirectory.aspx). Each EMS agency should establish a working relationship with its local ECLS center before the first actual transfer.

Patient Selection and Qualification for ECLS

Indications for ECLS rewarming in severe AH include HCA or hemodynamic instability to prevent subsequent CA.[12,25,36]

Hypothermic cardiac arrest

Extracorporeal support life support is indicated in patients with HCA, core temperatures <30°C (86°F), and estimated probability of survival ≥10%, based on the Hypothermia Outcome Prediction after ECLS (HOPE) score (Figure 2).[8,16,27,31,32,36] The HOPE score estimates the survival probability after ECLS support for patients with CA from AH.[8] An online calculator of the HOPE score is available at www.hypothermiascore.org.[8]

If the patient is considered a candidate for ECLS, CPR should be continued until ECLS is established. Core temperature should be measured using an esophageal probe (Figure 3).[8,16,31] Use caution when obtaining a potassium measurement from the femoral vessels as a hematoma (related to the coagulopathy) may complicate ECMO cannulation. Therefore, puncture of the femoral vessels should be ultrasound-guided. Unwitnessed HCA, asystole, long no-flow and low-flow times, age ≥70, and low end tidal carbon dioxide ($EtCO_2$) are not contraindications to ECLS for HCA (Figure 2).[8,16,36] There are significant differences between hypothermic and normothermic CA. Extracorporeal support life support criteria established for normothermic patients should not be used for hypothermic patients.[37]

Hypothermic Patients With Preserved Spontaneous Circulation

Indications for ECLS rewarming in severely hypothermic patients with preserved spontaneous circulation have not been precisely established, but hypotension <90 mm Hg or the presence of a ventricular arrhythmia typically determines if there is hemodynamic instability when deciding if a patient qualifies for ECLS. Victims of AH with hemodynamic instability may benefit from extracorporeal rewarming compared with less invasive methods.[22,30]

In patients in HCA, ECLS cannulation and rewarming should not be delayed for computed tomography (CT) scanning. If there are signs of trauma, consider ECLS rewarming with minimal or no anticoagulation. Once stable circulation has been achieved with venoarterial (VA) ECMO, patients with possible trauma may undergo CT scanning to assess injuries. In patients with preserved circulation and core temperature below 30°C, the decision to perform CT should be very carefully weighed against the benefits of imaging and the potential risk of CA—especially in the group of hemodynamically unstable patients who are candidates for ECLS.

ECLS Mode and Technical Considerations

Cardiopulmonary bypass (CPB) or VA ECMO may be used for rewarming depending on the immediate availability. However, VA ECMO needs fewer resources, is smaller, mobile, requires less heparin and is suitable for prolonged cardiorespiratory support in case of cardiopulmonary complications and may have superior outcomes.[1,7,17,26,30] It is reasonable to use CPB if ECMO is not available, especially in multicausality incidents with severe hypothermia. Extracorporeal treatment of patients with severe hypothermia serves not only to achieve normothermia but also to stabilize the cardiovascular and respiratory systems and to compensate for metabolic disorders. The preferred system is femoro-femoral VA ECMO with a distal perfusion cannula.

Vascular cannulation can be difficult because of the effects of low temperature on the vessels and surrounding tissues. The femoro-femoral configuration (arterial/venous) can rapidly be established without interrupting CPR and is the preferred configuration for establishing emergency access in adults, adolescents, and children >20 kg. Smaller children and babies are best cannulated by surgical cutdown on the right neck vessels.[4,11] Operators should consider the high risk of bleeding caused by hypothermia-associated coagulopathy and should choose the less invasive, percutaneous method of cannulation when feasible. Cannulation should be performed with ultrasound guidance. To maintain safety at key moments, such as puncture of the vessel, introduction of the guidewire and cannula, it is reasonable to interrupt CPR for a short time. Otherwise, interruptions in CPR should be kept to a minimum. Because of difficulties in obtaining blood for laboratory testing in hypothermic patients, it may be advisable to collect blood during cannulation to determine critical laboratory parameters.

Strict sterility of the operative field during cannulation is critical to prevent bloodstream infections. Cannulas should be positioned under fluoroscopic control or transesophageal echocardiography. Hypothermia increases the echogenicity of blood. In cardiac images, normal blood in the atria or ventricles may resemble blood clots.

