CASE REPORT

Severe accidental hypothermia treated with cardiopulmonary bypass

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SUMMARY

This case report describes the successful treatment of severe accidental hypothermia with cardiopulmonary bypass (CPB). A known intravenous drug misuser aged 22 years was found to be unresponsive at his home (winter evening) with a Glasgow coma scale of 3/15. In the ambulance, the patient went into cardiac arrest, cardiopulmonary resuscitation being started. On arrival to the emergency department, he had a core body temperature of 27°C which was refractory to conservative management. He underwent femoro-femoral CPB, which was successful in rewarming the patient slowly. The patient was discharged home with no neurological deficit 10 days later.

BACKGROUND

There are many modalities available for managing severe accidental hypothermia, with cardiopulmonary bypass (CPB) being one of them. This case report describes a successful outcome using CPB to treat severe accidental hypothermia.

CASE PRESENTATION

A man aged 22 years was found unconscious and unresponsive in his home, severely bradypnoeic and had a Glasgow coma scale of 3/15. He had known schizophrenia and was an abuser of cocaine, ecstasy and steroids. He was known to be well the night before but was found collapsed on the floor at home by his brother around 15:30 as he had missed a scheduled appointment for his paliperidone (antipsychotic) depot medication administration (normally taken every 2 weeks). There was evidence of used needles and empty alcohol cans at the bedside.

When paramedics arrived, his respiratory rate was ~ 5 bpm and pupils were constricted to 2 mm, suggestive of opiate abuse; however, he was maintaining a respiratory effort. He unfortunately suffered an out-of-hospital cardiac arrest. His cardiac rhythm demonstrated ventricular fibrillation followed by asystole in the ambulance. Cardiopulmonary resuscitation was started en route to the hospital and cardiac output was maintained by using a fully automated, automatic chest compression machine; the LUCAS 2 chest compression device. Alongside this, he was given naloxone and epinephrine.

On arrival to the emergency department, his core body temperature had fallen to 27°C, treated conservatively with a Bair Hugger and warm intravenous fluids.

INVESTIGATIONS

Venous blood gas on emergency department admission: pH 6.83, PCO₂ 19 kPa, PO₂ 2 kPa, base excess 2 mmol/L, lactate 9.5 mmol/L, glucose 5.4 mmol/L, potassium 5.4 mmol/L, sodium 142 mmol/L, bicarbonate 10.2 mmol/L.

Bloods on ITU admission: Hb 115 g/L, WCC 15.6/L, Plt 256/L, sodium 151 mmol/L, potassium 3.4 mmol/L, urea 5.6 mmol/L, creatinine 165 µmol/L, creatine kinase 2650 U/L.

Drug abuse screen (on admission)

Urine opiates: positive,
Urine cocaine metabolite: positive,
Urine cannabinoids: negative,
Urine amphetamines: negative,
Urine methadone: negative,
Urine benzodiazepine: negative.

DIFFERENTIAL DIAGNOSIS

Cardiac arrest secondary to:

- hypothermia,
- drug/steroid abuse.

TREATMENT

The patient began conservative rewarming treatment, with the aim to raise the core temperature to 34°C, alongside continued cardiopulmonary resuscitation, using the LUCAS automated chest compression device. After 1 hour, the patient's core temperature had only raised to 30°C, and hence following a discussion with the cardiothoracic team, a decision was made to rewarm the patient with CPB.

CPB was performed via the femoro-femoral approach. Mechanical cardiopulmonary resuscitation continued until full CPB was established. Rewarming with CPB continued, core temperature slowly improving. Once core temperature rose to 34°C, and the patient being in ventricular fibrillation, a single DC shock was administered, restoring sinus rhythm and spontaneous circulation. The patient was slowly weaned off bypass and transferred to ITU.

The patient was taken directly to ITU from theatre. Core temperature was maintained at 32–34°C for the first 24 hours.

OUTCOME AND FOLLOW-UP

The patient recovered well in ITU without any major complications. A CT head showed no abnormalities the day after treatment and echocardiogram showed a left ventricular ejection fraction of >55%.

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During his ITU admission, the patient's mean systolic arterial pressure was maintained at 75–80 mm Hg with inotropic support (norepinephrine 0.9–4 mg/hour), weaned down. He was seen to have runs of ventricular tachycardia during ITU admission, thought to be due to metabolic imbalances. He was treated with an amiodarone infusion and his gross acidosis was corrected with sodium bicarbonate. He was successfully extubated at day 3; awake and alert, demonstrating normal cognition, maintaining a core temperature of 36°C.

