NEAR DROWNING

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Prolonged immersion in a fluid results in drowning if the victim asphyxiates, but in near drowning should he survive. The clinical picture is usually one of asphyxiation, often with pulmonary edema caused by water inhalation, in a profoundly cold subject. Complete recovery after 40 minutes' submersion has been documented. (1) The resuscitation and subsequent management of near-drowned victims differs from all other emergencies in which cardiopulmonary arrest is a feature.

INCIDENCE

The incidence of near drowning is unknown but that of drowning ranges from 0.4 to 9.0 deaths per 100,000 per year, being highest in the warmer and less well-developed countries. Overall male deaths outnumber female by 4 to 1. In the age range 1-14 years, only road traffic accidents and cancers account for more deaths. Two-thirds die in fresh water, chiefly because the opportunity to drown in unguarded inland waters is greater than in the sea. (2) Between 25% and 50% of adults who drown show evidence of recent alcohol ingestion. (3)

PATHOPHYSIOLOGY

Death following submersion is by asphyxiation, but a person who survives receives a thermal challenge if the water is below body temperature, lung injury if water is inhaled and brain injury if the resulting hypoxemia is not treated promptly.

Effects of cold

Both the specific heat and thermal conductivity of water are significantly greater than those on air, and so body cooling is much faster in water than in air at the same temperature. Sudden immersion of an unacclimatized subject in ice-cold water results in reflex hyperventilation and tachycardia – often with supraventricular ectopic beats and hypertension, a response known as 'cold shock'. (4) Drowning may occur at this early stage unless a buoyancy aid is used, enabling the airway to be held above the surface of the water. A clothed adult immersed in water below 5C can be expected to lose consciousness in less than an hour. Without a correctly inflated life jacket, water will then enter the unprotected airway. Cold water also severely limits swimming ability as a result of loss of synchrony between stroke and breathing.(5)

Post-immersion collapse

Head-out upright immersion in water at body temperature results in a 32-66% increase in cardiac output caused by the pressure exerted by the surrounding water, an effect similar to wearing a gravity suit. On leaving the water the assistance to circulation is removed and, in addition, there is gravitational venous pooling. In normal individuals with intact homeostatic responses, these changes are compensated for by baroreccptor reflexes. The result is an increase in heart rate, cardiac output and vascular smooth muscle tone. Following prolonged immersion in cold water these responses are compromised. It is likely that post-immersion circulatory collapse is the cause of death among those found conscious in cold water wearing a life jacket, but who perish within minutes of rescue. A mean increase in heart rate of 16% during vertical lifting from water compared with lifting the victim in a horizontal or sifting position has been reported. (6)

Asphyxiation

Infants show the apneic phase of the 'diving response' when thrown into water, but this reflex tends to wane by the toddler stage. (7) After infancy submersion beyond the breath-hold breaking point ends in involuntary gasps and aspiration.

Postmortem measurements of lung weight show that between 10% and 18% of those who drown inhale very little water, hence the term, 'dry drowning'. (8) Failure of water to enter the lungs has been attributed to laryngospasm. However, the trachea and bronchial tree form a blind ending tube and filling may well not occur, if for example, the victim is submersed face down or head down. Doubtless there is a gradation from asphyxiation with very little water in the lungs to lungs that fill completely.

Recovery from asphyxia following long periods of submersion occurs in circumstances that favour rapid cooling, such as those arising when a small child or infant is submerged in ice-cold water, typically below 50C. (9) It seems probable that circulatory arrest occurs well after the head is immersed so that cerebral perfusion continues during the cooling process. Experience in children undergoing open head surgery shows that, with hypothennia, circulation can be arrested for at least 30 minutes.