Venting of the left ventricle is rarely necessary, as the heart usually starts ejecting after rewarming and oxygenation. However, venting should be considered following usual criteria and ECLS practice if left ventricle (LV) distention persists or if left atrial or pulmonary congestion supervenes. Bilateral femoral cannulation is associated with reduced risk of compartment syndrome, bleeding, need for fasciotomy or vessel repair during ECLS, and lower in-hospital mortality compared with other configurations.[38]

Patient and Circuit Management During ECLS

Defibrillation pads should be applied instead of electrocardiogram (ECG) leads as there is less electrocardiographic artifact from shivering. Defibrillator pads allow rapid detection

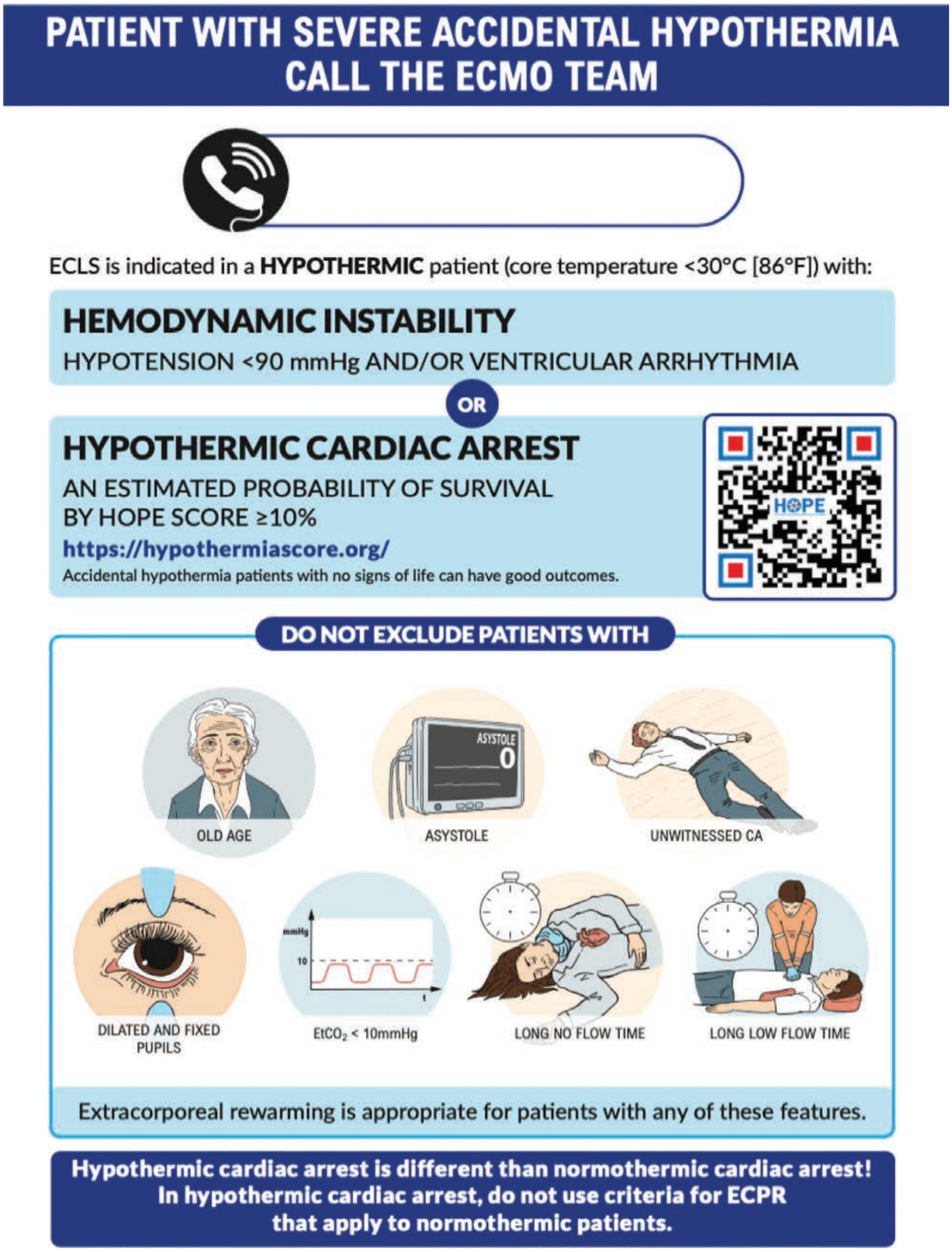

Figure 2. Indications for ECLS rewarming. There is no absolute contraindication to ECLS rewarming of hypothermic CA patients whose core temperature is <30°C. ECLS rewarming of hypothermic CA patients whose core temperature is between 30°C and 32°C, or whose estimated probability of survival by HOPE is <10% may be considered on an exceptional basis. CA, cardiac arrest; ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation. Figure published with permission (*ASAIO*).

