Mild hypothermia in the battle casualty

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Abstract

- Mild hypothermia increases morbidity and mortality in trauma patients and battle casualties.
- Physiological responses to hypothermia can be harmful.
- Measurement of core temperature without measuring limb temperature, leads to under-detection of hypothermia.
- Understanding the mechanisms of heat loss allows us to develop effective strategies to prevent minimize and treat hypothermia.
- Simple preventative measures in the field can prevent or minimize its occurrence.
- Where possible hypothermia should be treated aggressively by active warming as early as possible.
- Recently developed devices make this possible.

Introduction

Mild hypothermia (a drop of core temperature of 1°-3°C) is potentially harmful, or can even prove fatal, for battle casualties. Hypothermia is not confined to cold climates. It can occur in temperate and even sub tropical climates[1] and is endemic in air conditioned hospitals.[2]

While there has been a traditional belief in the military that hypothermia is beneficial to the battle casualty, this is not the case. In the 19th century it was believed that casualties who suffered severe hypothermia lost less blood.[3] Even in the Falkland's war there were reports that severe hypothermia was life saving. Close examination has shown this to be taken out of context.[4]

Mild hypothermia is associated with impaired immunity, increased wound infections, delayed wound healing, coagulopathy, increased requirement for blood transfusion, and post-operative cardiac events, such as myocardial infarction and severe arrhythmias.[5,6,7]

Controversy remains over the optimal management of the head injured patient. While it is known that patients who fail to regain consciousness following medical cardiac arrest benefit from induced moderate hypothermia, at present it is regarded that while hypothermia may be beneficial to the brain, the complications of hypothermia in the injured patient outweigh any benefits.[8] This is the subject of further study.

Hypothermia in trauma is now regarded as part of the lethal triad along with coagulopathy and metabolic acidosis. Rapid reversal of acidosis, early use of blood products and aggressive management of hypothermia, decreased trauma mortality in Iraq from 65% to 19% in one study.[9] The Australian military experience in Afghanistan with this method of resuscitation has also been positive.[10]

The Queensland Trauma Registry Study demonstrated that a drop of core temperature of 2°C quadrupled the fatality rate in severely injured patients. Patients who arrived normothermic but became hypothermic in hospital were 2.5 times more likely to die than those kept normothermic.[1] Severe hypothermia (a drop of core temperature of greater than 5° C) in association with severe injury has close to a 100% mortality rate.

How does hypothermia occur?

Understanding the physics and the physiology of heat loss and hypothermia is the basis of effective strategies. Heat is lost by three mechanisms; radiation, convection and conduction. i) Radiation heat loss is to cool objects that are not in contact with the body. Heat loss from an exposed patient to cool surroundings is proportional to the fourth power of the temperature difference between the two.5 Therefore slight decreases in environmental temperature lead to big increases in heat loss. Conversely warm environments dramatically slow heat loss. ii) Convective heat loss is due to air movement over the body. While still or entrapped air is an effective insulator, evaporation of sweat in moving air is an effective cooling mechanism, even if air temperature exceeds body temperature. Air movement over wet clothing leads to significant heat loss. iii) Conductive heat loss occurs to cold objects in contact with the body and is proportional to the area of contact, the temperature difference and the thermal conductivity of the material (Fourier's Law).

Physiological response to hypothermia

There are four major physiological responses to hypothermia; all of which have undesirable side effects in the injured patient. These are vasoconstriction, shivering, behavioural mechanisms and countercurrent mechanism.

i) Vasoconstriction. Decreased skin blood flow insulates the body core from a low temperature environment. This however slows heat from external body warming being transported to the inner core of the body. Core rewarming by external heating techniques can be delayed by several hours once skin vasoconstriction has been established. The decreased skin blood flow is also considered to be a major factor in delaying wound healing and the incidence of wound infections. This situation is exacerbated in the hypovolaemic patient, who peripherally vasoconstricts to maximize blood flow to essential organs. It is important to note that in order to preserve brain temperature the scalp and forehead do not vasoconstrict in cold environments. This is why exposure of the head and neck to cold environments has a dramatic cooling effect and should be prevented wherever possible in casualties. It is also why forehead temperature correlates well with core temperature, and is a reasonably accurate way of non-invasively assessing core temperature in certain conditions.