He was subsequently stepped down to the ward and discharged home on 10th postoperative day. The patient remained well at the first follow-up, no long-term complications.

DISCUSSION

This case report describes the successful treatment of a young man presenting with primary, severe accidental hypothermia using CPB. In this case, the patient was found unconscious in a poorly heated home, wearing minimal clothing during the winter months, likely causing his observed hypothermia. Admission bloods showed an acute kidney injury and raised serum creatine kinase, suggesting a degree of rhabdomyolysis probably secondary to a long lie, additionally contributing to the hypothermia.

Hypothermia is classified based on the core temperature of the patient as well as their overall clinical appearance. The Swiss staging model for hypothermia categorises this in increasing severity, stages I–IV (table 1).¹ The condition is additionally classified based on core temperature as being:²

- mild (32–35°C),
- moderate (28–32°C),
- severe (<28°C).

Hypothermia is additionally classified into primary or secondary depending on whether patient was unwell prior to the hypothermia. Primary hypothermia occurs when excessive cold overcomes heat production in an otherwise healthy person, whereas secondary hypothermia occurs in an ill patient with comorbidities, even when the surroundings are warm.¹ Accidental hypothermia is caused mainly due to outdoors events such as immersion/submersion in cold water or prolonged exposure to cold surroundings.³ Nonetheless, hypothermia can occur in a more urban environment such as in occupational disasters.⁴

With regard to the management of accidental hypothermia, conservative methods are used first before more invasive modalities are considered. The two major invasive treatment options are CPB and extracorporeal membrane oxygenation (ECMO). Thoracic lavage, haemodialysis and peritoneal dialysis have also been used to rewarm patients.¹

In this case report, the decision was made to undergo CPB as the rewarming modality of choice. The rationale leading to this decision was first due to the fact that the patient had no cardiac rhythm. Cardiac output was generated by external massage via

an automated chest compression device; however, this was not considered a tenable long-term option. Hence, CPB was considered appropriate in maintaining adequate organ perfusion and protection. Additionally, the patient potentially could have entered a ventricular fibrillation rhythm during the arrest which would have caused ventricular distension. CPB was used to minimise the risk of myocardial damage. Finally, this case occurred at a large teaching hospital with excellent access to cardiothoracic support and hence CPB was felt to be the preferred option as it was more readily available.

CPB provides efficient and immediate circulatory support and seems to be the fastest method of rewarming a patient.⁵ Furthermore, it improves tissue perfusion by haemodilution and can also correct metabolic and toxic derangements.⁵ CPB can also prevent shock due to peripheral vasodilation by rewarming the heart before the rest of the body.⁵ CPB is particularly useful for patients with cardiovascular instability,² and can be performed through the femoral artery approach or through a sternotomy. Advantage for the former approach includes not needing a theatre and not having to explore the chest in a patient who has already received chest compressions.^{2 6–8} However, using the femoral artery does have its drawbacks, including increased risk of pulmonary oedema due to left ventricular dilation, distal limb ischaemia, pseudoaneurysm formation, among others.²

Many studies have been performed looking at treatment of accidental hypothermia with CPB. Vretenar *et al*⁹ performed a collective literature review to assess the role of CPB in treating accidental hypothermia. The overall survival rate of victims (68 in total) was 60% including case reports (41/68). Excluding case reports, the survival dropped to 50%. In their review, 80% of survivors (32/41) resumed work or their previous level of activity. Eighteen of 27 did not survive due to an abnormal cardiac rhythm, or not being able to wean off CPB. Furthermore, they found climbing and avalanche victims to have higher mortality compared with other causes, such as alcohol abuse/drug abuse. The mean core temperature of patients in this series was 21°C. They concluded that CPB should be the method of choice for treating patients with hypothermia and cardiac arrest.⁹

Morita *et al*¹⁰ examined the efficacy of portable and percutaneous cardiopulmonary bypass (PPCPB) for patients with accidental deep hypothermia. They compared several characteristics of 68 patients with 30 of 68 who underwent conventional rewarming methods (blanket, warm intravenous fluids) and 38 who underwent CPB. Fourteen of 30 (46.7%) patients survived with conventional rewarming methods, whereas 32 of 38 (84.2%) survived with CPB. Overall mortality was 32.4%.¹⁰ Glasgow outcome scale, another patient characteristic that the authors used to evaluate the two methods, found survival to be significantly higher in the CPB group compared with the conventional rewarming group (4.8±0.6 vs 4.1±1.1). Their study showed an average rewarming time to 34°C to be 6.3±2.3 hours which was slightly longer compared with our case report (4 hours). The authors advocated the use of PPCPB due to its low cost, less invasive nature, short setup time and being able to use it in the emergency department or at patient's bedside, as opposed to conventional CPB which normally requires theatre and special surgical considerations. Nonetheless, in 4 of 38 patients, PPCPB failed; hence, surgeons were consulted to rewarm patients.¹⁰ PPCPB is similar to conventional CPB with regard to rapidly rewarming patients, maintaining a haemodynamic state and maintaining blood flow to the brain during the rewarming process, attributes which make CPB an excellent choice to rewarm patients who have severe accidental hypothermia.

