Near-drowning and hypothermia

The term near-drowning is applied to a submersion victim who is taken to an emergency facility and survives 24 hours.[1] The quality of survival is not mentioned, but permanent brain damage is common owing to the brain's vulnerability to asphyxia.

In Canada, water temperatures may range from 15°C to less than 5°C throughout most of the year. When a child falls into very cold water but does not remain totally submerged, the body temperature decreases within 5 to 20 minutes to levels of moderate hypothermia (34° to 28°C or less). This cooling, termed immersion hypothermia, may cause death by several mechanisms, but, paradoxically, it protects the brain from hypoxia. If rescue occurs within 10 to 30 minutes complete recovery is possible.

The term submersion hypothermia is applied when immersion hypothermia is complicated by submersion and asphyxia. Although cooling and drowning may occur separately, simultaneously or sequentially, each process is distinct and requires different treatment.

It is well known that when an inadequately clothed person suffers prolonged exposure to cold, accidental hypothermia may develop.[2] Immersion hypothermia is an accelerated version of the same process. No amount of shivering or exercise can compensate for the great heat loss that occurs when one is immersed in icy water. The cooling process is more rapid in vigorous swimmers owing to skeletal muscle vasodilatation and the consequent accelerated heat loss from the extremities. Children are even more vulnerable because of their larger surface area relative to body volume and their lack of insulating fat. The temperature of the water is crucial, for the rapidity of cooling and death are directly related. A water temperature below 12°C causes paralysis of precapillary sphincters, which allows unimpeded blood flow through the cutaneous capillaries.[3] When the temperature of the water is 0°C death usually occurs within 1 hour, whereas when it is 15°C death usually occurs within 6 hours. However, when the temperature is 20°C or higher almost all persons survive.[4]

If a person is properly supported by a life-jacket the head remains above the surface of the water; therefore asphyxia will not occur. Brain damage will only develop after cardiorespiratory failure.

Several mechanisms leading to cardiac arrest may cause death from immersion hypothermia. The usual course of events is a relentless reduction of core temperature, with delirium when it is 35°C, unconsciousness when 32°C and spontaneous ventricular fibrillation when less than 28°C.[5] It is important to appreciate that in this situation cooling precedes the development of bradycardia and subsequent cardiac arrest. The sequence is similar to that of elective hypothermia for cardiovascular operations, and it is therefore not too surprising that a person can make a complete neurologic recovery after much longer periods of immersion and cardiac arrest than previously thought possible.

Death from immersion hypothermia may also occur as a result of two less common mechanisms associated with a poorer prognosis. Rarely the sudden shock of entering ice-cold water causes immediate ventricular fibrillation (the immersion syndrome[6]) before preliminary cooling has occurred. More frequently, unconsciousness from cooling leads to cessation of swimming and subsequent drowning, or, if the person is properly supported, cooling continues until cardiorespiratory arrest occurs (usually at a core temperature of 25°C). Obviously, core temperature and duration of bradycardia or cardiac arrest are crucial factors that affect potential recovery, but the exact limits are unknown. Therefore, treatment must be instituted in all cases, and resuscitation must be continued, regardless of the time required, until the body temperature reaches at least 30°C and cerebral death is obvious.

When rescued, all these persons appear to be dead, but if cardiorespiratory arrest has not occurred the chances of complete recovery are excellent if proper treatment is given. Oxygen should be administered by mask, and warm blankets should be applied. The patient should be handled gently so that ventricular fibrillation is not triggered during transportation of the patient to hospital. If it is unknown whether cardiac arrest has occurred, closed-chest massage and artificial respiration should be started immediately. These two measures must be continued

without pause during rapid transport to the nearest hospital.

In the emergency department the following measures should be undertaken without delay and in the following order:

- A nasotracheal tube should be inserted for ventilation with 100% oxygen while cardiac massage is continued.
- A blood-pressure cuff and electrocardiogram leads should be applied to monitor the circulation, and defibrillation should be performed if necessary.
- A large-bore intravenous cannula should be inserted to withdraw blood for laboratory studies such as hemolysis tests, crossmatch and typing, culture, and determination of the hematocrit and concentrations of serum electrolytes, blood urea nitrogen and hemoglobin. Volume expanders (plasma, Ringer's solution or dextran) should also be administered.
- After an arterial blood sample is taken for blood-gas determinations, up to 50 mL (the dose for adults) of sodium bicarbonate should be given intravenously to counteract the severe metabolic acidosis of hypothermia and to facilitate the action of inotropic drugs if they are required.
- A rectal thermometer and a urethral catheter should be inserted.
- When the circulation has been satisfactorily re-established an arterial line should be inserted for serial blood-gas measurements and continuous monitoring of blood pressure.
- A central venous catheter may be considered for blood volume management, but stimulation of the right atrium by the catheter tip may trigger atrial fibrillation.
- A chest roentgenogram and examination for head injuries must be included as part of the initial routine management of these cases.

