Management of Profound Accidental Hypothermia with Cardiorespiratory Arrest

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Complete recovery following rapid rewarming is described in three tourists who were admitted in a state of profound hypothermia with total cardiorespiratory arrest (rectal temperature ranging from 19 to 24 C). In all three patients, respiration and circulation had ceased during the rescue operation. Rapid core rewarming was achieved by thoracotomy and continuous irrigation of the pericardial cavity with warm fluids in one patient, whereas in the other two patients rewarming was accomplished with extracorporeal circulation using femoro-femoral bypass. In the first patient, the heart could not be defibrillated earlier than 90 minutes following thoracotomy; in the other patients rewarming was attained very rapidly, and within half an hour after institution of bypass, resuscitation of the heart was successful. The patients fully recovered their intellectual and physical abilities, despite the prolonged periods of circulatory arrest lasting from 2½ to 4 hours. We conclude that rapid core rewarming is the adequate therapy for profound accidental hypothermia with circulatory arrest or low cardiac output. If feasible extracorporeal circulation represents the method of choice because it combines the advantage of immediate central rewarming with the benefit of efficient circulatory support, the heart is rewarmed before the shell, thus preventing the "rewarming shock" due to peripheral vasodilatation. Resuscitative efforts should be promptly initiated and vigorously pursued, even in the state of clinical death; in profound hypothermia neurologic examination is inconclusive regarding prognosis.

ACCIDENTAL HYPOTHERMIA caused by prolonged exposure to low temperature is probably a more frequent event than commonly recognized and still carries a high mortality rate, with a reported average of 80% in patients with body temperatures between 24 and 35 C.[1-4] The prognosis is related partly to the degree of hypothermia and partly to whether or not there is an underlying complicating disease like atherosclerosis in old age or chronic alcoholism.[5,6]

The occurrence of circulatory arrest as a consequence of accidental hypothermia poses a multiplicity of therapeutic challenges. The initial and perhaps most difficult one is the decision to initiate resuscitation, recognizing that at low body temperature clinical death is not synonymous with biological death. Once this decision is made, the major problem becomes one of raising the core temperature. In this report, our experience with three consecutive patients with profound accidental hypothermia who recovered completely after rapid central rewarming is presented. All three patients were, incidentally, victims of mountaineering in the Swiss Alps, and they all developed cardiorespiratory arrest during the rescue operation. Upon arrival in our institution, they were clinically dead, being unresponsive, apneic and flaccid with fixed, dilated pupils, and ECG monitor revealed ventricular fibrillation in two cases and asystole in one case, and rectal temperature ranged from 19 to 24 C.

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Case Reports

Case 1. A 41-year-old civil servant (HO) was buried by an avalanche and remained trapped under several feet of packed snow for 2½ hours. When rescue came the patient stopped breathing and lapsed into cardiac arrest. After tracheal intubation on the scene by a doctor accompanying the Heliswiss aircraft he was immediately flown to our emergency center in Berne. Cardiac massage was continued in the helicopter. Upon arrival we recorded ventricular fibrillation, a core temperature of 22 C measured rectally, and dilated fixed pupils. When all attempts at closed chest defibrillation had proved unsuccessful, thoracotomy was performed, and active rewarming started by continuous irrigation of the pericardial cavity and the stomach with warm saline. It took about 1½ hours and 40 liters of saline to bath the heart and raise the core temperature to 26 C, at which time the heart was defibrillated successfully (Fig. 1, graph at the top). Strikingly, at the beginning of active rewarming the heart was found to be hard as stone and it is hardly conceivable how effective external cardiac massage could have been during the helicopter flight. Apart from temporary pulmonary edema, the postoperative course was uneventful, and the patient was dismissed two weeks later with an astonishing full recovery of his intellectual and physical abilities.

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Submitted for publication: September 9, 1981.