and treatment of shockable rhythms.[11] Ventricular arrhythmias and asystole may be refractory until the patient has been rewarmed >30°C.[11]

In a VA femoro-femoral configuration, the intra-aortic mixing point between native cardiac output oxygenated by the lungs and ECMO blood flow *via* the return cannula moves distally down the aorta as native cardiac output improves. Oxygen saturation and partial pressure of oxygen in the right radial artery are almost equal to the blood perfusing the brain. Pulse oximetry (SpO_2) and PaO_2 should be measured in the right arm.[39] In HCA, peripheral oxygen saturation (SpO_2) and partial pressure of oxygen in arterial blood (PaO_2) decrease as native cardiac output improves, reflecting distal movement of the mixing point with more blood flow being partially oxygenated by the injured lung. Differential oxygenation may occur in a femoro-femoral VA configuration if lung function is impaired by aspiration or trauma. In such conditions, the upper part of the body receives a significantly reduced amount of oxygen, and there is a risk of brain ischemia. If this occurs, the configuration should be changed to

Figure 3. Initial management in accidental hypothermia-related cardiac arrest before ECLS cannulation. CPR, cardiopulmonary resuscitation; ECLS, Extracorporeal life support. Figure published with permission (*ASAIO*).

venoarteriovenous (VAV).[39,40] To ensure adequate cerebral perfusion, the target for mean systemic pressure should be between 50 and 70 mm Hg. Monitoring with near-infrared spectroscopy (NIRS) should be used to measure cerebral oxygenation.[40] Cerebral perfusion pressure should be maintained by fluid resuscitation with warm, isotonic crystalloid and vasopressors.[16] In the initial stages of treatment, there is a great need for fluid therapy. Fluids may be delivered *via* the ECLS circuit in the absence of adequate peripheral vascular access.

Surviving victims of avalanches or immersion are at high risk of suffering respiratory complications such as aspiration pneumonia and post-resuscitation chest trauma.[41] Protective lung ventilation should be used (Table 2). Infection prevention and treatment are the same as in other patients supported by ECMO.

Table 2. Ventilator Parameters During ECLS Rewarming

Usually ≤6 ml/kg ideal body weight
Rate 10–12/min
PEEP any level (5–15 cm H_2O)
Plateau pressure <30 cm H_2O
Driving pressure (Δ*P*: plateau pressure—PEEP <15 cm H_2O)
FiO_2 0.3–1.0 (avoiding hypoxia or hyperoxia)
PCO_2 (alpha stat): 4.5–5.5 kpa (35–45 mm Hg)

ECLS, extracorporeal life support; FiO_2, fraction of inspired oxygen; PCO_2, partial pressure of carbon dioxide; PEEP, positive end expiratory pressure.

Anticoagulation should be used to prevent thrombotic complications during ECLS. VA ECMO may be safely managed with no or low levels of anticoagulation for a limited time if there is profound coagulopathy. Anticoagulation should be monitored.[42–45]

- Administer unfractionated heparin or bivalirudin by continuous infusion with activated clotting time (ACT) target 150–180 sec, activated partial thromboplastin Time (aPTT) ratio 1.5–2, PTT 60–80 seconds (if using direct thrombin inhibitors), or antiXa (if using Heparin) 0.2–0.3 IU/ml
- If there is a high risk of bleeding, start ECMO without anticoagulant
- Stop anticoagulation if there is excessive bleeding
- Adopt an anticoagulation protocol based on current evidence
- Define priorities in case of bleeding requiring less invasive treatment

Blood gas management should follow institutional protocols (Table 3).[46–48] Arterial blood gas measurements should use alpha STAT procedure (not temperature-corrected).[11,47]

The target rewarming rate is up to 5°C/hour to a core temperature of 30°C or return of spontaneous circulation (ROSC), whichever occurs first. Further rewarming should follow guidelines for therapeutic hypothermia.[49–55] Oxygenator arterial outlet temperature should be monitored continuously. A temperature gradient between the venous inflow and arterial outlet of ≤4°C, should not be exceeded. The water heater set temperature should not exceed 10°C above the venous inflow temperature, up to a maximum of 42°C. Failure to follow these rules may cause serious neurological complications and hemolysis of blood cells. Core temperature should be monitored.[8,56] Because of warming of the descending aorta and a rapid increase in esophageal temperature, the measured temperature may not reflect the true core temperature. Core temperature should also be monitored at an additional location.[54]

Consideration of stopping ECLS should be given if there is no ROSC at 32°C –35°C (89.6°F–95°F). The decision to stop treatment should also be based on additional clinical information, such as uncontrollable hemorrhage, new information relating to the cause of CA, or signs of severe anoxic brain injury.[57]

Sedation and analgesia may be needed to avoid uncontrolled awakening, movement, or coughing. Sedation may be reduced or discontinued when normothermia with stable hemodynamic and pulmonary function is achieved.[58]

Complications

Complications during ECLS are frequent, decreasing survival probability.[40] Complications during ECLS for rewarming are similar to other indications for VA ECMO and include problems with access, systemic circulation, and the circuit.[57,59]

In prolonged CA, there is a possibility of chest injury with resultant respiratory failure requiring prolonged mechanical ventilation and extracorporeal membrane support.

