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Cold Induced Thermoregulatory Failure: 2: Management and Outcomes[1]

by
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Abstract
This is the second part of a two-part review, which looks at the effects of cold on the body. In this article, the management of accidental hypothermia and the management outcomes are addressed.

Management of Accidental Hypothermia
The presence of rigor mortis, dependent lividity, and fixed and dilated pupils, all commonly associated with death in the normothermic individual, become unreliable indicators of death in the presence of hypothermia. Resuscitative measures must be terminated only when cardiac arrest persists despite adequate rewarming.

General Measures in Management
Prevention of further heat loss should include:

- the removal of all wet garments;
- protection against heat loss and wind chill by the use of blankets and insulating equipment;
- maintenance of a horizontal position; and
- avoidance of rough movements and excess activity.

Electronic rectal temperature probe measurement of core temperature and monitoring of cardiac rhythm is essential. Aggressive rewarming is mandatory for the treatment of arrest rhythms as pharmacological and electrical cardia-versions are invariably unsuccessful when core temperatures remain below 30° C. All CPR must be continued until core temperatures rise to 35° C.

In the hypothermic victim who has not yet developed cardiac arrest, many physical manoeuvres, such as endotracheal or nasogastric intubation, temporary pacemaker or pulmonary artery catheter insertion, have been reported to precipitate ventricular fibrillation. [1] None of these procedures, however, should be withheld when urgently indicated. Intubation with pre-oxygenation may diminish the risk of ventricular arrhythmias. [2]

In the hypothermic setting the treatment of cardiac arrest is beset by many new problems.

The hypothermic heart may be unresponsive to cardioactive drugs, pacemaker stimulation or defibrillation. Drug metabolism is reduced and if drugs are repeatedly administered, toxic accumulation may result. Aggressive core rewarming is the primary object in management of hypothermic victims in cardiac arrest or unconscious with a slow heart rate. [3] Presently the most promising antiarrhythmic agent for use at low temperatures is bretylium tosylate, which acts to increase the ventricular-arrhythmia threshold despite increasing the catecholamine levels. [4]

The hypothermic patient is typically volume-depleted and, therefore, the maintenance of intravascular volume, by central venous access with the tip at a reasonable distance from the endocardium, is essential. Cold-induced vasoconstriction causes a fluid shift to the deep capacitance veins and a resultant diuresis. With further

temperature reduction, diuresis is renewed due to the loss of distal renal tubular reabsorption of water and a decreased sensitivity to ADH following direct cellular cold injury. [5]

Airway control, by facemask in mild cases and by endotracheal intubation in severely hypothermic victims, is routine. Prophylactic antibiotics in the diabetic adult and in neonates/infants are recommended. [6] The thawing of frostbitten dermis by warm water bathing should be instituted early.

Rewarming Techniques

In the Field.

The prevention of further heat loss may be afforded by enclosing victim in a sleeping bag or by any available insulating material available. This must include the head since up to 70% of total heat production can be lost by this route. Wet clothing should only be removed once the victim has reached a warm dry sheltered environment; otherwise, any available insulation should be applied on top of wet clothing. Space blankets may be no more effective than similar thickness of plain plastic. The victim should be elevated from the ground with branches, clothing, leaves, etcetera, and afforded wind protection by tent, polythene sheeting, or by positioning in a snow hole or behind large boulder. [7]Although body to body warming is often quoted as a useful measure, difficulties encountered include the standard sleeping bag usually only accommodates one person, the transportation of two persons is often impossible, and the benefit equates to that of mild surface rewarming. [8]

In Hospital.

The decision to use passive or active measures is governed largely by the degree of hypothermia, with mild cases (arbitrarily regarded as > 32° C) best managed with passive rewarming techniques. In those cases with poikilothermia (< 32°C), cardiac instability, risk factors predisposing to hypothermia, [9] or where previous passive rewarming was unsuccessful or inadequate, active rewarming measures are mandatory.

Active External Rewarming Measures.

These include:

- Hot Bath. This is the fastest method with the recommended temperature of 40° C. The benefit of this method may be seen within 20 minutes of removal from the cold. Hot bath immersion is only suitable for those in whom no CPR is required, who are conscious, shivering and uninjured. [10]
- Heating pads and hot water bottles placed at the neck, axilla and groin.
- Electric or plumbed heating blankets.
- Radiant heat sources.
- Forced -air rewarming. This is readily available in postoperative care units and is a most practical technique of providing convective heat transfer and preventing heat loss.