0003-4932/82/0400/0492 $00.70

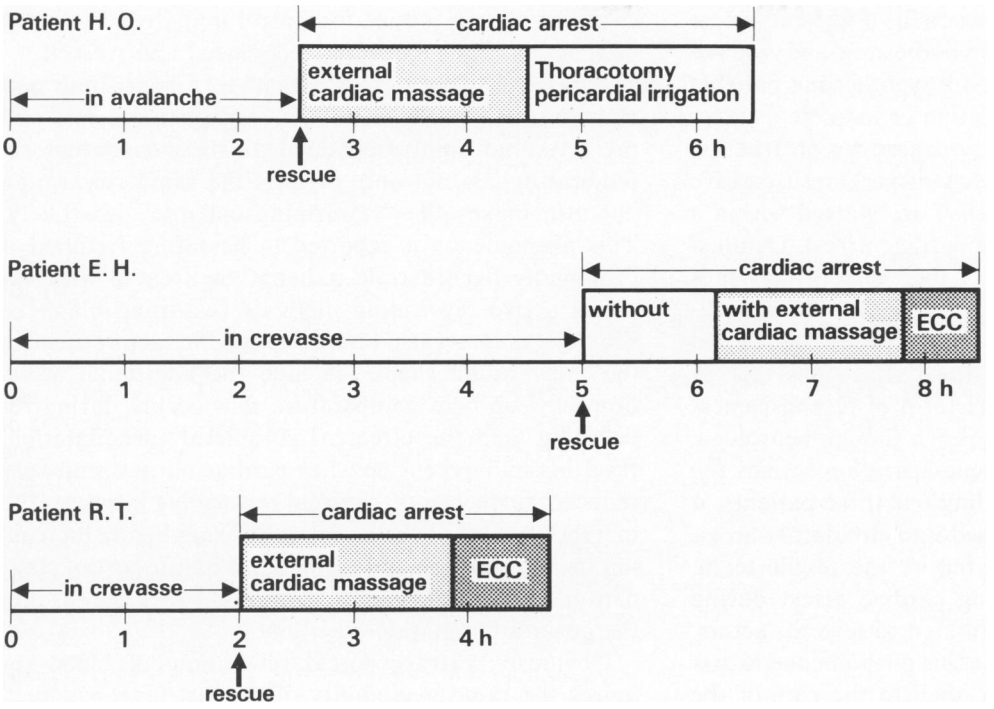

FIG. 1. Diagram showing the therapeutic measurements in three patients suffering from profound accidental hypothermia with circulatory arrest (reference to lapse of time). ECC = extracorporeal circulation.

Case 2. A 42-year-old electrotechnician (EH) was also caught by an avalanche and thrown into a crevasse where he lay covered by 7 meters of snow and ice for five hours before being freed. By that time he was unconscious, pulseless, and had stopped breathing. Therefore, no attempt was made to resuscitate the patient who was nevertheless flown to the nearby hospital. The ECG revealed asystole and pupils were dilated and fixed. The rectal temperature was 19 C. It was thought that with so much refrigeration the patient stood a chance. Therefore, 70 minutes after rescue the decision for tracheal intubation and external cardiac massage was made (Fig. 1, graph in the middle). The patient was then flown to our department where active rewarming was started three hours after rescue. This time cardiopulmonary bypass via a femoral vein and artery was used for rapid warming of the heart. Simultaneously a midline sternotomy was performed. The heart was motionless and frozen stiff. Direct cardiac massage was of little avail owing to the intensity of myocardial contracture. With the extracorporeal circulation a flow of 2½–3 liters per minute was maintained, resulting in a mean arterial pressure of 50 mm Hg. Within 20 minutes, the core temperature had risen to 36 C with the heart gradually softening up, and ventricular fibrillation beginning first in the right ventricle, then extending to the left ventricle. Half an hour after starting active rewarming electric defibrillation was successful. The postoperative course was marked by severe pulmonary edema and renal shutdown, but the patient eventually recovered fully and has resumed his prior occupation.