Because of metabolic disorders and the pathophysiology of severe hypothermia, there is a possibility of renal failure requiring the use of renal replacement techniques.[57,59]

Weaning From ECLS

Cardiac failure is a common finding, presenting as left, right, or combined ventricular stunning.[58,59] Inotropes may be added. Serial echocardiography (LV function/concentric contraction) should be used to assess native cardiac output, left ventricular function, and aortic valve opening, and to exclude major valvular pathologies.

A weaning attempt may be performed once the core temperature is >35°C (95°F). With evidence of improved left ventricular ejection fraction by echocardiography and stable hemodynamics, ECLS blood flow may be reduced to 50%, then to 25% of adequate cardiac output. When ECLS support is less than 30% of total, native cardiorespiratory function may

Table 3. Alpha Stat vs. pH Stat in Hypothermia

Alpha Stat	pH Stat
Named because the ionization state of enzymatic α-histidine-imidazole groups is maintained constant	So called because pH is maintained at 7.4 regardless of blood temperature
Blood gas analysis results are not corrected for body temperature	Blood gas analysis results corrected for body temperature
Target = "normal" blood gases at 37°C	Target = "normal" blood temperature
Temperature-corrected hypocarbia and alkalosis tolerated	Temperature-uncorrected hypercarbia and acidosis tolerated
No additional CO_2 administered to patient	Additional CO_2 administered to patient
Maintains cerebral autoregulation	Uncouples cerebral autoregulation
Avoids potential problems of excess cerebral blood flow such as intracranial hypertension and increased microembolization	Cerebral blood flow increases independent of cerebral metabolic demand that may cause intracranial hypertension and increased microembolization
The alkaline pH improves cerebral protection during the ischemic insult	Carbon dioxide causes systemic vasodilatation resulting in faster, more homogeneous cooling
Intracellular trapping of metabolic intermediates and protein function maintained	Counteracts the leftward shift of the hemoglobin–oxygen dissociation curve that occurs with hypothermia and hypothermia-induced alkalemia increases offloading of hemoglobin to the tissues and may increase oxygen delivery which may optimize myocardial function
Preferred strategy in accidental hypothermia	Not preferred strategy in accidental hypothermia

be adequate to allow discontinuation of ECLS.[59] Weaning from mechanical circulatory support is successful in 30–70% of patients.[16,59,60]

Vasopressors and inotropes may be required to counteract vasoplegia and cardiac stunning.

The selection and dosing of inotropes, vasopressors, and inodilators (medications with both inotropic and vasodilator effects) should be tailored to the hemodynamic profile. There is little evidence to support specific practices in this area and considerable variability among institutions including those avoiding inotropic support altogether to rest the heart[60–62]

However, in CA patients treated with ECPR, use of levosimendan in the intensive care unit (ICU) was associated with significantly lower in-hospital mortality, higher rates of weaning from ECMO, and substantially lower rates of anoxic brain injury.[63,64]

Weaning may be delayed because of persistent respiratory failure.[61] In hemodynamically stable patients with persistent respiratory failure, VA ECMO may be converted to venovenous (VV) ECMO for respiratory support. The weaning strategy should be tailored to the needs of individual patients. Extracorporeal treatment of patients in severe hypothermia involves not only extracorporeal rewarming but also hemodynamic and metabolic stabilization and correction of respiratory disorders. Supplemental information, about circumstances in the field, primary or secondary diagnoses, and the clinical course of the resuscitation process may be helpful.

A post-resuscitation care bundle should be implemented, including adequate oxygenation and ventilation, coronary reperfusion, hemodynamic monitoring and management, seizure control, temperature regulation, general intensive care management, outcome prediction, and rehabilitation.[64] Neurologic outcome prediction should be performed in consultation with a neurologist once sedation is discontinued.

