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Case report

Management of hypothermic submersion associated cardiac arrest in a 5-year-old child: A case report

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Abstract

We report a case of severe accidental hypothermia (core body temperature of 26.8 °C) in a five-year-old boy due to submersion in freezing lake water. The child was brought to the hospital intubated, in cardiac arrest rhythm of pulseless electrical activity and with dilated and nonreactive pupils. We continued with cardiopulmonary resuscitation and administered adrenaline in boluses (10 µg/kg) and infusion (0.2 µg/kg/min). Spontaneous circulation returned after 50 minutes. Rewarming was performed with minimally invasive techniques. Post resuscitation he was admitted to the intensive care unit, where he required venovenous extracorporeal membrane oxygenation due to respiratory failure. He was discharged from the hospital neurologically intact and without organ damage on day 17 post arrest.

Keywords: Accidental hypothermia, Submersion, Cardiac arrest, Adrenaline, Rewarming

Introduction

Accidental hypothermia is defined as an involuntary drop of body core temperature below 35 °C and is further categorised by temperature into mild, moderate and severe.¹ In severe hypothermia, below approximately 28 °C, all body systems begin to fail, with severe impairment or absence of consciousness, ventilation and circulation.² Drowning is a leading cause of death in children between 1 and 14 years of age.³ Outcome is worst in drowned children who present with cardiac arrest, especially in the case of prolonged resuscitation beyond 30 minutes.⁴ The morbidity and mortality associated with drowning and accidental hypothermia can be minimised with early identification and aggressive treatment. Parental consent was obtained for the publication of this case report.

Clinical record

A previously healthy 5-year-old boy, with body weight of 20 kg, was playing on a frozen pond when the ice broke beneath him. He was rescued after being underwater for approximately 10 minutes. Rescuers were unable to feel a pulse and started with cardiopulmonary resuscitation [CPR]. When ambulance officers arrived, they found a palpable pulse, but he was unresponsive with Glasgow Coma Score of 3. His pupils were medium sized and reactive to light. He was intubated on site. He received atropine as premedication and etomidate and succinylcholine for anaesthesia. He went into circulatory arrest with pulseless electrical activity during transport to University Medical Centre Ljubljana. CPR started in the ambulance and he received the first dose of adrenaline [200 µg].

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Upon transfer to emergency department the patient was still in pulseless electrical activity and we resumed with CPR. The team leader was an anaesthesiologist, but a paediatric intensivist was also called to assist. The patient's pupils were dilated and fixed [right 8.2 mm and left 7.9 mm] on arrival. We removed wet clothing. Urinary catheter with temperature sensor was inserted and revealed a core temperature of 26.8 °C. He was warmed with the infusion of warmed intravenous crystalloids and application of forced air warming blanket [Bair Hugger, 3 M]. He received 9 boluses [200 µg] of adrenaline [total 1.8 mg], total 60 mEq of sodium bicarbonate and two 200 ml boluses of saline. We started with adrenaline infusion [0.2 µg/kg/min] after 25 min of CPR. Return of spontaneous circulation [ROSC] was achieved after 50 minutes. After ROSC, he was sedated with midazolam and fentanyl. Ventilation was poor due to low compliance of the lungs. Initially manual bag ventilation was required to overcome high airway pressures. After initial stabilisation he was put on volume controlled ventilation, but the set tidal volumes [6 ml/kg] were not achieved due to peak airway pressures exceeding limitations of 35 cmH₂O [actual delivered tidal volume was around 80 ml]. He was ventilated with 100% oxygen, his saturation was 94%. Blood sample was drawn after ROSC [Table 1]. As per local protocol we carried out imaging with chest x-ray [Fig. 1], abdominal ultrasound and CT scan of the head, neck and thorax. Head and neck CT scan were normal, CT scan of the chest showed marked lung oedema of noncardiogenic origin, with more than 90% of lung parenchyma being impacted.

After imaging, we transferred him to paediatric intensive care unit. Up until the transfer we could not lower the continuous support with adrenaline infusion at 0.2 µg/kg/min. Rewarming was sustained with external rewarming modalities [Criticool, Belmont Medical]. The medical team continued with controlled mechanical ventilation with 100% oxygen. His oxygenation was worsening despite inhaled nitric oxide. That is why venovenous extracorporeal membrane oxygenation [ECMO] was started 8 hours after transfer to the intensive care unit. At that time his core temperature was 33 °C. He was kept hypothermic [at 33 °C] for 24 hours according to the standard post arrest guidelines.⁵ He developed multiorgan failure with acute respiratory distress syndrome, acute liver and kidney failure. He was on ECMO for 5 days, intubated for 6 days and in the intensive care unit for 12 days. On the day he was extubated, he was already alert and able to answer questions. He was discharged from the hospital neurologically intact with Paediatric Cerebral Performance Category [PCPC] score of 1 and without organ damage on day 17 post arrest.⁶

Table 1 – Blood sample drawn in the emergency department after ROSC.

