Received: 4 January 2020 | Revised: 18 February 2020 | Accepted: 21 February 2020

DOI: 10.1002/emp2.12048

JACEP OPEN WILEY

CASE REPORT

Emergency Medical Services

Accidental hypothermic cardiac arrest and extracorporeal membrane oxygenation: a case report

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Funding and support: By *JACEP Open* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Abstract

Background: Accidental hypothermic cardiac arrest, an involuntary drop in core body temperature resulting in cardiopulmonary arrest, is linked to 1500 deaths annually. We highlight the challenges with the treatment of accidental hypothermic cardiac arrest and describe improved preparations necessary for an integrated health system to care for similar patients.

Case Report: Emergency medical services (EMS) were dispatched to a 34-year-old female who had been missing for several hours during a January snowfall. The patient was found unconscious over an embankment. The patient was found with a weak carotid pulse and two empty bottles of clozapine, an atypical antipsychotic. The EMS crew extricated the patient, performed a rapid trauma assessment, passive rewarming, and airway management. During transport, the patient suffered a ventricular fibrillation cardiac arrest, received defibrillation, and advanced life support measures. Resuscitative efforts continued in the emergency department while the treatment team addressed environmental exposure, assessed for traumatic injury and toxicologic exposure. On emergency department (ED) arrival, the patient's core temperature was 24°C, and despite aggressive resuscitation, the patient remained in cardiac arrest. The ED care team used extracorporeal membrane oxygenator (ECMO) and successfully resuscitated the patient with extracorporeal cardiopulmonary resuscitation. The patient achieved full neurologic recovery 15 days post-ED arrival.

Conclusion: This case highlights the importance of early recognition of accidental hypothermic cardiac arrest by EMS clinicians, rapid transport to a tertiary facility, and the timely application of active rewarming and in-hospital ECMO. Accidental hypother-

Supervising Editor: Karl A. Sporer, MD

mic cardiac arrest is a reversible state; prompt and correct treatment allows for a high probability of a favorable neurologic outcome.

KEYWORDS
accidental hypothermic cardiac arrest, extracorporeal membrane oxygenation

1 | BACKGROUND

Accidental hypothermic cardiac arrest refers to an involuntary drop in core body temperature that results in complete cessation of cardiopulmonary circulation.[1] It is associated with cold exposure and/or impaired thermoregulation and is linked to 1500 deaths annually.[2] Hypothermic cardiac arrest is reversible and treated differently than other causes of cardiac arrest.[1,2] Survival to discharge associated with medical, non-accidental hypothermic cardiac arrest is 9.1%,[3] whereas survival for accidental hypothermic cardiac arrest exceeds 70%.[4] In addition, 9 in every 10 accidental hypothermic cardiac arrest survivors recover to a good neurologic outcome.[4] Swift recognition of accidental hypothermic cardiac arrest in the out-of-hospital setting and timely treatment throughout the continuum of care is important for survival. Cases of accidental hypothermic cardiac arrest are rare and most emergency medical services (EMS)/emergency medicine clinicians will never initiate accidental hypothermic cardiac arrest-protocolized care. We highlight the challenges in the out-of-hospital and in-hospital management of accidental hypothermic cardiac arrest and describe the preparations necessary for an integrated health system to address a similar case. We report on a case of a female in her mid-30s, who experienced accidental hypothermic cardiac arrest in an urban environment.

2 | CASE REPORT

2.1 Out-of-hospital phase

At 1300 hours in mid-January 2014, EMS was dispatched for an unconscious female. The patient's father called 911 and reported that his daughter was missing. He stated that she suffered from depression and was a danger to herself. The weather in the area (as reported by the National Weather Service) was −2°C (≈28°F) with snowfall totaling 5–10 cm (2–4 inches). The patient was located at the bottom of a short embankment with a moderate grade (estimated at 15–20°). She was tangled in foliage and covered in snow. She was found unresponsive by her father who immediately requested EMS at 1404 hours.

A local EMS unit with one paramedic and one emergency medical technician basic arrived on scene at 1408 hours. The crew initiated a rapid trauma assessment and determined the patient was not responsive to verbal or painful stimuli. A weak peripheral pulse was detected. The airway was patent, yet respirations were shallow. The patient was rapidly extricated due to evolving weather conditions and difficult terrain.