Outcomes

Hypothermic Cardiac Arrest

Patients with out-of-hospital HCA had better survival with more favorable neurological outcomes than patients with normothermic CA.[65] Another study found higher survival (53.8% *vs*. 22.5%) in patients treated with ECLS for hypothermic circulatory arrest compared with normothermic CA.[66] Survival rate ranges from 37% to 85% and a good cerebral outcome may be expected in 80–90% of survivors.[8,17,22,30,66,67] Good results have been demonstrated in patients despite the occurrence of factors that are contraindications to the implementation of ECLS in normothermia. Unwitnessed HCA, asystole, long no-flow and low-flow times, age ≥70, and low $EtCO_2$ are not contraindications to ECLS for HCA.[8,16,27,31,32,36] In the study by Podsiadło *et al*.,[68] in the group of patients with unwitnessed HCA, a 27% survival rate was found. Most survivors (83%) have a good neurological result. In survivors, in 48% of cases, asystole was the leading rhythm of CA.

Despite the long duration of arrest, the protective role of hypothermia has shown good results in the extracorporeal treatment of patients with HCA.[8,69] Saczkowski *et al*.[69] show that the mean time to CA in patients with a good treatment outcome is 116 minutes. Similarly, Pasquier *et al*.[8] show a time of 106 minutes in this group of patients. In the literature, there are descriptions of patients with very long periods of HCA, lasting more than 5 hours, which were successfully completed recovery to the use of extracorporeal treatment.[70]

Despite the worse outcomes associated with age, older patients with HCA may survive with good prognosis. Age over 70 should not be a disqualifying factor for extracorporeal treatment of patients with severe hypothermia.

Follow-up

The International Hypothermia Registry collects data of hypothermic patients worldwide and evaluates the outcomes.[71] Data in hypothermic CA patients, including out-of-hospital and in-hospital data, the mechanism of hypothermic CA, current condition, including core temperature, ECG, duration of CPR, and serum potassium, are used to calculate the survival probability using the HOPE score.[67] Data should also be collected after hospital discharge. These may be useful to re-evaluate survival probabilities in future patients.

References

1. Walpoth BH, Walpoth-Aslan BN, Mattle HP, *et al*: Outcome of survivors of accidental deep hypothermia and circulatory arrest treated with extracorporeal blood warming. *N Engl J Med* 337: 1500–1505, 1500.
2. Caroselli C, Gabrieli A, Pisani A, Bruno G: Hypothermia: an under-estimated risk. *Intern Emerg Med* 4: 227–230, 2009.
3. Dow J, Giesbrecht GG, Danzl DF, *et al*: Wilderness Medical Society Clinical Practice Guidelines for the out-of-hospital evaluation and treatment of accidental hypothermia: 2019 update. *Wilderness Environ Med* 30: S47–S69, 2019.
4. Paal P, Gordon L, Strapazzon G, *et al*: Accidental hypothermia-an update. *Scand J Trauma Resusc Emerg Med* 24: 111, 2016.
5. Turk EE: Hypothermia. *Forensic Sci Med Pathol* 6: 106–115, 2010.
6. Iyer A, Rajkumar V, Sadasivan D, Bruce J, Gilfillan I: No one is dead until warm and dead. *J Thorac Cardiovasc Surg* 134: 1042–1043, 1042.
7. Walpoth BH, Maeder MB, Courvoisier DS, *et al*: Hypothermic cardiac arrest—retrospective cohort study from the International Hypothermia Registry. *Resuscitation* 167: 58–65, 2021.
8. Pasquier M, Hugli O, Paal P, *et al*: Hypothermia outcome prediction after extracorporeal life support for hypothermic cardiac arrest patients: The HOPE score. *Resuscitation* 126: 58–64, 2018.
9. Ruttmann E, Weissenbacher A, Ulmer H, *et al*: Prolonged extracorporeal membrane oxygenation-assisted support provides improved survival in hypothermic patients with cardiocirculatory arrest. *J Thorac Cardiovasc Surg* 134: 594–600, 2007.
10. Forti A, Brugnaro P, Rauch S, *et al*: Hypothermic cardiac arrest with full neurologic recovery after approximately nine hours of cardiopulmonary resuscitation: Management and possible complications. *Ann Emerg Med* 73: 52–57, 2019.
11. Paal P, Pasquier M, Darocha T, *et al*: Accidental hypothermia: 2021 update. *Int J Environ Res Public Health* 19: 501, 2022.
12. Van de Voorde P, Turner NM, Djakow J, *et al*: European Resuscitation Council Guidelines 2021: Paediatric Life Support. *Resuscitation* 161: 327–387, 2021.
13. Panchal AR, Bartos JA, Cabañas JG, *et al*; Adult Basic and Advanced Life Support Writing Group: Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 142: S366–S468, 2020.
14. Pasquier M, Strapazzon G, Kottmann A, *et al*: On-site treatment of avalanche victims: Scoping review and 2023