Case 3. A 24-year-old nurse (RT) fell into a 7-meter deep crevasse where she lay for two hours, half submerged in ice cold water before being brought to the surface of the glacier. She developed cardiorespiratory arrest during the rescue operation and was flown to the nearest hospital where ventricular fibrillation and rectal temperature of 24 C was recorded. Following tracheal intubation and beginning of cardiac massage she was referred to us. Rapid rewarming was started with partial cardiopulmonary bypass in the manner described above (case 2). Within 20 minutes, the core temperature had risen to 29 C, and subsequent resuscitation of the heart was successful (Fig. 1, lower graph). This time we refrained from any form of thoracotomy. The postoperative course was uneventful apart from transient pulmonary edema. At the time of discharge no loss of intellect or change in behavior could be perceived.

Discussion

It is well known that low temperature reduces whole body and, specifically, cerebral oxygen requirements, thus permitting an extended period of interrupted circulation before permanent brain damage occurs. This recognition forms the basis of the hypothermia techniques used in neuro- and cardiac surgery. At a body temperature of 20 C the ischemic tolerance of the brain is considered to be increased approximately by tenfold as compared to normothermic conditions. This feature has to be kept in mind when resuscitation is started, and it should prompt every involved physician not to terminate the resuscitative effort too early. The attempts should be vigorous and prolonged, even when the patient demonstrates symptoms indicating irreversible cellular damage in the normothermic state. Below 27 C life is difficult to detect; the patient may be motionless and pulseless with flaccid limbs and fixed dilated pupils.[7] It has been stated that failure to respond to resuscitation is the only definite criteria for diagnosis death from hypothermia;[8,9] therefore, the necessity of a prolonged resuscitative effort should not be a source of discouragement. The applicability of this conception is illustrated by the history of our three patients who had periods of circulatory arrests lasting from 2½ to nearly 4 hours and showed no permanent neurologic deficit following active core rewarming.

It is evident, that resuscitation after prolonged cir-

culatory arrest can only be successful if cardiac arrest is the direct consequence of hypothermia and not the sequel of anoxia and acidosis. In hypothermic patients who present ventricular fibrillation or asystole as a result of concurrent asphyxia (as caused by obstruction of the airways and other mechanisms), resuscitative efforts are only promising if they are started within a few minutes following onset of cardiac arrest. Detailed information about the course of the accident may provide useful hints with regard to prognosis of resuscitative attempts. At all events, however, the latter should never be denied if the victim shows vital signs such as spontaneous breathing or some form of responsiveness immediately before the rescue, even though neurologic examination following the rescue operation reveals the state of clinical death. Regarding our three patients, it is striking that all of them lapsed into circulatory arrest the moment they were recovered by the rescue team. The grave risk of precipitating cardiac arrest during salvage operations can be attributed to several factors. The most likely explanation for this phenomenon is that cold blood is shifted from the shell to the core of the body during the maneuvers necessary for rescue. It also has been demonstrated that any physical stimulus can trigger the onset of ventricular fibrillation in hypothermic monkeys.[10] Therefore, rough handling of the hypothermic patient showing a depressed but still preserved circulatory function should be avoided.

For treatment of the hypothermic patients, a variety of methods is reported in the literature and the appropriate type of rewarming remains controversial. In the presence of circulatory arrest, however, the need for a rapid active rewarming procedure is mandatory in order to reverse ventricular fibrillation or asystole. The following methods are available to reach this goal: peritoneal dialysis using warm solutions,[11,12] thoracotomy and irrigation of the heart with warm fluids,[13-16] or extracorporeal blood warming by using partial bypass with the heart-lung machine and the heat exchanger. Theoretically, the best treatment of cold-induced cardiac arrest appears to be the rewarming procedure with the aid of extracorporeal circulation (femoro-femoral bypass). As compared to peritoneal dialysis and mediastinal irrigation, partial bypass has the following advantages: (1) it can be instituted rapidly using a groin incision, (2) it is the fastest method of rewarming, (3) it provides the obvious advantage of circulatory support, and (4) improves tissue perfusion by using hemodilution. Sternotomy and exposure of the heart as performed in our second case is not indispensible after institution of cardiopulmonary bypass. Thoracotomy does, however, offer the possibility of direct cardiac massage, thus increasing coronary flow and accelerating rewarming of the myocardium; moreover, with the chest open, cardiac action is easier to control and rhythm disturbances can immediately be recognized and treated.