The patient was loaded into the ambulance at 1415 hours. On reassessment, the patient had a heart rate of 50 bpm with absent peripheral pulses and weak central pulses. The patient's wet clothing was removed and she was covered in blankets to limit heat loss. The heat in the ambulance was increased and hot packs were applied to groin and axilla to facilitate passive rewarming. While removing the patient's clothing, crew members identified two prescription medication bottles labeled with the antipsychotic medication clozapine, one bottle was empty. Active warming was initiated with a warm crystalloid infusion, and an oropharyngeal airway was placed with minor difficulty secondary to poor jaw mobility. Trismus was noted, which prevented the placement of an advanced airway. The patient's respirations were agonal at a rate of 4 breaths per minute. Ventilations were assisted with a bag-valve-mask. The crew noted adequate compliance and chest rise with bag-valve-mask ventilations using the oropharyngeal adjunct. At 1417 hours, the patient became pulseless with ventricular fibrillation on the cardiac monitor. The patient was defibrillated at 360 joules (monophasic) followed by chest compressions at a rate of 30 compressions to 2 ventilations (30:2). The patient was covered with blankets during cardiopulmonary resuscitation (CPR). Due to the potential of trauma, overdose, and assumed hypothermia, the decision was made to initiate immediate transport to the closest trauma center capable of emergent invasive rewarming.

After the first defibrillation, the patient's cardiac rhythm changed to a slow pulseless electrical activity with a wide complex rhythm and a rate of 20 per minute. One crew member continued CPR while the second gained intravenous access in the upper extremity. A 500 mL normal saline bolus was initiated (at 1422 hours). Four minutes later, 1 mg of epinephrine 1:10,000 was prepared. The patient's intravenous line was inadvertently dislodged. Intraosseous (IO) access was then established at 1428 hours in the left tibial plateau. Epinephrine was administered via the IO site. At 1430 hours, the patient's cardiac rhythm returned to ventricular fibrillation and the crew delivered a second defibrillation at 360 joules (monophasic). The patient's cardiac rhythm was pulseless electrical activity. At 1435 hours, the ambulance arrived at the emergency department and care was transferred to the resuscitation team.

2.2 In-hospital phase

On arrival, the trauma team continued CPR and initiated a primary trauma survey. The patient's initial recorded temperature was 24°C via an esophageal temperature probe. Moments after ED arrival, clinicians recorded a return of spontaneous circulation. The patient was intubated with a 7.5-mm tube, placed at a depth of 23 cm. During the intubation, the patient went into cardiac arrest again and the trauma team began CPR. The patient received 1 mg of epinephrine (1:10,000). The patient had return of spontaneous circulation, and a pulse rate of 80 was detected using Doppler. The trauma team performed a secondary survey and adjunctive testing with plain radiographs and a focused abdominal sonogram for trauma. Initial pertinent lab results included: lactate = 9.7, potassium = 2.7, troponin = negative, and urine drug screen = negative. The hypokalemia was likely a result of the extreme hypothermia driving the potassium into the cells; this will normalize as the patient is rewarmed. The patient received 100 mEq of sodium bicarbonate and 1 amp of calcium in the ED given concerns over acidosis and poor cardiac contactility. The patient remained hypotensive and was placed on an epinephrine drip at 0.05 μg/kg/min. Despite aggressive titration, a palpable pulse was not detected.

Clinicians continued with CPR and the "shock team" was activated for extracorporeal membrane oxygenation (ECMO). Central access was obtained simultaneously in the right femoral artery with a 19 French catheter while right femoral vein was obtained with a 27 French catheter. At the time of ECMO cannulation, clinicians reported pulseless electrical activity on the cardiac monitor with a bradycardic rhythm and a rate of 20 bpm. At 1503 hours, the patient was successfully placed on ECMO generating a flow of 5 lpm. At this point, CPR was stopped. A chest x-ray detected 1 right rib fracture of the fifthrib. Within minutes of being on ECMO, the patient's core body temperature showed improvement to 29.6°C, and the patient was rewarmed to 33°C for targeted temperature management. Vasopressin and norepinephrine drips were administered to increase the patient's blood pressure to a systolic pressure of 90 mm Hg. Once stable on ECMO, the patient was transferred to the ICU where she received a distal bridge of the right lower extremity due to ischemia, an expected complication of femoral arterial cannulation. The patient was placed on antibiotics for aspiration pneumonia and remained on ECMO support for 3 days.

The patient was extubated after 6 days and was able to communicate with the care team but did not recall the events that led to the accidental hypothermic cardiac arrest. Following extubation, the patient underwent a mini-mental status exam and scored a 28/30, which is evidence of good neurologic outcome. On day 7, the patient was transferred to the medical floor for observation and consultation with psychiatry and internal medicine. The patient was discharged to a psychiatric facility after 15 days post-ED arrival.