recommendations of the International Commission for Mountain Emergency Medicine (ICAR MedCom). *Resuscitation* 184: 109708, 2023.
15. Brugger H, Bouzat P, Pasquier M, *et al*: Cut-off values of serum potassium and core temperature at hospital admission for extracorporeal rewarming of avalanche victims in cardiac arrest: A retrospective multi-centre study. *Resuscitation* 139: 222–229, 2019.
16. Swol J, Darocha T, Paal P, *et al*: Extracorporeal life support in accidental hypothermia with cardiac arrest—a narrative review. *ASAIO J* 68: 153–162, 2022.
17. Bjertnæs LJ, Hindberg K, Næsheim TO, *et al*: Rewarming from hypothermic cardiac arrest applying extracorporeal life support: A systematic review and meta-analysis. *Front Med (Lausanne)* 8: 641633, 2021.
18. Jarosz A, Darocha T, Kosiński S, *et al*: Profound accidental hypothermia: Systematic approach to active recognition and treatment. *ASAIO J* 63: e26–e30, 2017.
19. Balik M, Porizka M, Matousek V, *et al*: Management of accidental hypothermia: an established extracorporeal membrane oxygenation centre experience. *Perfusion* 34: 74–81, 2019.
20. Musi ME, Sheets A, Zafren K, *et al*: Clinical staging of accidental hypothermia: The Revised Swiss System: Recommendation of the International Commission for Mountain Emergency Medicine (ICAR MedCom). *Resuscitation* 162: 182–187, 2021.
21. Takauji S, Hayakawa M, Yamada D, *et al*: Outcome of extracorporeal membrane oxygenation use in severe accidental hypothermia with cardiac arrest and circulatory instability: A multicentre, prospective, observational study in Japan (ICE-CRASH study). *Resuscitation* 182: 109663, 2023.
22. Podsiadło P, Smoleń A, Brožek T, *et al*: Extracorporeal rewarming is associated with increased survival rate in severely hypothermic patients with preserved spontaneous circulation. *ASAIO J* 69: 749–755, 2023.
23. Romanelli D, Farrell MW. AVPU Scale. 2023 Apr 3. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2024 Jan–.
24. Vanden Hoek TL, Morrison LJ, Shuster M, *et al*: Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 122: S829–S861, 2010.
25. Podsiadło P, Brožek T, Balik M, *et al*; Hypothermia Study Group: Predictors of cardiac arrest in severe accidental hypothermia. *Am J Emerg Med* 78: 145–150, 2024.
26. Podsiadło P, Smoleń A, Kosiński S, *et al*: Impact of rescue collapse on mortality rate in severe accidental hypothermia: A matched-pair analysis. *Resuscitation* 164: 108–113, 2021.
27. Darocha T, Kosiński S, Jarosz A, *et al*: The chain of survival in hypothermic circulatory arrest: Encouraging preliminary results when using early identification, risk stratification and extracorporeal rewarming. *Scand J Trauma Resusc Emerg Med* 24: 85, 2016.
28. Gordon L, Paal P, Ellerton JA, Brugger H, Peek GJ, Zafren K: Delayed and intermittent CPR for severe accidental hypothermia. *Resuscitation* 90: 46–49, 2015.
29. Darocha T, Kosinski S, Moskwa M, *et al*: The role of hypothermia coordinator: A case of hypothermic cardiac arrest treated with ECMO. *High Alt Med Biol* 16: 352–355, 2015.
30. Morita S, Inokuchi S, Yamagiwa T, *et al*: Efficacy of portable and percutaneous cardiopulmonary bypass rewarming versus that of conventional internal rewarming for patients with accidental deep hypothermia. *Crit Care Med* 39: 1064–1068, 2011.
31. Rousson V, Hall N, Pasquier M: HOPE survival probability cutoff for ECLS rewarming in hypothermic cardiac arrest. *Resuscitation Plus* 18: 100616, 2024.
32. Lott C, Truhlar A, Alfonzo A, *et al*: European resuscitation council guidelines for cardiac arrest in special circumstances. *Resuscitation* 161: 152–219, 2021.
33. Podsiadło P, Darocha T, Kosiński S, Sanak T, Gałązkowski R: Body temperature measurement in ambulance: A challenge of 21-st century? *BMC Emerg Med* 1919: 44, 2019.
34. Henriksson O, Björnstig U, Saveman BI, Lundgren PJ: Protection against cold—A survey of available equipment in Swedish prehospital services. *Acta Anaesthesiol Scand* 61: 1354–1360, 2017.