ii) Shivering. This may triple metabolic heat generation but also increases oxygen consumption. In trauma patients where oxygenation may be marginal, this is highly undesirable.

iii) Behavioural mechanisms. Humans are highly dependent on behavioral changes (such as seeking shelter and adding warm clothing) to stay warm in cold environments. As a patient, the ability to don extra clothing or change the environment is limited or impossible. The patient becomes totally reliant on their caring staff to make the necessary changes. Too often fully clothed (particularly those in theatre gowns), active staff overlook the needs of the partially naked and inactive patient. Heightened awareness of this is essential for all staff.

iv) Countercurrent mechanism. The major proximal limb blood vessels run adjacent to each other in a common sheath. This allows warm arterial blood to transfer its heat to cool venous blood. The net effect is to maintain warmth in the core by sacrificing limb heating. Hypothermia therefore has two stages. Firstly there is a loss in limb heat and a fall in limb temperature, while core temperature and heat is preserved. If the four physiological defenses are inadequate, core temperature will then start to drop. Severe heat loss may occur before the core temperature drops. For example, it is common for frostbite cases to have a normal core temperature. If we rely purely on core temperature to asses heat loss, we will not detect the peripheral hypothermia, which may lead to generalized hypothermia. Increasing blood flow through cold limbs, paradoxically, may convert peripheral hypothermia to generalized hypothermia. This occurs following the administration of resuscitation fluids (even if they are warm) or anaesthesia agents (which are all vasodilators). This is known as redistributional hypothermia and occurs within minutes of resuscitation or anaesthesia induction. It has been shown that platelets and white blood cells that traverse a cold limb even when the patient's core is normothermic, are inhibited,[11,12] and may therefore contribute to increased blood loss and increased incidence of infection.

Hypothermia therefore should be avoided where possible by anticipating the problem, and both peripheral and generalized hypothermia treated aggressively.

Prevention and treatment of hypothermia

There are two key methods commonly used to prevent and treat hypothermia; passive and active. Passive insulation only works to keep warm people from getting cold. The body at rest produces an average of 70 -100 kilocalories (Kcal) of heat per hour (e.g. enough to heat two cups of coffee). If we assume passive insulation is perfect, this amount of heat will raise a 70 kg patient's temperature by 1°-1.3°C per hour. In reality, insulation from the cold is less than perfect and temperature rise is usually much slower. The use of heated cotton blankets has been shown to have no positive effect on patient re-warming.[13] Therefore passive warming is inadequate in managing severe trauma cases.

Active warming can be classified as invasive and non-invasive. Invasive methods includes femoro-femoro bypass therapy and more recently the use of femoral central lines incorporating balloons flushed with hot saline.[14] At present they are not logistically appropriate for consideration by the defence force (though this may rapidly change). Non-invasive warming devices include warm air blankets, electrical warming mattresses and foil blankets incorporating chemical heat packs. Their role in hypothermia prevention and treatment is discussed below.

Practical strategies for avoiding or treating mild to moderate hypothermia in battle casualties

Hypothermia avoidance and treatment is not difficult, and is largely a combination of awareness and common sense. These are suggestions only and must be viewed in the light of the strategic and tactical situation. They should be considered by all clinical staff in cold, temperate, sub-tropical and air conditioned environments. The likelihood of hypothermia in battle casualties should be anticipated and prepared for, prior to any field operation.

Pre-hospital

Simple measures at this stage can prevent the problem before it occurs, which is far preferable to treating hypothermia after it is established. This can be life saving. Formal temperature measurement in this environment is both difficult and probably unnecessary as simply feeling the patient and considering the situation and environment will determine whether anti-hypothermia measures are required.

