Back from the dead: extracorporeal rewarming of severe accidental hypothermia victims in accident and emergency

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Abstract

Severe accidental hypothermia in an urban environment is usually associated with drug or alcohol abuse or serious illness in elderly or debilitated patients. In the presence of cardiovascular instability, extracorporeal rewarming by cardiopulmonary bypass is the gold standard of treatment of such patients. Three cases of profound hypothermia with circulatory collapse are presented. Each was successfully resuscitated to a full neurological recovery using this method in an accident and emergency (A&E) department, although one died later of respiratory complications. All three cases had a serum potassium in the normal range at the start of treatment. Where facilities exist, extracorporeal rewarming can be performed in A&E for patients with profound hypothermia and circulatory collapse. Cardiopulmonary resuscitation must be continued throughout the rewarming process.

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Severe hypothermia, defined as a core temperature below 28°C, is usually associated with cardiovascular instability and carries a grave prognosis if not recognised and treated adequately. We present three such cases initially assumed to have a hopeless outlook, who were successfully resuscitated and rewarmed using extracorporeal femoro-femoral cardiopulmonary bypass in an A&E department.

Case 1

A 53 year old chronic alcoholic female was found by her husband at 09.00 hours lying in a wet bed at home. She was unresponsive, cold and blue. He had last seen her at around 23.00 hours the previous evening, intoxicated. On arrival in A&E she was in cardiorespiratory arrest in asystole with fixed dilated pupils and a rectal temperature of 22°C. Cardiopulmonary resuscitation (CPR) was started with mechanical external compressions using a "Thumper" cardiopulmonary resuscitator system (model 1005; Michigan Instruments, Grand Rapids, Michigan, USA) which delivers a fixed rate of 80 compressions per minute and ventilation with 100% oxygen, in this case through an endotracheal tube. Initial biochemistry showed that her urea and electrolytes were all in the normal range, with a potassium of 4.1 mmol/l.

Through a femoral cutdown, cardiopulmonary bypass was instituted in the resuscitation room. CPR at a reduced amplitude was maintained throughout to prevent cardiac distension. Rewarming was begun at a flow dictated by the venous drainage to the cardiopulmonary bypass circuit, and oxygenation was provided through the extracorporeal membrane oxygenator, adjusted according to regular blood gas analysis. At 33°C blood temperature, cardiac activity in the form of a nodal bradycardia was seen and cardiac compressions stopped as ejection was evident. A transvenous pacing lead was inserted and when a core temperature of 37.5°C was reached bypass was discontinued on a moderate dose of adrenaline. The patient was transferred to the intensive care unit, where the adrenaline was weaned and she was extubated on day 3. Apart from a chest infection which responded to antibiotics, she made a complete neurological recovery and was discharged home after 14 days.

Case 2

A 48 year old known alcoholic man was found having apparently lain all night in a car park on a cold and snowy night, and brought to accident and emergency by ambulance at 10.00 hours. On arrival he had a barely palpable pulse, though spontaneous respirations were noted with evidence of aspiration of gastric contents. His eyes were open but he was otherwise unresponsive. His rectal temperature was 24.3°C. His potassium was measured at 4.2 mmol/l, and the other electrolytes were also in the normal range. Moments after his arrival he developed ventricular fibrillation (VF) from which he was successfully defibrillated at 200 joules. He then developed asystole followed by several further VF arrests which responded to defibrillating shocks, initially at 200 joules and subsequently at 360 joules. He was intubated without sedation but maintained spontaneous ventilation through a T piece. A stable cardiac rhythm could not be maintained despite intravenous lignocaine and minimal external stimulation. A decision was made to actively rewarm him using cardiopulmonary bypass in the resuscitation room. Under light sedation with 2 mg midazolam and local anaesthesia, femoro-femoral cannulation was performed and rewarming was begun at 26.2°C. A core temperature of 35°C was achieved after 80 minutes, when atrial fibrillation developed. Two 50 joule synchronised shocks were given,

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restoring a stable sinus rhythm at a rate of 120 per minute. Bypass was discontinued after 135 minutes at a core temperature of 37.5°C. The patient was transferred to the intensive care unit where he was extubated on the following day, having regained consciousness. He was noted to be alert and orientated and required only a low dose adrenaline infusion to maintain normal cardiovascular status. Two days after admission his condition began to deteriorate and he developed adult respiratory distress syndrome. Thereafter he slowly deteriorated despite reventilation and died 16 days after admission.

Case 3

A 53 year old male insulin dependent diabetic was found unresponsive at home by a relative, after he had not been seen for two days. He was given intramuscular glucagon by ambulance staff and admitted to A&E at 09.30 hours. On arrival he had a rectal temperature of 26°C, poor respiratory effort, a pulse rate of 86 per minute, and a blood pressure of 170/140 mm Hg; however, there was no eye opening or verbal response and he had a flexion withdrawal response to pain. Despite high flow oxygen and warmed intravenous fluids, his condition rapidly deteriorated until his blood pressure became unrecordable and he developed bradycardia and anuria. Laboratory analyses showed haemoconcentration, acute renal failure (urea 49.7 mmol/l, creatinine 525 µmol/l), and hyperglycaemia (glucose 62.5 mmol/l). His potassium was slightly raised at 5.2 mmol/l. A diagnosis of hyperosmolar non-ketotic diabetic coma was made.