Glucose	25.0 mmol/l
Potassium	5.6 mmol/l
Sodium	141 mmol/l
Calcium	1.72 mmol/l
Lactate	18.12 mmol/l
PT	0.49
INR	1.58
APTT	103.5 s
Fibrinogen	1.1 g/l
TT	27.4 s

Discussion

Clinical signs of hypothermia worsen as the core temperature declines and severe hypothermia can progress to cardiac arrest. Because of the neuroprotective effects of hypothermia, complete recovery of patients with cardiac arrest caused by hypothermia is possible despite prolonged resuscitation.^{7,8} Except in the presence of obvious lethal injury, the declaration of death should be withheld until the core temperature has reached at least 32 °C.² Signs associated with death such as rigor mortis and dilated fixed pupils have little prognostic value in severe hypothermia, as was also evident in our patient.⁹ Pupillary light reflex is depressed and dilated pupils are observed below a core temperature of about 29 °C.¹⁰

Key management principles of severe accidental hypothermia include: prevention of further heat loss, initiation of rewarming, supporting airway, breathing and circulation and, in cardiac arrest, providing cardiopulmonary support until completely rewarmed.¹¹ Rewarming is a vital cornerstone of treatment and should begin as soon as possible. It is divided into passive external, active external and active internal rewarming methods.² All three techniques have a role in severe hypothermia management. Active external rewarming applies heat to the skin and depends mainly on the circulation to warm the core. External rewarming in cases of arrested circulation may be so slow as to produce extremely long resuscitations, but reports of successful active external rewarming even in cases of cardiac arrest have been described.^{12,13}

Active internal rewarming is preferred to external rewarming in hypothermic patients with arrested circulation because it is more effective.² The techniques include intravenous administration of warmed crystalloid, irrigation of the thorax or peritoneum, and extracorporeal blood rewarming either by cardiopulmonary bypass [CPB] or by ECMO.^{2,11} Extracorporeal life support [ECLS] is the preferred technique in arrested patients not only because it is a more effective rewarming strategy but mostly because it supports the circulation and therefore better than any other active internal technique supports blood supply and oxygenation of the brain and heart.¹⁴ It was used successfully in severely hypothermic patients with cardiac arrest with favourable neurological outcomes.^{15,16} The latest European Resuscitation Council [ERC] guidelines state that in hypothermic cardiac arrest rewarming should be performed with ECLS, preferably with ECMO over CPB.¹⁴ Many patient and facility factors, however, will govern the choice of technique, and successful resuscitation has been reported using a large array of methods.² In our patient, we used a combination of passive external [removing wet clothes], active external [forced warm air device] and active internal rewarming techniques [warmed intravenous crystalloid administration]. We employed a stepwise approach and our patient achieved ROSC before we could initiate extracorporeal blood rewarming.

Arrhythmias are common in severe hypothermia. Sinus bradycardia is physiologic, but with lowering of core temperature the conversion to cardiac arrest rhythms such as ventricular fibrillation and asystole may occur. There is some controversy surrounding defibrillation attempts and the use of vasoactive medications in hypothermia patients.⁵ ERC recommends up to three defibrillation attempts until the core temperature is greater than 30 °C.¹⁴ American Heart Association [AHA] states that it may be reasonable to perform defibrillation attempts according to the standard basic life support algorithm concurrent with rewarming strategies.⁵