35. Karlsen AM, Thomassen O, Vikenes BH, Brattebø G: Equipment to prevent, diagnose, and treat hypothermia: A survey of Norwegian pre-hospital services. *Scand J Trauma Resusc Emerg Med* 21: 63, 2013.
36. Pluta M, Darocha T, Pasquier M, Mendrala K, Kosiński S: Hypothermic cardiac arrest: Criteria for extracorporeal cardiopulmonary resuscitation. *Resuscitation* 204: 110410, 2024.
37. Mendrala K, Darocha T, Pluta M, *et al*; Hypothermia Study Group: Outcomes of extracorporeal life support in hypothermic cardiac arrest: Revisiting ELSO guidelines. *Resuscitation* 205: 110424, 2024.
38. Simons J, Di Mauro M, Mariani S, *et al*: Bilateral femoral cannulation is associated with reduced severe limb ischemia-related complications compared with unilateral femoral cannulation in adult peripheral venoarterial extracorporeal membrane oxygenation: Results from the Extracorporeal Life Support Registry. *Crit Care Med* 52: 80–91, 2024.
39. Chung M, Shiloh AL, Carlese A: Monitoring of the adult patient on venoarterial extracorporeal membrane oxygenation. *ScientificWorldJ* 2014: 393258, 2014.
40. Merkle J, Azizov F, Fatullayev J, *et al*: Monitoring of adult patient on venoarterial extracorporeal membrane oxygenation in intensive care medicine. *J Thorac Dis* 11: S946–S956, 2019.
41. Abrams D, Grasselli G, Schmidt M, Mueller T, Brodie D: ECLS-associated infections in adults: What we know and what we don't yet know. *Intensive Care Med* 46: 182–191, 2020.
42. Esper SA, Welsby IJ, Subramaniam K, *et al*: Adult extracorporeal membrane oxygenation: An international survey of transfusion and anticoagulation techniques. *Vox Sang* 112: 443–452, 2017.
43. Kander T, Brokopp J, Friberg H, Schott U: Wide temperature range testing with ROTEM coagulation analyses. *Ther Hypothermia Temp Manag* 4: 125–130, 2014.
44. Gennaro M, Giovanna P, Giovanna O, *et al*: Anticoagulation and transfusions management in veno-venous extracorporeal membrane oxygenation for acute respiratory distress syndrome: Assessment of factors associated with transfusion requirements and mortality. *J Intensive Care Med* 34: 630–639, 2017.
45. Martucci G, Giani M, Schmidt M, *et al*; International ECMO Network (ECMONet): Anticoagulation and bleeding during veno-venous extracorporeal membrane oxygenation: Insights from the PROTECMO study. *Am J Respir Crit Care Med* 209: 417–426, 2024.
46. Polderman KH, Herold I: Therapeutic hypothermia and controlled normothermia in the intensive care unit: Practical considerations, side effects, and cooling methods. *Crit Care Med* 37: 1101–1120, 2009.
47. Patel RL, Turtle MR, Chambers DJ, James DN, Newman S, Venn GE: Alpha-stat acid-base regulation during cardiopulmonary bypass improves neuropsychologic outcome in patients undergoing coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 111: 1267–1279, 1996.
48. Murkin JM, Martzke JS, Buchan AM, Bentley C, Wong CJ: A randomized study of the influence of perfusion technique and pH management strategy in 316 patients undergoing coronary artery bypass surgery. II. Neurologic and cognitive outcomes. *J Thorac Cardiovasc Surg* 110: 349–362, 1995.
49. Pynnonen L, Falkenbach P, Kamarainen A, Lonnrot K, Yli-Hankala A, Tenhunen J: Therapeutic hypothermia after cardiac arrest—cerebral perfusion and metabolism during upper and lower threshold normocapnia. *Resuscitation* 82: 1174–1179, 2011.
50. Paal P, Gordon L, Strapazzon G, *et al*: Accidental hypothermia-an update: The content of this review is endorsed by the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). *Scand J Trauma Resusc Emerg Med* 24: 111, 2016.
51. Berg KM, Soar J, Andersen LW, *et al*; Adult Advanced Life Support Collaborators: Adult Advanced Life Support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation* 142: S92–S139, 2020.
52. Linardi D, Walpoth B, Mani R, *et al*: Slow versus fast rewarming after hypothermic circulatory arrest: Effects on neuroinflammation and cerebral oedema. *European J Cardio Thoracic Surg* 58: 792–800, 2020.

