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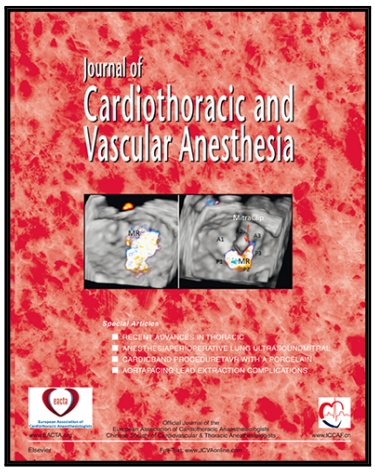

Anesthesiological management of successful extracorporeal resuscitation of cardiac arrest due to severe accidental hypothermia

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Authors' contributions:

RB: Conceived this case report, supervised data collection, took part in manuscript preparation, and took responsibility for the paper as a whole.
MR: supervised data collection, contributed substantially to the revision and design of the manuscript.
XR: took part in manuscript preparation, supervised data collection, contributed substantially to the revision and design of the manuscript.
GS: contributed substantially to the revision and design of the manuscript.
TD: contributed substantially to the revision and design of the manuscript.
IS: contributed substantially to the revision of the manuscript.

All authors read and approved the final manuscript.

Consent for publication:

Written informed consent was obtained from the patient for the publication of this case report. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

Conflicts of interest:

None declared.

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Abstract:

Accidental hypothermia (AH) in Mediterranean countries is often underestimated. AH should always be suspected in patients also in moderate climates throughout all seasons. Compared to other countries, the mortality rate due to AH in Spain is low and hypothermia is rarely recognized and treated. We report a case of a woman under cardiac arrest due to severe AH resuscitated for 6 hours with full neurologic recovery. This case highlights how the application of extracorporeal cardiopulmonary resuscitation (eCPR) guidelines is different in AH patients, how in-hospital (HOPE score) triage criteria should be applied, and how the establishment of clear standard operating procedures and education strategies should be promoted.

Keywords: Cardiac arrest, Hypothermia, ECMO, Resuscitation, Extra-Corporeal Assisted Rewarming.

Introduction:

Accidental hypothermia (AH) is defined as the unintended drop in core body temperature under 35ºC. AH can be caused by unintentional exposure to a cold environment or may complicate acute and chronic illnesses. There have been up to 23.7 deaths per year in Spain due to accidental hypothermia during the last decades. Cases of survival at very low core temperature have been described (11.8ºC accidental, 4.0ºC induced)[1,2]. A decrease in metabolism can lead to a neuroprotective effect and explain survival with no neurological damage. The survival of hypothermic patients in cardiac arrest (CA) is improved by extracorporeal life support (ECLS)[3]. We report the first survival case from severe AH with CA in Spain resuscitated with ECLS. The patient was resuscitated for 164 minutes before ECMO placement and 203 minutes in extracorporeal cardiopulmonary resuscitation (eCPR). Total time of 359 minutes in cardiac arrest. This case highlights how the application of eCPR guidelines is different in AH patients, how in-hospital (HOPE score) triage criteria should be

applied, and how the establishment of clear standard operating procedures and education strategies should be promoted.

Case presentation:

A 34-year-old female patient, with no relevant medical history, was trekking in the Pyrenees with her husband when they were trapped in a snowstorm at 9:50. At 13:00, she had dysarthria and incoherent talking. At 14:18, she lost consciousness, and at 15:08, her husband reported no breathing, confirmed by the search and rescue helicopter crew (15:35). Within eleven minutes, she was transferred to the closest helipad, where cardiopulmonary resuscitation (CPR) maneuvers were initiated (38 minutes after witnessed CA) and maintained while organizing the transport to an ECLS center. Specifically, the first rhythm was asystole, the first infrared-tympanic temperature was 18ºC (Riester ri-thermo® N, Rudolf Riester GmbH, Jungingen, Germany), and the airway was secured with tracheal intubation. At 15:53, the first 1 mg bolus of adrenaline was administered (overall, a total of 7 doses of 1 mg were given). At 15:58, a mechanical chest-compression device was placed (LUCAS®, model 2, Physio-Control, Lund, Sweden) and maintained during helicopter emergency medical system (HEMS) transport. At 16:09 and 16:12, defibrillations were performed due to ventricular fibrillation (VF). ROSC was not achieved at any time. At 17.45, she arrived at the ECLS center (Vall d'Hebron University Hospital, Barcelona) in asystole for veno-arterial ECMO placement (transport time from the accident site of 130 minutes). A multidisciplinary ECLS team (cardiac surgeons, intensivists, perfusionists, and anesthesiologists) was waiting for the patient. At 17:56, she was transferred to the operation room (OR) in VF, and veno-arterial ECMO was commenced at 18.19 with a right femoro-femoral surgical access (Cannula size: 17Fr arterial and 21Fr venous). The temperature gradient was 8-10ºC between the venous blood and the heat exchanger, perfusion of 1.8 L/min per meter squared, and speed of 2600rpm. The rewarming rate achieved was 3-4ºC per hour. Serum potassium was 4.6 mmol/L