The survival advantage bestowed by submersion in ice-cold water is exemplified by the unique set of circumstances surrounding a young female skier. She was with friends when she fell down a water filled gully and became trapped beneath an ice sheet. She struggled for 40 minutes while attempts were made to extract her before all movements ceased. Her body was recovered through a hole cut in the ice one hour and nineteen minutes later. Though she was clinically dead, cardiopulmonary resuscitation was administrated throughout the air-ambulance flight to hospital where her core temperature was 1 3.70C. She was resuscitated by means of an extracorporeal membrane oxygenator and then spent a further 35 days on a ventilator. At 5 months, her faculties had recovered sufficiently to allow her to return to work as a hospital doctor. (10) (Table 1)

Fluid-electrolyte effects

Much higher death rates follow immersion in fresh water than in the sea. However, this has little to do with the salinity of the water, but derives from the quality of the rescue services, which are sparse on inland waters by comparison with the coast. Experiments with dogs suggest that fresh water instilled into the trachea produces more lung injury than either isotonic or hypertonic saline. (11) However in humans, fresh water washes out surfactant, causing atelectasis and intrapulmonary shunting. By contrast, salt water aspiration appears to be associated with very liftle alveolar-capillary damage. (12) Earlier claims that red cell hemolysis gives rise to hyperkalemia has been refuted. On the contrary, hypokalemia is seen after both fresh and salt water aspiration. The volume of water that would have to be inhaled to cause clinically significant red cell hemolysis is greatly in excess of that which can produce irreversible pulmonary damage. (13) Ventricular fibrillation following immersion is predominately a complication of hypothermia and not of electrolyte imbalance. The electrolyte changes that are seen probably result from absorption of ingested fluid from the stomach rather than from the lungs. High serum sodium and magnesium levels may be seen after immersion in sea water but seldom require treatment. Water intoxication causing convulsions in infants has been described rarely.

EMERGENCY MANAGEMENT

Swimmers recovered unconscious from shallow water should be assumed to have suffered fracture or dislocation of the cervical spine, particularly if there is injury to the face or head. Care must be taken not to over-extend the neck during expired air resuscitation. The head and neck must be immobiliscd during transport to hospital. Rupture of the liver or spleen may have occurred if the victim has entered the water from a height.

After removal from the water the subject should be laid prone and cardiopulmonary resuscitation carried out in all other respects in the usual way. (14) The quality of the resuscitation procedure is the single most important factor that determines outcome. The subject’s prognosis is transformed if the heart can be restarted at once. Simcock reported that around 70% of subjects arriving in the emergency room of a hospital apneic, but with a pulse, could be expected to survive, compared with only 8% in whom the heart was not restarted outside hospital. (15) It may be necessary to continue chest compression for an hour or more, and attempts at resuscitation should not be abandoned while the subject remains cold. Pragmatic advice on the management of hypothermia in the field is available from the Medical Commission on Accident Prevention. (16)

Regurgitation of gastric contents during resuscitation occurs in nearly all unconscious victims. The airway should therefore be secured with an endotracheal tube as early as possible and high-concentration oxygen given. The pulse may be slow and of low volume making assessment very difficult. An added dilemma is that bradyarrhythmias may be converted to ventricular fibrillation by chest compression in profoundly cold subjects. For this reason, great care is needed in assessing the carotid pulse. Palpation for at least 10 seconds is recommended.

MANAGEMENT IN HOSPITAL

Near drowning is a medical emergency. At worst the subject may present deeply unconscious with acidosis and profound hypothermia. Pulmonary edema is an early complication. Cerebral edema and septicemia may develop later and are life threatening.

Early measures

Subjects who appear to be completely well should be kept under observation for 6 hours in case of delayed-onset pulmonary edema (secondary drowning). They may then be discharged provided there is no cough or lung crackles, the chest radiograph shows no shadows and the respiratory rate and arterial oxygen level is normal with the subject breathing air. Anyone who has inhaled water is at risk of infection and should be followed up with a chest radiograph. Unconscious or apneic subjects require intubation and positive pressure ventilation with a high concentration of oxygen. Venous access through a central line is essential both for monitoring pressure and for giving fluids or drugs. An electrocardiogram may reveal bradyarrhythmias or ventricular fibrillation in those who appear to be pulseless. Blood should be drawn for both erobic and anerobic culture. Broad-spectrum antibiotics effective against Gram-negative organisms should be given (Table 2).