Linking a hypothermic patient to a heart-lung machine may also be indicated if cardiac function is still preserved but highly depressed. In these cases femoro-femoral bypass not only permits the rapid rewarming but also makes the "rewarming collapse" less likely. This phenomenon is reported to be rather frequent if profoundly hypothermic patients are treated with external active rewarming methods (warming blankets, submersion in a warm bath.[17,18] Possible factors causing the "rewarming shock" include the additional afterdrop in deep body temperature that occurs during rewarming, and the effect of peripheral vasodilatation, resulting in hypotension when cardiac output is already reduced; furthermore, external rewarming increases the metabolic needs of the peripheral tissues before increasing tissue perfusion and enhances the transport of stagnant blood with high concentrations of metabolites into the general circulation.

Obviously, extracorporeal rewarming of blood requires the rapid availability of a heart-lung machine. In the absence of this condition, the internal core rewarming can be achieved by thoracotomy and continuous irrigation of the pericardial cavity with warm solutions, possibly supplemented by gastric warming. As shown in our first case, hypothermic subjects suffering ventricular fibrillation can be resuscitated successfully by this method even when rectal temperature does not exceed 22 C. In contrast to the femoro-femoral bypass, this procedure does not provide instantaneous rewarming. Furthermore, the fact has to be taken into consideration that massage of a profoundly hypothermic heart is of little avail due to the intensity of cold-induced myocardial contracture; the rigid and contracted heart does not allow an appropriate ventricular filling, thus the amount of blood volume pumped into the great arteries by massage alone remains very restricted.

It will hardly be necessary to underline the importance of other intensive therapeutic measurements that are imperative to warrant a successful rewarming. The resuscitative attempts include adequate ventilation and serial monitoring of acid-base balance. Alternations of blood gases as well as metabolic and electrolyte changes have to be immediately recognized and corrected. Special care should be taken with regard to the hydration status of the patient; hypovolemia, often occurring when vasoconstriction following rewarming is overcome, must be searched for and treated without delay.[18]

In the literature only a few reports deal with successful resuscitations of profoundly hypothermic patients by using partial bypass with the heart-lung machine and the heat exchanger. We have found five single communications, each of them referring to one single

patient treated with this method for cold-induced circulatory arrest; in all five patients ventricular fibrillation developed after they had entered the hospital.[18-22] In four other subjects extracorporeal bypass was instituted for blood rewarming in the absence of circulatory arrest.[18,23,24] A review of the referred articles shows that virtually all treated patients with a measured core temperature below 25 C suffered from pulmonary complications after rewarming. Pneumonia and pulmonary edema are considered to be a feature that regularly follows profound accidental hypothermia.[18,25] In our three patients, a positive-end-expiratory pressure (PEEP) treatment had to be instituted in the postoperative period because of pulmonary edema. Capillary damage to the lungs, due to prolonged hypoxia, is suggested to be largely responsible for this complication. Serial determination of left atrial pressure after the rewarming procedure demonstrated normal values in our patients; on this account it is unlikely to assume that pulmonary edema has to be attributed to a left heart failure.

In conclusion, we think that resuscitative measures should be initiated in any patient suffering from cardiorespiratory arrest caused by deep hypothermia and that efforts should be maintained for considerably longer periods than in normothermic patients, without regard to clinical appearances or duration of circulatory standstill. Every profoundly hypothermic patient, even in the state of clinical death, has the potential for full recovery. If feasible, extracorporeal circulation is considered to be the method of choice for rapid rewarming. It offers an efficient assisted circulation and has the distinct advantages of rapidity and of rewarming the core before increasing metabolic requirements at the periphery; thus, the "rewarming collapse" as a result of premature peripheral vasodilatation may be prevented.

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