Rewarming the patient to correct the total metabolic effects of immersion hypothermia is an urgent need. However, if the patient has suffered prolonged cardiac arrest or submersion, the effects on the brain of rapid rewarming may be disastrous. In this situation, treatment should follow the guidelines suggested for the treatment of submersion hypothermia outlined below. Core temperatures as low as 30° to 31°C are amenable to either treatment regimen, and are consistent with full recovery. The best method of warming patients with immersion hypothermia remains controversial, but it is determined by whatever means are available.

A hot bath (water temperature of approximately 40°C) is simple and always available. Unfortunately, warming by such means is slow and causes an "after-drop" of temperature, creates large temperature gradients predisposing to ventricular fibrillation under circumstances that make defibrillation risky, and requires the patient to be in the unsatisfactory head-up position. The use of peritoneal dialysis with warm Ringer's solution (at a temperature of 40°C) is simple, effective and available, and it produces more rapid core rewarming. Other methods, such as perfusion of warm fluids per rectum, by gastric lavage or by thoracotomy, have been described.[2,7-9]

The use of heated vapours is controversial owing to the low specific heat of gases. The use of extracorporeal warming is ideal but seldom available.

The term submersion hypothermia is applied when cooling follows acute asphyxia. The risk of brain damage is consequently much greater and the maximum submersion time consistent with full recovery is correspondingly shorter. Nevertheless, the cooling process in children is rapid and may be greatly benefitted by the "diving reflex",[10] the circulatory reflex triggered neurologically by apnea and immersion of the face that shunts blood and available oxygen to the heart and brain and is accompanied by bradycardia, thus permitting prolonged submersion. This reflex is particularly active in children when they are submerged in very cold water.

Numerous instances have been reported of children surviving submersion in cold water for as long as 10 to 40 minutes.[11-14]

At the time of rescue and transportation to hospital, patients with submersion hypothermia should be treated as outlined previously, except that no rewarming efforts should be initiated unless the core temperature is less than 30°C. Body temperature should be maintained at 30°C to facilitate recovery of brain function.

Following resuscitation and stabilization of the circulation, comatose patients should be aggressively treated in a critical care unit to preserve brain function and forestall an increase in intracranial pressure. The details of this management[15] can be summarized as follows: Dehydration is induced by diuretics and limited administration of fluids. Ventilation is controlled by the use of inspired oxygen concentrations of more than 70%, and the carbon dioxide pressure of arterial blood is maintained at 30 mm Hg. To reduce cerebral oxygen requirements, the temperature is maintained at 29° to 31°C and large doses of barbiturates (e.g., 3 mg/kg of pentobarbital administered intravenously once every hour) are used. Dexamethasone sodium phosphate (1.0 mg/kg daily in four doses), relaxants (e.g., pancuronium bromide, 1 mg/kg administered intravenously), chlorpromazine (5 to 25 mg administered intramuscularly) and other drugs are used as needed. This therapy requires intensive monitoring, including continuous direct measurement of intracranial pressure. For treatment to be successful it must be started within 1 to 2 hours and be maintained for at least 48 to 72 hours. At the Hospital for Sick Children in Toronto this regimen reduced the frequency of permanent brain damage from 30% in 30 patients from 1970 through 1974 to 7.7% in 26 patients from 1975 through 1977.[16]

It is essential that all submersion victims, even when they are conscious and alert, be admitted for 24 hours of observation and investigation. Approximately 15% of near-drowning victims who are conscious at the time of admission die of "delayed" drowning from pulmonary and cerebral causes.[11] A recommendation that all unconscious patients, whether hypothermic or normothermic, should receive full "cerebral salvage" treatment appears to be

justified. Complications such as aspiration, hemolysis and renal failure can be treated successfully with recognized methods; however, they are of secondary importance.

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