Arterial blood gases

A low PAO2 in a subject breathing air provides an early indication that water has been inhaled and suggests pulmonary edema or atelectasis with shunting. Arterial gases and pH should be measured in all subjects, including those who are conscious and apparently well on arrival in hospital. Modern analysers assume a normal body temperature of 370C. Failure to enter a low core temperature in those who are hypothermic will result in a falsely high arterial oxygen reading. Differences become significant when core temperature is as little as 10C below normal. As, in practice, recordings around 300C are not unusual, this correction is essential. An initial arterial pH of 7 or less is a poor prognostic sign.

Electrocardiography

In immersion victims, abnormalities of cardiac rhythm are the result of hypothermia coupled with hypoxia rather than of changes in serum electrolytes. Sinus or nodal bradycardia is common, making the carotid pulse very difficult to find in some cases. Nevertheless circulation may still be adequate, so early monitoring of the electrocardiogram is essential to establish cardiac activity. Ventricular dysrhythmias induced by hypothermia do not respond to DC cardioversion; once established, the treatment of fibrillation is to support the circulation with chest compression until the temperature of the myocardium (deep body) excçeds 280C.

Venous pressure and intravenous drugs

A central venous line provides access and allows pressure measurement. This becomes important in the event of pulmonary edema when its use to monitor the optimum level of positive end-expiratory pressure (PEEP) may be critical. Central venous pressure is often low initially and plasma expansion is indicated. Acidosis is managed with mechanical hyperventilation; sodium bicarbonate is seldom needed. Use of systemic corticosteroids has not been convincingly shown to prevent the development of pulmonary edema or to influence its course, and is not recommended. (17) Antibiotics should be given after first obtaining a blood culture.

Hypothermia

A fully conscious subject may be hypothermic and yet not shiver, underlining the importance of rectal temperature readings. Hypothermic subjects must be rewarmed and their rectal temperature measured with a low reading thermometer. The probe should be placed at least 10cm beyond the anal sphincter to avoid erroneously low readings from the cooler periphery. Aspiration of stomach contents by nasogastric tube prevents further absorption of water or salt and removes the risk of regurgitation. Rewarming in bath water at 400C is most satisfactory. If not possible, then passive rewarming is achieved by insulation in thick woollen blankets after first cutting off wet clothing. A short-lived fall in core temperature, commonly seen as rewarming commences and known as the 'after drop', is caused by continued loss of heat through conduction from the core to the cooler peripheral tissues. It occurs independently of blood supply and is not a risk factor. (18)

Active rewarming by heating the blood with extracorporeal bypass can be life saving for those found unconscious with profound hypothermia. (19) Bolte and colleagues (20) used this technique to revive a child who had been submerged in ice cold water for 66 minutes. Letsou et al.(2l) reviewed the clinical course of five subjects each presenting with a rectal temperature below 260C all of whom were rewarmed on bypass. Three survived to be discharged with normal mental scores. Over several years, Swiss mountain, rescue teams have recovered the bodies of 46 victims of avalanche or incarceration in ice, all were sent to one of three major centres in Switzerland with extracorporeal blood rewarming facilities. Fifteen out of 32 people rewarmed in this way have survived. (22) (Table 3)

Pulmonary edema

Pulmonary edema occurs only in those who have inhaled water and usually within 4 hours of aspiration. (23) It is believed to be the result of a plasma leak through a damaged alveolar-capillary membrane and not of fluid overload. Left atrial pressure remains normal throughout, a picture similar to adult respiratory distress syndrome.

The earliest sign of impending pulmonary edema is a falling PAO2, and may precede any changes seen on the chest radiograph. Respiratory distress should be treated promptly by assisted ventilation and with positive end expiratory pressure (PEEP). The pressure setting is that which maintains the PAO2 above 10kPa with a FI02 that ideally should not exceed 0.6. Pressures above 2.0kPa may be needed to obtain satisfactory arterial oxygenation following fresh water aspiration but are poorly tolerated because of impairment of cardiac output.

Cerebral edema

Cerebral edema is the result of hypoxemia and contributes further to any damage the hypoxia may already have induced. There was a vogue for more aggressive treatment in children with prolonged hypothermia by means of barbiturate-induced coma. However, no improvement in outcome has been demonstrated, so the technique has been abandoned, and with it the need to monitor intracranial pressure.

(24) Reducing the PACO2 by mechanical hyperventilation induces cerebral vasoconstriction and may be useful. Early use of diuretics such as mannitol may also help.