(venous blood gas values and timings are shown in Figure 1), and initial end-tidal carbon dioxide was 17 mmHg. Arterial blood gases were interpreted based on the alpha-stat approach. The first arterial line temperature was 19.4ºC, and the first esophageal temperature was 19.7ºC. The initial examination showed no reactive mydriasis. A transesophageal ultrasound was performed, showing no relevant cardiac findings (cardiac rupture, massive thrombus or, cardiac tamponade). The ultrasound assessment was evaluated with caution because of the misleading hyperechoic blood. Additional rewarming measures were initiated via warm fluids and a hot-air blanket. At 19:00, the temperature rose up to 20.4ºC. Partial reversal of mydriasis and gag reflex were observed. At 19:40, she was transferred to the Intensive Care Unit (ICU) with a core temperature of 22.4ºC in VF. The first blood test showed hemoglobin (Hb) 8.1g/dL, platelets 42.000x10E9/L, prothrombin time ratio >25, international normalized ratio >25, fibrinogen <0.5g/L, activated partial thromboplastin *time ratio* >4, potassium 4.75mmol/L, lactate 12.6mmol/L. At 21:40, 30ºC were reached, and at 21:45, a deliberated single 150 J biphasic defibrillation was performed, recovering ROSC with palpable peripheral pulses. Arterial blood gases after recovery ROSC showed a pH 7.23, base excess -11.2mmol/L, potassium 4.3, and a lactate of 8.9 mmol/L. A total resuscitation time of 359 minutes was recorded. The main complications during the first 24 hours of admission in ICU were: acute pulmonary edema, thrombocytopenia, bleeding from cannulation sites, elevated transaminases secondary to CPR, and liver laceration. Blood transfusion was required to restore hemodynamics (eight blood bags, four fresh frozen plasma units, two bags of platelets, 6g of fibrinogen, 1g of tranexamic, and 1000UI prothrombin complex concentrates). Veno-arterial ECMO withdrawal occurred 44 hours after cannulation. Extubation was performed after 56 hours on mechanical ventilation. The electroencephalography showed no signs of neurological damage. The patient was discharged home fully recovered eleven days after hospital admission (cerebral performance category score of 1). Further exams showed an

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ischemic peripheral neuropathy of the ulnar, and median nerves of both arms. Written informed consent for publication of the case report was obtained from the patient.

Discussion:

This case provides the first successful resuscitation in Spain of a patient in AH with CA and early integration of veno-arterial ECMO placement. The resuscitation of such patients can become a real challenge to the resuscitation team. It is necessary to create a survival chain for victims of deep hypothermia[4]. Clear standard operating procedures should be developed for pre- and in-hospital providers, in-hospital triage criteria should be applied, and education strategies should be promoted.

In the pre-hospital phase, emergency teams rarely have the option of measuring core temperature[5-6]. All patients with suspected deep hypothermia in cardiac arrest or cardiovascular instability must be consulted by ECLS staff to qualify for extracorporeal therapy.

Initiation and prolonged CPR maneuvers in a patient with AH in CA can be a difficult decision. Some apparent signs of death (e.g., non-reactive mydriasis, absence of corneal reflex, bruises, or apparent rigor mortis) should not be considered in these patients. Only in patients with lesions incompatible with life as an incompressible chest, avalanche victims buried more than 60 minutes without an air pocket and asystole, and serum potassium >12 mmol/L, prolonged resuscitation maneuvers should be withheld[7]. However, data from serum potassium can be influenced by different biologic factors and can show variability within 2mmol/L based on sample location, questioning if resuscitation should be based on an isolated value[8]. *Pasquier et al* validated a prognostic score (HOPE - www.hypothermiascore.org) that may be helpful in the triage of patients that would benefit from rewarming in ECLS[9-10]. The HOPE score includes gender, age, related mechanism, CPR duration, potassium levels, and temperature. The development of prognostic scores in these unusual situations has a high medical

value avoiding futile ECLS rewarming attempts, improving the availability of resources, and guiding professionals who are not used to resuscitating and triage these patients[11]. The unsuitable allocation of ECLS can be costly and futile. Current standard guidelines of ECLS in CA cannot be applied to a patient in CA with severe AH. Some survival predicting variables in normothermic patients under CA should not be considered in hypothermic patients; therefore, some contraindications of ECLS in CA should not be applied. Asystole as initial rhythm, chest compressions not initiated within 10 min of CA, or unwitnessed CA should not be considered as a contraindication. Besides, some apparent signs of bad prognostic or death should be considered with caution in hypothermic patients. Poor blood gas results (pH of <6.8 and a baseline lactate level of >20 mmol/L), low end-tidal carbon dioxide values, and initial examination showing no reactive mydriasis can be qualifying pitfalls for the clinicians and result in an inappropriate treatment that could worse survival[12].