Concern has been expressed about externally heating the extremities and rapidly alleviating peripheral vasoconstriction due to core-temperature after drop. This refers to the continuing decrease in the core temperature after the initiation of rewarming. It becomes important after the onset of the diuresis and fluid sequestration characteristic of chronic hypothermia. A limitation to the application of external trunk heat in conjunction with active core rewarming may minimise the circulatory problems associated with other forms of rewarming. [4]

Active Core/Internal Rewarming Measures.

A wide variety of techniques can be used to deliver heat internally. Many texts provide an algorithm for rewarming. The one presented by the American Heart Association in the 1992 JAMA issue on resuscitation is recommended. [3]

This involves:

- Airways Rewarming. While the respiratory tract is a less efficient heat exchanger, from the administration of heated humidified air or oxygen, than the peritoneum or pleura, access is far simpler.

This method raises body temperature by an average of 1-2° C per hour. The usual inhaled temperatures are 40-45° C and the method is a useful adjunct to other measures.

- Gastric/Colonic/Bladder Irrigation.
- Closed Pleural Irrigation. This may be performed via large-bore thoracostomy tubes instilling sterile saline at 40-42°C. These should not be placed in the left pleural cavity, thereby avoiding the precipitation of ventricular fibrillation.
- Peritoneal Lavage.
- Haemodialysis.
- Hot Intravenous Fluids.

Extracorporeal rewarming remains the most efficient means of rewarming. This is performed by a standard cardiopulmonary bypass (CPB) circuit incorporating a mechanical pump with an oxygenator and heat exchanger. Bypass can be instituted by either femora-femoral bypass or standard aortic-right atrial bypass.

Extracorporeal rewarming allows for perfusion and oxygenation whilst rewarming proceeds with recovery of myocardial function. The use of heparin-bonded bypass circuits has minimised heparin requirements during bypass and thus reduced bleeding complications.

Thus, extracorporeal rewarming should be considered for those patients without perfusion who have no documented contraindication to resuscitation, patients with severe hypothermia, and those with completely frozen extremities. Often it is the only effective approach in those with hypothermia after major trauma or tissue destruction with resultant rhabdomyolysis and shifts in potassium concentrations. [4]

Management Outcomes

Death from hypothermia may result from ventricular fibrillation due to hypoxia, abnormalities of electrolyte balance and acidosis or, more commonly, mechanical myocardial irritation (external irritation as in general body movements or internal irritation via central venous cannulation). The commonest cause of death after rescue and during rewarming is pulmonary and cerebral oedema. Shivering induces marked increases in oxygen consumption, which may be particularly dangerous for those critically ill patients with multi-trauma and hypovolaemia, and those with pre-existing myocardial or pulmonary disease. Continued unrelieved cooling leads to progressive myocardial ischaemia and terminal pulmonary oedema.

Survival of accidental hypothermia has been reported in a child with a rectal temperature of 14.4° c. [12] Subsequently, the lowest temperature recorded in a survivor of accidental hypothermia is 13.7°C, in an otherwise healthy adult skier. [13]

The effectiveness of cardiopulmonary bypass in treating accidental hypothermia has been reported by Vretenar *et al* in a review of the outcomes of 68 patients. He reported overall survival of 60% in a select group with 80% of survivors returning to work. There was no difference in mean age between non- survivors and survivors. [14] A further report from Switzerland describes the largest series of patients with severe hypothermia treated with CPB. The cohort were young (mean age 25 years) and in excellent health (mountaineers, etc) and an impressive 47% were reported as long-term survivors with excellent functional neurological outcomes and minimal or no cerebral impairment. [15]

In 1996, Komberger and Mair reported their experience in managing 55 patients in the Innsbruck region with core temperatures < 30° C between 1980 and 1994. They reported a 100% survival in the group with stable haemodynamics treated with airway warming, warmed fluids and insulations (n=24). A group with haemodynamic instability treated with peritoneal dialysis had a 72% survival (n=7) and those with cardiocirculatory arrest treated with cardiopulmonary bypass achieved only a 13% survival (n=24). The report emphasizes the excellent prognosis in those without a hypoxic event preceding the hypothermia and the lack of any serious underlying disease. [16]

Victims of very deep accidental hypothermia with circulatory arrest should be seen as potentially resuscitable with a prospect of full recovery following the institution of prompt out of hospital responses, continuous CPR and rapid extracorporeal blood rewarming. Cardiopulmonary bypass is the resuscitative method of choice for victims with accidental hypothermia and cardiac arrest, or cardiovascular instability, and core temperatures of less than 32° C. It should also be considered in those with stable cardiovascular dynamics and temperatures of 30° C or less as the risk of cardiac arrest and malignant ventricular arrhythmias during rewarming is very high in this group. [17]

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