Septicemia

Lung infection is common following near drowning. Septicemia and brain abscess have also been reported suggesting that arterial embolization of infected material occurs, possibly as a result of pulmonary barotrauma. As well as common pathogens, exotic organisms have been described, including Pseudomonas puutrifaciens, (25) Pseudomonas pscudomallei, (26) Aspergillus fumigatus, (27) lactose-positive Vibrio sp. (28) and Petriellidium boydii. (29) Leptospirosis is a hazard well recognised in inland waters. Victims of such immersion should be warned of fever developing within a few days of the accident and offered short-term follow-up.

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TABLE 1 Essential factors concerning the immersion incident

- Length of time submerged
- Quality of immediate resuscitation
- Temperature of the water

• Shallow water

• A buoyancy aid being used by the casualty

• Nature of the water (fresh or salt)

Favourable outcome associated with submersion for less than 5 minutes

Favourable outcome if heart beat can be restored at once

Favourable outcome associated with immersion in ice cold water (below 50C) especially infant victims

Consider fracture/dislocation of cervical spine
Likely to be profoundly hypothennic.
Victim may not have aspirated water. See postimmersion collapse
Ventilationlperfusion mismatch from fresh water inhalation more difficult to correct. Risk of infection from river water high. Consider leptospirosis

TABLE 2 Essential early measures

• Tracheal intubation for unconscious victims

• Electrocardiogram

• Nasogastric tube

• Rectal temperature

• Arterial blood gases

• Chest x-ray examination

• Central venous line

• Culture blood for both erobic and anerobic organisms
Secures the airway in the event of regurgitation

Pulseless patient may have bradyarrhythmias or ventricular fibrillation

Decompresses the stomach thereby assisting ventilation. Reduces the risk of regurgitation

Use low reading thermometer. Insert the probe at least 10cm

Low PaO2 breathing air is a marker for pulmonary edema or atelectasis with shunting. A pH less than 7 associated with poor prognosis

Shows aspirated fluid. Early indication of pulmonary edema

Essential for monitoring level of positive end-expiratory pressure respiration

Septicemia common. Consider "exotic" organisms. Brain abscess a late complication

TABLE 3 Further measures

- Measure arterial gases: ensure low temperature correction
- In case of hypothermia raise core temperature above 280C before defibrillation
- Consider plasma expanders and prophylactic antibiotics
- Rewarm in bath water at 400C
- Remove wet clothing if casualty can be sheltered
- Actively rewarm with extracorporeal bypass if necessary

From the New England Journal of Medicine
Accidental Deep Hypothermia

To the Editior: The report by Walpoth et al. (Nov 20 issue)' on survivors of accidental deep hypothermia and circulatory arrest was very interesting. I was impressed by their favorable results. From the published characteristics of the patients it is impossible to determine the length of time during which each patient had documented circulatory arrest with fixed, dilated pupils. This information is known to he important for prognosiss and thus should he indicated.

Of the 32 patients in whom rewarming with cardiopulmonary bypass was attempted, 17 were not long-term survivors. It would certainly be of interest to analyze this population for possible prognostic factors.

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To *the* ***Editor*** Ever since Siebke et al. documented the occurrence of recovery without cerebral sequele after 40 minutes of submersion in ice-cold watet' others have pondered the mechanisms influencing survival in such circumstances. In their account of the resuscitation of patients with profound hypothermia with extreorporeal blood warming, Walpotl et al. speculate that the chances of surviving deep hypothermia are better if asphyxia follows cooling of the body (as it des after incarceration in ice, as they describe) than if it precedes it (as, for example, during drowning). They may well be right, but since there is no way of knowing precisely the timing of the cardiac arrest, their observation raises an important question. Should the rescue services recovering victims with hypothermia and cardiac arrest abandon attempts at rewarming but continue cardiopulmonary resuscitation until they reach the hospital in order to keep the victims' brains cool?