There have been reported some cases of hypothermia resuscitated without ECLS in Spain, up to 3 hours with minimally-invasive methods[13-14.] This case is noteworthy because it is the first time in our country that resuscitation of a patient in severe AH in CA using ECLS is achieved. Moreover, it is one of the longest resuscitations and at lower temperatures in the scientific literature. The patient was resuscitated for 164 minutes before ECMO placement and 203 minutes in eCPR. Total time of 359 minutes in cardiac arrest. ECLS and cardiopulmonary bypass (CBP) improve the survival of patients with severe AH in CA[15] compared with other rewarming methods. Up to now, the longest reported duration of CPR and eCPR with full neurologic recovery in a patient with AH in CA was 8 hours and 42 minutes (3 hours 42 minutes CPR + 5 hours eCPR)[16]. Hence, the transfer of patients with an acceptable HOPE score to a center with ECLS technology is recommended if transport to ECLS is available within 6 hours. Continuous or intermittent CPR maneuvers should be maintained. The longest hypothermic CPR without eCPR is 6h 30 min[17].

Extracorporeal membrane oxygenation (ECMO) or CPB are the rewarming treatments of choice without differences in survival. ECMO has become the preferred method as not only is it often more easily available and requires a lower amount of heparin but offers more therapeutic options for after rewarming complications. The main cannulation complications include hemorrhage, cannula mispositioning, vessel damage (dissection, false aneurysm, perforation), extremity ischemia, compartment syndrome, and acute embolism or thrombosis. ECMO seems to cause a less systemic inflammatory response, enabling the patient's transfer to an ICU room for prolonged support and cardiac or pulmonary or both configurations.

This case report highlights the importance of coordination and training of the different medical teams. The establishment of standard operating procedures may improve the quality of care of accidentally hypothermic patients, both pre- and in-hospital.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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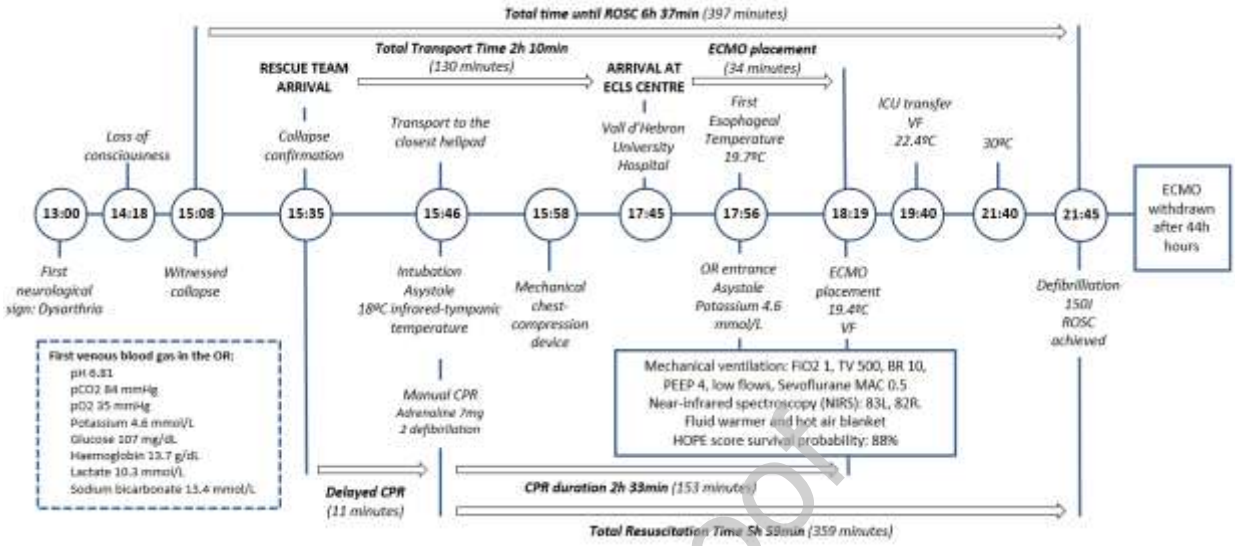

Figure 1. Time course of the management of resuscitation and veno-arterial ECMO.

AH: Accidental hypothermia, BR: Breathing ratio, CPR: cardiopulmonary resuscitation, ECLS: Extracorporeal life support, ECMO: Extracorporeal membrane oxygenation, HOPE: Hypothermia outcome prediction after Extracorporeal Life Support, ICU: Intensive care unit, MAC: Minimum Alveolar Concentration, OR: Operating room, PEEP: Positive end-expiratory pressure, ROSC: Return of spontaneous circulation, TV: Tidal volume, VF: Ventricular fibrillation.

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