As soon as possible, casualties should be removed from cold, wet, and windy environments. Any wet clothing should be replaced with dry clothing, even thought this means temporarily exposing the patient to the elements. Where possible the head and neck should be covered by using towels, beanies, or balaclavas. Cover with blankets as available and do not expose the patient unnecessarily.

If the casualty is lying on cold ground, place them on insulating material, such as a bed roll or sleeping bag. Canvas litters or stretchers, do not have the insulating qualities of proper mattresses, so placing a bed roll or sleeping bag underneath the stretcher (where body weight will not compress it), or even taping a foil blanket to the underside of the stretcher should further decrease radiation heat loss. This warrants extra study.

Where active heating devices are available, these should be instituted as early as possible. These may include foil blankets incorporating chemical heat packs, or battery operated clinical warming blankets. Ad-hoc active warming with non medical heat sources has great potential for causing burns. Infusing one litre of intravenous fluid at 20°C or one unit of blood at 4° C will drop mean body temperature by about 0.25°C, therefore IV fluids should be warmed, and equipment to do this in the field (Thermal Angel) is now available in the Australian Defence Force.

In hospital

The resuscitation room should be warmed prior to casualty arrival to 25°C-30°C. The colder the patient is likely to be, the warmer the room temperature. Casualties should be fully undressed for initial assessment and resuscitative procedures, and then covered as much as possible.

Core temperature should be recorded by the most accurate means possible. Ideally this should be by mid-oesophageal measurement. If this is not possible, rectal, axillary or oral temperature is preferable over ear canal measurements, which have been shown to be convenient but less accurate.[15] Limb temperature can be assessed by simply feeling the limbs or by using infra-red reflectance thermometers. Unfortunately the most accurate skin thermometer, for assessing deep tissue temperature, is only available in Japan.[16]

If either peripheral or generalized hypothermia is present, active warming by the use of warm air blankets and warming mattresses should be instituted, aiming to have both core and limb temperatures above 36°C. Warm air blankets are the mainstay of non invasive active patient warming. Reliability of these devices can be affected in the dusty military environment unless regular preventative maintenance is undertaken. The combination of a medical warming mattress and warm air blankets is far more effective in rapid rewarming than warm air blankets alone.[17] While there have been cases of patient burns by warming mattresses in the past, these may have been due to the fact that they were used as the sole heating source and/or technical faults. Present technology mattresses have been shown to be safe.[18] Battery powered medical warming mattresses are now available.

Most intravenous fluid warmers (including the Thermal Angel) are only effective up to flow rates of 150 mls/min. This is inadequate for in-hospital battle casualty resuscitation. High volume warmer infusors capable of warming fluids at flow rates up to 700 mls/min should be utilized.

Operating theatre

All the above actions need to continue in the operating theatre. Maintaining such high temperatures can be a challenge for scrub staff, but are warranted. The wearing of ice vests by scrub staff has been shown to be useful. All irrigation fluids need to be warmed. The theatre table should also be pre-warmed and or utilize a warming mattress. "Gel" mattresses and pads have a high thermal conductivity and great potential to drain body heat. They should be pre-warmed.

Surgery should be abandoned as soon as possible if an increasing core and limb temperature is not achievable (i.e. Damage Control Surgical principles).Postoperatively, temperature monitoring must continue. Ward temperature must be dictated by the needs of the patient rather than the comfort of the staff.

Conclusion

Mild hypothermia is harmful to battle casualties. Prevention is better than cure and the earlier it is managed, the better. It is easily overlooked in countries, such as Australia, that are largely temperate and sub tropical, and it occurs far more commonly than is realized. Current thinking is that definitive treatment should be both aggressive and by active means, but simple preventative strategies in the field can also have dramatic effects on casualty outcomes through less blood loss, less infections and less cardiac complications.

Conflict of Interest

I have no financial affiliation, agreements present or pending, nor have I ever received any financial benefit from any of the product manufacturers or retailers of the products reviewed.

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