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1. Sicbke H, Rod T, Breivik, H, Link B. Survival after 40 minutes' submersion without cerebral sequele. Lancet 1975;1:1275-7

To *the Editor:* Walpoth et al. report a beneficial neuropsychological outcome for survivors of accidental deep hypothermia, but the long-term consequences for the peripheral nervous system remain unclear. As stated by the authors and by Dr Lazar in the accompanying editorial,1 the encouraging outcome is most likely related to the young age and good health of the patients, the type of accidental hypothermia, the clinical experience of the rescue organizations, and the easy availability of cardiopulmonary-bypass techniques. In general, the management and long-term prognosis of accidental (deep) hypothermia also depend on the recognition of its pathophysiology and on the treatment of underlying, predisposing disorders.2 In the management and prevention of accidental hypothermia, it is pivotal to differentiate between hypothermia caused by severe cold stress and other types of hypothermia occurring in less severe environmental conditions, as welI as between acute and intermittent or chronic hypothermia.2,3 Serious, recurrent hypothermia can often be prevented by an adequate assessment of its pathophysiologv, treatment of predisposing conditions, and improvement of thermoregulatory behavior.

Guidelines for the optimal rewarming strategy in accidental hypothermia that is not caused by severe cooling vary depending on the type and severity of hypothermia and underlying disorders; often, external rewarming techniques are appropriate in patients with stable cardiovascular function. However, unlike active core rewarming, external rewarming after severe cold stress carries the potential risk of a subsequent drop in core temperature, particularly in patients with decreased metabohism.2-4 In patients with thermoregulatory failure, preventive measures are crucial and active rapid rewarming can induce an overshoot in core temperature.

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The authors reply:

To the Editor: Dr. Offenstadt asks how long each patient had documented circulatory arrest. Six of our 15 patients had cardiorcspiratory arrest when they were rescued. Three of them had fallen into a crevasse and one into cold water. They became unresponsive 5, 15, 60, and 135 minutes before their rescue. Two of the six had attempted suicide. Thus, the time at which cardiac function ceased in these six patients is unknown. As noted in the article, nine patients had vital signs at the time of rescue**,** but cardiopulmonary arrest occurred an average (+/-SD) of 14.8±18.6 minutes after rescue. The mean interval from the detection of cardiorespiratory arrest to the initiation of rewarming with cardiopulmonary bypass was 141±50 minutes, during which time intubation, ventilation, and cardiac massage (cardiopulmonary resuscitation) were performed.

Dr Offenstadt's second question relates to the cause of death of the 17 patients who died. Most were avalanche victims who presumably suffered asphyxia before hypothermia developed. This corroborates our assumption, addressed by Dr. Harries, that the chances of surviving deep hypothermia are better if asphyxia follows cooling than if it prece4es cooling. Asphyxia did not occur in any of the 15 survivors, whereas it did occur in most of the 17 who died. A Swiss multicenter study that involved 234 patients with mild, moderate, or deep accidental hypothermia analyzed prognostic factors.1 Multiple regression revealed the following: asphyxia was associated with a 30-fold increase in the chance of dying, invasive rewarming with a 20-fold increase, a slow rate of cooling with a 10-fold increase, asystole in cardiac arrest with a 9-fold increase, pulmonary edema or acute respiratory distress syndrome with an 8-fold increase, elevation of serum potassium with a 2-foId increase per millimole per liter, and age with a 1.03-fold increase per year of age. Rapid cooling increased the likelihood of survival 10-fold, ventricular fibrillation in cardiac arrest increased it 9-fold, and ingestion of narcotics or alcohol increased it 5-fold. Surprisingly, core temperature did not influence survival. Similar factors were identified by other authors.2

In answer to Dr Harries: we believe that attempts at rewarming victims with deep hypothermia outside the hospital should be abandoned. If circumstances permit, such persons should be transported expeditiously to a hospital experienced in the use of rewarming with cardiopulmonary bypass. Hypothermia should be maintained and cardiopulmonary resuscitation continued during transportation.

We and others agree with Dr. MacKenzie that the choice of the appropriate rewarming technique has to be individualized for each patient,3 depending on the level of hypothermia and the patient's cardiovascular condition. Forced air seems to be an effective external rewarming technique for patients with moderate or even deep hypothermia and stable cardiovascular function.4 However, in patients with cardiopulmonary arrest, we consider core rewarming with extracorporcal bypass to be the method of choice.

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