3 | DISCUSSION

3.1 Pathophysiology

Accidental hypothermic cardiac arrests are rare events and most emergency medicine clinicians may never encounter such a case. Accidental hypothermic arrest usually occurs with exposure to temperatures below 10°C. Substance use is common in accidental hypothermic cardiac arrest.[5-7] Substance use contributes to accidental hypothermia both through direct pharmacologic effects such as peripheral vasodilation and through impaired perception and judgment. Prescription medications may also impair judgment, perception, or thermoregulation. In this case, clozapine can alter hypothalamic thermoregulation inducing hypothermia or impairing response to low ambient temperatures.[8]

Our case offers the opportunity to review pathophysiology and discuss key elements of protocolized care. During mild hypothermia, the heart rate and respiratory rate and vasoconstriction increases leading to improved cardiac output. As the core body temperature falls so does the heart rate. Mild hypothermia can lead to a prolonged ventricular contraction and a 40% increase in contractile force.[9] Moderate hypothermia is associated with bradycardia caused by decreased spontaneous depolarization of the pacemaker cells. Hypothermic bradycardia is refractory to atropine due to decreased parasympathetic overtone. EKG changes may include QRS widening, prolonged PR intervals, third degree AV block, or a "J" wave also known as an "Osborne wave." Acidosis and ischemia of the heart muscle, due to poor profusion, may manifest as ST elevation or depression. At the cellular level, the prolongation of the action-potential is the result of a delay in the activation of the repolarizing potassium current, slowed inactivation of the sodium current, and delayed inactivation of the inward calcium current. The slowed myocardial conduction is a direct consequence of the reduced and delayed activation of the inward sodium current.[10]

In severe hypothermia, below 24°C, the risk for asystole increases.[9] Conversely, ventricular fibrillation has been linked to active rewarming (between 24°C and 27°C).[9] Although the likelihood of cardiac arrest due to hypothermia is high, the odds of survival are greater than in normothermic cardiac arrest, due in part to the inherently reversible cause of the arrest and the protective effects of the hypothermia itself.[1]

3.2 Management of accidental hypothermic cardiac arrest

There are substantial differences between the treatment of accidental hypothermic cardiac arrest patients versus normothermic cardiac arrest patients.[1] If cardiac arrest is suspected, begin CPR immediately. Once a core body temperature is recorded and the patient is confirmed to be hypothermic, begin active rewarming. Outside of CPR, this is the most important treatment for these patients. Consider placement of an advanced airway to facilitate movement to a facility capable of rewarming and provide warm and humidified oxygen during ventilation. Mechanical CPR may facilitate movement of the patient without sacrificing CPR quality. Further treatments are dependent on core body temperature. If the core body temperature is below 30°C, limit the number of defibrillations to 3 for ventricular fibrillation or ventricular tachycardia.[11] Patients whose core body temperature is below 30°C should not receive any medications in the cardiac arrest algorithm as they will be poorly circulated and metabolized. For a patient who has a core body temperature above 30°C, the EMS crew should follow protocols for normothermic cardiac arrest, with the exception of allowing longer times between doses of medication given impaired metabolism. Treatment requires transport to the most appropriate facility, ideally one capable of advanced rewarming capabilities including ECMO.

Out-of-hospital management requires safe patient handling and early identification of the patient's core body temperature. Maintaining a horizontal position and avoiding sudden movements may prevent a life-threatening arrhythmia and cause cardiac arrest.[1] Core body temperature is rarely measured in the out-of-hospital setting and studies have shown that few ambulances (ie, ≈3% of ambulances) are properly equipped to check it.[12] Education and training of EMS providers should place special emphasis on recognition of hypothermia and extrication from the scene to the ambulance while maintaining high-quality CPR. Coordination of resources such as mechanical CPR, transport to a regional resource center, and activation of an ECMO team are critical.[13]

Inpatient management focuses on providing high-quality CPR and rapidly moving to active rewarming strategies. External rewarming methods using heat packs, forced air blankets, or water jackets run the risk of creating a paradoxical after drop, peripheral vasodilation, and shunting of cool blood to the core.[14] Invasive measures are more effective including gastric, bladder, thoracic, and peritoneal lavage but carry increasing risks and do not provide circulatory support. ECMO provides circulatory support and can rapidly reverse hypothermia and tissue hypoxia.[15] With the addition of a renal replacement circuit, ECMO can also rapidly correct acidosis and electrolyte abnormalities.[16] A systematic review identified 67% survival with 62% good neurologic outcome from accidental hypothermic cardiac arrest treated with extracorporeal rewarming.[17] This review also concluded that ECMO may be beneficial following accidental hypothermic cardiac arrest in cases of arrhythmia, hypotension, refractory acidosis, profound hypothermia (<28°C) and failure of other rewarming methods. Relative contraindications associated with poor outcome include hypoxic arrest, temperature >32°C and serum potassium >10 mmol/L. See Appendix for a proposed checklist for out-of-hospital and in-hospital care delivery.