In view of his severe hypothermia, anaesthesia was induced with intravenous etomidate and suxamethonium followed by endotracheal intubation. Cardiopulmonary bypass was instituted in the resuscitation room through a femoro-femoral cutdown and anaesthesia was maintained using small doses of intravenous propofol and alfentanil. Extracorporeal rewarming to a blood temperature of 37.5°C was achieved after 90 minutes and the patient transferred to intensive care on a low dose adrenaline infusion. His blood glucose was not formally retested after rewarming, but bedside capillary blood analysis on arrival to the intensive care unit confirmed continuing hyperglycaemia of more than 44 mmol/l and he was begun on a sliding scale insulin infusion with simultaneous rehydration. He was extubated the following day and transferred to a medical ward. He made a full recovery with his neurological status preserved intact and was discharged home after 10 days with normal renal function and resumption of his subcutaneous insulin regimen.

Discussion

In all three cases cardiopulmonary bypass was performed with full heparinisation at 300 U/kg and was readily established using femoral artery Bardic (C R Bard, Murray Hill, New Jersey, USA) 16–18F arterial cannulas and venous 24–28F intercostal drains, with the tip lying at the atrio-caval junction. Cobe CML membrane oxygenators (Cobe Cardiovascular,

Arvada, Colorado, USA) with 40 micrometer arterial line filters were used with a heater-cooler unit. Adequate flow was achieved to allow rewarming without compromising tissue perfusion. During circulatory arrest, CPR was performed and sinus rhythm was regained at 33–35°C. Before restoration of a spontaneous output, an arterial pressure of 50–70 mm Hg is generated on bypass by the extracorporeal pump and it is essential that, in the absence of cardiac activity, the heart is regularly emptied by external chest compressions to prevent ventricular distension and pulmonary oedema.

The neurological status of all three patients was normal on gross testing following extubation, although no pre-arrest comparison could be made. The second patient died of adult respiratory distress syndrome and sepsis on day 16, presumably secondary to aspiration during the initial event. During this patient's initial resuscitation he was successfully defibrillated several times at a confirmed core temperature of less than 28°C. Conventional teaching suggests that this is very unlikely to be successful, but our experience in this case showed that it was indeed possible to convert ventricular fibrillation to a sinus rhythm; however, a stable rhythm could not be maintained and the smallest stimulation precipitated further ventricular fibrillation. We suggest that at this temperature efforts should be directed towards rewarming and maintaining an adequate circulation for the body's metabolic demands rather than continued attempts at defibrillation.

Although extracorporeal rewarming is recognised as the treatment of choice for severe hypothermia¹ there are few published reports describing its use in an emergency department.^{2,3} As in a similar case previously reported from this unit,⁴ when prolonged CPR is required in addition to extracorporeal rewarming, the use of a mechanical cardiac compression device such as a "Thumper" proves invaluable and is to be recommended. Percutaneous bypass cannulas are also available and, provided the femoral pulse can be located, would shorten the time to institution of bypass. If systemic heparinisation is contraindicated, as in hypothermia associated with multiple trauma or intracranial haematoma, heparin bonded bypass circuits have been successfully used.⁵

Though exposure to cold is a common cause of death in the inner cities of the Western world, the true prevalence of reversible accidental hypothermia remains unknown. In the younger population this condition is associated with drug and alcohol abuse, whereas in the elderly it reflects poor socioeconomic support and underlying debilitating illness.⁶ In mountain accidents this form of exposure is associated with skeletal and asphyxiating trauma, which makes full functional recovery unlikely^{1,7} but, if hypothermia is the primary insult, recovery should be expected in a higher percentage of patients. The prognosis for this acute physiological insult remains poor, mainly because of our poor understanding of the pathological process. Thus interventions which may improve the chances of survival are not performed and rewarming attempted without

attention to maintenance of the circulation. This may increase metabolic requirements without improving tissue perfusion, thereby causing severe damage to vital organs and making survival unlikely. There is controversy about whether CPR should be instituted out of hospital where the priority should be to transport the patient to an advanced life support facility as rapidly as possible—the protective effect of hypothermia probably justifying the minimal use of CPR during this phase. It is clear that once in hospital, where active rewarming is being started in the absence of a monitored perfusing rhythm, CPR should be instituted and continued during cardiopulmonary bypass to prevent cardiac distension until cardiac ejection occurs.

It has previously been observed that hyperkalaemia (> 10 mmol/l) in the presence of profound hypothermia is associated with an adverse outcome⁸ and it may be significant that all three of these cases presented with potassium levels in the normal range. The common adage that “you are not dead until you are warm and dead” could possibly therefore be qualified thus: “...unless your potassium is greater than 10 mmol/l”.

We conclude that extracorporeal rewarming is extremely effective in accidental hypothermia with circulatory collapse in the absence of hyperkalaemia. It can be rapidly instituted in A&E using femoro-femoral bypass where

facilities are available. The protective effect of the hypothermia should, however, be maintained until extracorporeal circulation can be established, even if this requires transfer to specialist centres. It is essential to maintain CPR (ideally with a mechanical device) until bypass can be instituted, rather than attempting other forms of rewarming which may increase metabolic needs without improving the circulation.

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