Table 1 Swiss staging model for hypothermia

Stage	Clinical findings	Core temperature, °C
I	Clear consciousness, active shivering	32–35
II	Impaired consciousness, no shivering	28–32
III	Unconscious, vital signs present	24–28
IV	No vital signs	<24

Walpoth *et al*⁵ looked at long-term outcomes of 15 of 32 (47%) patients successfully treated with CPB due to accidental hypothermia with circulatory arrest. All patients resumed their active lifestyles in their study with no significant neurological deficit. Survival rate of 46% is keeping in with previous literature review by Vretenar *et al*.⁹ The authors described five reasons for the good survival rate. These included: the presence of deep hypothermia which leads to increased tolerance of brain to ischaemia while slowing down metabolic processes leading to reduced oxygen consumption. Their second reason was that in the surviving 15 patients, cause of hypothermia was not due to incidents such as avalanche or drowning which often leads to asphyxia or hypoxic brain damage.⁵ This is keeping in with findings by Vretenar *et al*⁹ who showed poor survival rates as well (32% for climbing/avalanche victims). Furthermore, Walpoth *et al* described age to be a good indicator of survival as the victims were young with no major comorbidities (mean age; 25.5 ± 9.9 years). They also attributed their improved survival to the experience of their centre. Their most important factor according to the authors that lead to improved survival was using of CPB. Once again, they concluded that CPB was the method of choice in patients with accidental deep hypothermia with cardiac arrest.⁵

The other major modality used in treating severe accidental hypothermia is ECMO. Compared with CPB, ECMO does not have risks associated with the arterial approach as it can be performed percutaneously.² Furthermore, ECMO does not require cardiopulmonary resuscitation to be stopped and can do the same job as CPB.² ECMO can be performed without needing complete heparinisation as required for CPB.² Ruttman *et al*¹¹ compared CPB with ECMO in accidental hypothermia with cardiac arrest and hypothesised that ECMO was superior to CPB in rewarming patients. Their data showed a relatively overall poor survival rate (20.3%, 12/59). However, their data suggested a 6.6-fold higher chance of survival in ECMO patients (RR 6.6, 95% CI -1.2 to 49.3, $p=0.042$). The authors advocated the use of ECMO due to its provision of prolonged extracorporeal support until cardiopulmonary function in a patient has been stabilised, as opposed to CPB which has to be terminated immediately after rewarming due to risk of bleeding, haemolysis and inflammatory response.¹¹ Their data alongside that of Walpoth *et al*,⁵ and Vretenar *et al*,⁹ showed pulmonary complications, such as oedema, to be a significant cause of death among non-survivors following successful weaning from CPB.

Several authors have suggested adverse prognostic factors that can be of significance in treating patients with hypothermia. Hyperkalaemia (>10 mmol/L) has consistently been shown to be a predictor of poor prognosis.^{1 12-15} Brown *et al*¹ suggested termination of cardiopulmonary resuscitation if potassium levels exceed 12 mmol/L and recommended a review by the ECMO or CPB team if potassium levels are between 10 and 12 mmol/L. Besides this, other useful adverse prognostic factors stated in the literature include pH <6.50 , activated clotting time >400 s¹³ and elevated ammonia levels >250 μ L.¹⁵

CPB is an extremely useful modality to treat accidental hypothermia and should be considered by physicians in refractory hypothermia, especially when patients have good prognostic

indicators such as young age, non-asphyxia on admission and blood markers (potassium) within range.

Learning points

- ▶ Cardiopulmonary bypass (CPB) is a suitable modality to treat accidental hypothermia refractory to conservative treatment should the facility be available.
- ▶ CPB as a modality is particularly useful in patients with cardiac arrest.
- ▶ Precaution is advised when patients have hyperkalaemia (>10 mmol/L) to continue treating them as it has persistently been shown to be an adverse prognostic factor.

Contributors All authors of this paper contributed to its final submission equally. There were no additional contributors to the case report. The guarantor to this case report is UD, consultant cardiothoracic surgeon. The case report was written by MADG, BSJ and AC who all contributed equally to the planning, conducting and reporting of the work submitted.

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