4 | CONCLUSION

This case highlights the importance of early recognition of accidental hypothermic cardiac arrest by the emergency medical system, rapid transport to a tertiary facility, and the timely application of active rewarming and in-hospital ECMO. Our case was discharged 15 days after arrival at the ED with good neurologic outcome. While the outcome was positive, this case raises a number of questions for the systems of care for accidental hypothermic cardiac arrest cases. First, it is important to determine what resources are available locally for rapid invasive rewarming (ECMO, hemodialysis, or intravascular warming). The EMS and local hospital systems should determine and coordinate the additional resources that may be available for treating a patient with this type of exposure along with the associated trauma and/or drug overdose. These may include, but are not limited to, trauma services, emergent dialysis, and ability to perform active rewarming through thoracic, bladder, or peritoneal lavage. All emergency medicine clinicians should be trained how to identify and activate these resources and should be prepared to determine the most appropriate means of transport (ground, air, critical care transport). Proper preparation and training are important. Given that accidental hypothermic cardiac arrest is a reversible state, prompt and correct treatment allows for a high possibility of a favorable neurologic outcome.

ACKNOWLEDGMENTS

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Patterson PD, Hupfeld TC, Forbes N, et al. Accidental hypothermic cardiac arrest and extracorporeal membrane oxygenation: a case report. *JACEP Open*. 2020;1:158–162. https://doi.org/10.1002/emp2.12048

APPENDIX

Prehospital Checklist for AHCA

- ❑ Scene safety
- ❑ Assess for signs of circulation: If No Circulation begin CPR
- ❑ Assess core temperature
- ❑ Given high probability of recovery, plan for rapid extrication and transport

- ❑ Temp<35 degrees Celsius*
- ❑ Limit heat loss
  - ❑ Remove wet clothing
  - ❑ Increase ambient temperature
- ❑ Active rewarming
  - ❑ Warm IV fluids
  - ❑ External heat packs
- ❑ Minimize movement
- ❑ Limit drug therapy
  - ❑ Increase time between dosing
  - ❑ Limit to 3mg Epinephrine
- ❑ Consider advance airway
- ❑ Consider mechanical CPR
- ❑ Notify receiving hospital
- ❑ Consider transport to an ECMO center

- ❑ Temp ≥35 degrees Celsius*
- ❑ Passive Rewarming
  - ❑ Remove Wet Clothing
  - ❑ Increase Ambient Temperature
  - ❑ Cover With Warm Blankets
- ❑ Continue ACLS
- ❑ Notify receiving hospital
- ❑ Transfer to closest appropriate hospital

*EMS crews may not have accurate means to measure core temperature <35 and a patient in cardiac arrest should be treated as a hypothermic cardiac arrest in these circumstances (Brown et al., N Engl J Med, 2012;367(20):1930-1938).

In Hospital Checklist for AHCA

- ❑ Assess for signs of circulation: If no circulation begin CPR
- ❑ Reassess temperature

- ❑ Temp <35 degrees Celsius
- ❑ Limit heat loss
  - ❑ Remove wet clothing
  - ❑ Increase ambient temperature
- ❑ Place an advance airway
  - ❑ Provide warm humidified ventilation
- ❑ Consider mechanical CPR
- ❑ Evaluate for ECMO
  - ❑ Exclusions
    - ❑ Poor premorbid function
    - ❑ DNR
    - ❑ Potassium >10 mmol/L
    - ❑ Prolonged hypoxic arrest
    - ❑ Advanced age
- ❑ Coordinate ongoing ACLS
- ❑ Initiate ECMO if appropriate
- ❑ Rewarm to 32 degrees Celsius
- ❑ Reassess Goals of Care

- ❑ Temp ≥35 Celsius
- ❑ Continue passive rewarming
  - ❑ Remove wet clothing
  - ❑ Increase ambient temperature
  - ❑ External warming
    - ❑ Forced air blanket
    - ❑ Water jacket warmer
    - ❑ Warm IV fluids
- ❑ Continue ACLS
- ❑ Targeted temperature management
- ❑ Minimize secondary injury after ROSC
  - ❑ Prevent further exposure to hypotension, hypoxia, hypocarbia