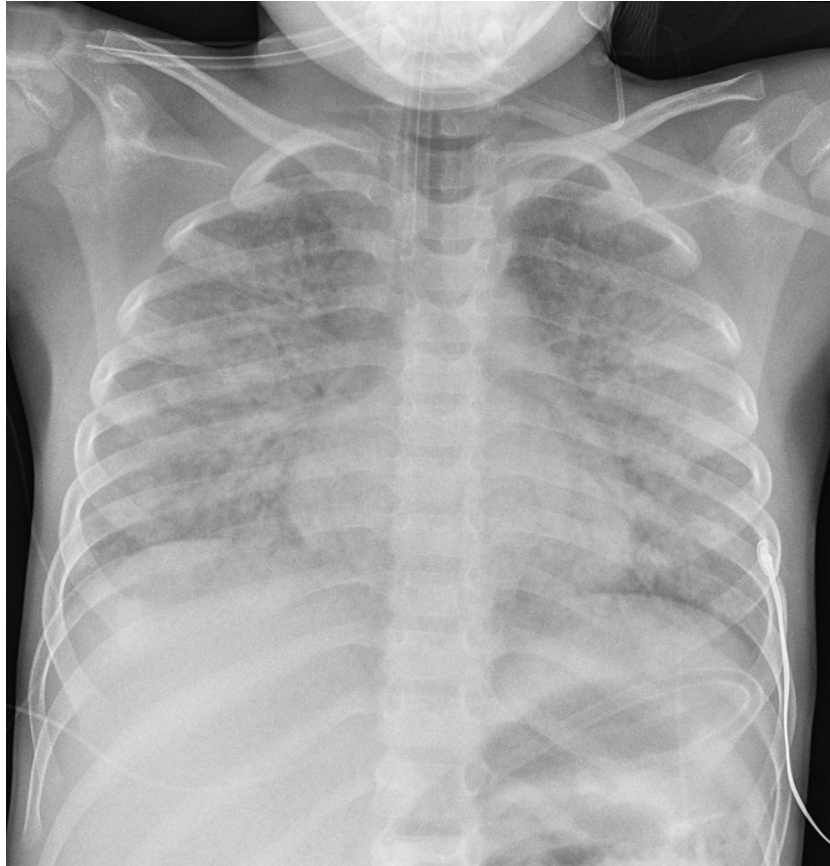


Fig. 1 – Initial chest radiograph in the emergency department.

Similar to defibrillation attempts, the use of vasopressors and other medications are also unclear. It has been proposed that the metabolism of these medications may be impaired and could accumulate to toxic levels in hypothermic patients. And yet in animal studies vasoactive drug administration appears to be associated with increased rates of ROSC.¹⁷ Human trials of medication use in accidental hypothermia do not exist, although case reports of survival with use of intra-arrest medication have been reported.^{11,18} Guidelines have approached recommendations differently. Currently, AHA considers the administration of vasoactive medications to be reasonable according to the standard Advanced Cardiovascular Life Support [ACLS] algorithm.⁵ On the other hand, ERC recommends withholding adrenaline until a core temperature of 30 °C.¹⁴ In addition, ERC recommends the dosing interval of medications be doubled when the patient's temperature is 30–34.9 °C.¹⁴

For our patient, medications were administered according to the standard ACLS algorithm, without doubling the intervals. Adrenaline [intravenous boluses and infusion] was administered and during cardiac arrest the patient received 1.9 mg of adrenaline in total [boluses and infusion]. Furthermore, he was still hypothermic after ROSC and continued to require vasopressor support. Despite theoretical concerns of toxicity when administering vasoactive drugs during hypothermia, our patient suffered no such toxicity. Overall, he was discharged 17 days later neurologically intact with no organ damage.

The reported case demonstrates complete neurological recovery in a child with severe hypothermia due to submersion injury, which usually carry a poor outcome.⁴ According to ERC guidelines in-hospital prognostication of successful rewarming should be based

on the HOPE or ICE score.¹⁴ The HOPE survival probability of our patient was 10%,¹⁹ which is the same as the cutoff proposed during external validation to determine which hypothermic patients in cardiac arrest would benefit from ECLS rewarming.²⁰

Rescue collapse is defined as the occurrence of cardiac arrest related to the movement of the patient during extrication or transfer of a patient suffering from profound hypothermia,²¹ which was also the precipitating factor for cardiac arrest in our patient. The study analysing witnessed hypothermic cardiac arrests found excellent prognosis of patients after rescue collapse with a 73% survival rate.²¹ Nonetheless, the occurrence of rescue collapse is linked to doubling of the risk of death compared to severely hypothermic patients with retained circulation.²² Therefore, movements, which can be potential triggers of rescue collapse, should be performed with special care.

Resuscitation of a cardiac arrest in a drowned victim is an added challenge owing to a combination of hypothermia, fluid aspiration and consecutive lung damage. Due to damage to the lungs and difficulties maintaining a satisfactory oxygenation we even had to initiate venovenous ECMO eight hours after admission to paediatric intensive care unit. Respiratory failure is common after cardiac arrest related to accidental hypothermia and may require ECMO treatment. That is why ECMO is recommended over CPB in the ERC and International Commission for Mountain Emergency Medicine [ICAR MEDCOM] guidelines.^{14,23} In this specific case, submersion with near drowning may have contributed to the respiratory failure of this patient. Teams facing a similar patient should remember to transfer and treat such patients in a centre with ECLS capabilities, because of

ECLS rewarming being recommended as the treatment of choice in arrested hypothermic patients and as a backup for respiratory failure after ROSC.

Conclusions

In conclusion, more research is needed to obtain clear guidelines on the use of vasoactive drugs and defibrillation during treatment of cardiac arrest in severely hypothermic patients. In addition, continuing research is required regarding the choice and timing of initiation of rewarming methods in severe hypothermia in children. Hypothermic patients with haemodynamic instability or cardiac arrest should be transported and treated in an ECLS hospital.

CRedit authorship contribution statement

Vanessa Anadolli: Investigation, Writing – original draft, Writing – review & editing. **Jasmina Marković-Božič:** Writing – review & editing, Supervision. **Janez Benedik:** Writing – review & editing, Supervision.

Conflict of interest

The authors have no conflict of interest to declare.

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