53. Filseth OM, Kondratiev T, Sieck GC, Tveita T: Functional recovery after accidental deep hypothermic cardiac arrest: Comparison of different cardiopulmonary bypass rewarming strategies. *Front Physiol* 13: 960652, 2022.
54. Saczkowski R, Kuzak N, Grunau B, Schulze C: Extracorporeal life support rewarming rate is associated with survival with good neurological outcome in accidental hypothermia. *European J Cardio Thoracic Surg* 59: 593–600, 2021.
55. Watanabe M, Matsuyama T, Morita S, *et al*: Impact of rewarming rate on the mortality of patients with accidental hypothermia: Analysis of data from the J-Point registry. *Scandinavian J Trauma Resuscit Emerg Med* 27: 1–0, 2019.
56. Walpoth B, Galdikas J, Leupi F, Mühlemann W, Schläpfer P, Althaus U: Assessment of hypothermia with a new tympanic thermometer. *J Clin Monit* 10: 91–96, 1994.
57. Cheng R, Hachamovitch R, Kittleson M, *et al*: Complications of extracorporeal membrane oxygenation for treatment of cardiogenic shock and cardiac arrest: A meta-analysis of 1,866 adult patients. *Ann Thorac Surg* 97: 610–616, 2014.
58. Lorusso R, Shekar K, MacLaren G, *et al*: ELSO Interim Guidelines for venoarterial extracorporeal membrane oxygenation in adult cardiac patients. *ASAIO J* 67: 827–844, 2021.
59. Darocha T, Sobczyk D, Kosiński S, *et al*: New diastolic cardiomyopathy in patients with severe accidental hypothermia after ECMO rewarming: A case-series observational study. *Cardiovasc Ultrasound* 13: 31, 2015.
60. Kosiński S, Darocha T, Jarosz A, *et al*: Clinical course and prognostic factors of patients in severe accidental hypothermia with circulatory instability rewarmed with veno-arterial ECMO—An observational case series study. *Scand J Trauma Resusc Emerg Med* 25: 46, 2017.
61. ELSO Guidelines for Cardiopulmonary Extracorporeal Life Support. Extracorporeal Life Support Organization, Version 1.4 August 2017 Ann Arbor, MI, USA. www.elso.org. Accessed April 1, 2025
62. Brahmbhatt DH, Daly AL, Luk AC, Fan E, Billia F: Liberation from venoarterial extracorporeal membrane oxygenation: A review. *Circ Heart Fail* 14: e007679, 2021.
63. Ortuno S, Delmas C, Diehl JL, *et al*: Weaning from veno-arterial extra-corporeal membrane oxygenation: Which strategy to use? *Ann Cardiothorac Surg* 8: E1–E8, 2019.
64. Chen YW, Lee WC, Wu PJ, *et al*: Early levosimendan administration improved weaning success rate in extracorporeal membrane oxygenation in patients with cardiogenic shock. *Front Cardiovasc Med* 9: 912321, 2022.
65. Takiguchi T, Tominaga N, Hamaguchi T, *et al*; SAVE-J II Study Group: Etiology-based prognosis of extracorporeal CPR recipients after out-of-hospital cardiac arrest: A retrospective multicenter cohort study. *Chest* 165: 858–869, 2024.
66. Tanizawa S, Kojima M, Shoko T, *et al*; SAVE-J II study group: Extracorporeal cardiopulmonary resuscitation in hypothermic cardiac arrest: A secondary analysis of multicenter extracorporeal cardiopulmonary resuscitation registry data in Japan. *Resusc Plus* 19: 100705, 2024.
67. Pasquier M, Rousson V, Darocha T, *et al*: Hypothermia outcome prediction after extracorporeal life support for hypothermic cardiac arrest patients: An external validation of the HOPE score. *Resuscitation* 139: 321–328, 2019.
68. Podsiadło P, Darocha T, Svendsen OS, *et al*: Outcomes of patients suffering unwitnessed hypothermic cardiac arrest rewarmed with extracorporeal life support: A systematic review. *Artif Organs* 45: 222–229, 2021.
69. Saczkowski RS, Brown DJA, Abu-Laban RB, Fradet G, Schulze CJ, Kuzak ND: Prediction and risk stratification of survival in accidental hypothermia requiring extracorporeal life support: An individual patient data meta-analysis. *Resuscitation* 127: 51–57, 2018.
70. Boue Y, Lavolaine J, Bouzat P, Matraxia S, Chavanon O, Payen JF: Neurologic recovery from profound accidental hypothermia after 5 hours of cardiopulmonary resuscitation. *Crit Care Med* 42: e167–e170, 2014.
71. Cools E, Walpoth B, Meyer M, Courvoisier D. International Hypothermia Registry. https://hypothermia-registry.org. Accessed February 11, 2024.