

of more and bigger windows. In the event of an impending nuclear attack, people are advised to keep away from the windows. Something can be done to lessen the hazard by the use of fly screens, by drawing curtains across the windows, and lowering the blinds. Failing a sealed shelter, possibly the safest place to be in at the moment of the burst is a shallow hole out in the open, after which refuge should be taken inside a basement which has been sealed to protect against the radioactive products of the burst. The flash of an atomic explosion precedes arrival of the blast wave. Thus, for a 20-Mt. burst, the time interval at the 15-p.s.i. level, which is the threshold for primary lung injury by an unreflected wave (Table I), is as long as seven

seconds. This gives ample time to take cover if a foxhole has been prepared, or at least to move away from any windows, to lie down, and take firm hold of some solid immovable object.

This paper owes much to J. M. Dewey, Associate Professor of Physics, University of Victoria, who contributed Fig. 1, not hitherto published, and who revised and corrected the opening paragraphs. His help is gratefully acknowledged.

REFERENCES

1. CLEMEDSON, C. J. AND PETTERSSON, H.: *Amer. J. Physiol.*, 174: 316, 1953.
2. CLEMEDSON, C. J. *et al.*: *Aerospace Med.*, 34: 714, 1963.
3. HAMIT, H. F. *et al.*: *J. Trauma*, 5: 117, 1965.
4. WHITE, C. S., BOWEN, I. G. AND RICHMOND, D. R.: Environmental medical aspects of nuclear blast (DASA 1341) Technical Progress Report, Defence Atomic Support Agency, Washington, D.C., 1962.
5. WHITE, C. S., BOWEN, I. G. AND RICHMOND, D. R.: *Health Phys.* 10: 89, 1964.

The Management of Accidental Hypothermia

WALTER ZINGG, M.D., *Toronto*

Accidental general hypothermia is defined as an unintentional lowering of the body temperature in a previously conscious patient due to exposure. Even mild degrees of hypothermia may be followed by death if treatment is not instituted promptly. Hypothermic patients who are still conscious may re-warm spontaneously. They should not be left unattended and, if the facilities are available, rapid rewarming appears to be the treatment of choice. Unconscious patients who are presumed to have a lower temperature of prolonged duration may not benefit from rapid rewarming. All hypothermia victims showing signs of life are potential survivors, but even with good facilities the mortality rate may be high.

THIS paper outlines the background upon which treatment of general hypothermia may be based. At the present time one cannot be dogmatic. A few definite recommendations can be made regarding the treatment of local cold injury, but so little is known about general hypothermia that only tentative recommendations can be made. In two of the previous issues of this Journal devoted to the Emergency Health Services^{1,2} the plea was made for the publication of the experiences of those who provide medical care to patients suffering from exposure

On appelle hypothermie générale accidentelle un abaissement involontaire de la température du corps chez un malade auparavant conscient, par suite d'une exposition au froid. Une hypothermie, même légère, peut être suivie de mort si on ne prend pas les moyens d'y remédier rapidement. Les malades en hypothermie qui sont encore conscients peuvent se réchauffer spontanément. Il importe de s'occuper d'eux et, dans tous les cas où la chose est possible, un réchauffement rapide est le traitement le meilleur. Quant aux malades inconscients que l'on soupçonne d'avoir subi une température basse pendant une longue période, ils risquent de ne pas bénéficier d'un réchauffage rapide. Toutes les victimes de l'hypothermie qui présentent des signes de vie peuvent survivre mais, même si on dispose des moyens appropriés, la mortalité reste élevée.

and general hypothermia. It is realized, of course, that studies are difficult to carry out. All the large-scale disasters with large numbers of hypothermia casualties occurred during wartime and do not lend themselves to scientific assessment. After World War II, the meagre data available were compiled in several countries. Peace-time experiences have been published mainly as individual case reports. The relevant literature has recently been reviewed.³ Valuable though these reports are, they do not provide sufficient information regarding the *treatment* of general hypothermia. Reference to animal experiments and to the vast experience with induced hypothermia may be helpful, but the limitations must

From the Department of Surgery, University of Toronto, and Department of Surgery and Research Institute, The Hospital for Sick Children, 555 University Avenue, Toronto 2, Ontario.

The research for this paper was supported by the Defence Research Board of Canada, grant numbers 9310-100 and 9310-111.

be realized. No experiment can possibly duplicate the accident situation, the mental and physical exhaustion, or the combination of injuries found in hypothermia victims.

DEFINITION

In the present context general hypothermia is defined as an unintentional lowering of the body temperature due to exposure in a previously conscious patient. Therefore this kind of accidental hypothermia is entirely different from the controlled therapeutic hypothermia induced in anesthetized patients, but it also differs significantly from the unintentional hypothermia encountered in the operating room mainly during pediatric surgery. If a normal person is exposed to a cold environment, the body maintains a normal temperature by increasing thermogenesis. The heat production is increased by various reflex mechanisms, shivering being the most obvious example. If the heat loss exceeds the increased heat production, the body temperature falls in spite of the increased heat production. During the initial phases of the hypothermia, therefore, heat production is increased, possibly to a maximum level, and the oxygen consumption is increased accordingly. Later on, when lower temperatures are reached, some of the reflex mechanisms may fail (for instance, shivering may cease) owing to the effect of hypothermia or to exhaustion.

As has been recognized clinically and substantiated experimentally, hypothermia is better tolerated under anesthesia. The anesthesia may be that induced in the operating room or that associated with an alcoholic stupor. It is not known whether unconsciousness due to other causes affects the tolerance to low body temperature, for instance that due to cerebral injuries or concussion. Parenthetically, lesions in the hypothalamic area may disturb temperature regulation; prolonged hypothermia due to such causes is on record.

It is also well known that newborn humans and animals tolerate lower body temperature much better than adults. There is no information about how long this condition persists in man after the newborn period. There is some meagre evidence that females may tolerate exposure better than males, which does not necessarily mean that females can tolerate lower body temperatures: they may only be better insulated. Very little is known about the response of old people to hypothermia; in this connection, several workers have stressed that old people die with subnormal body temperature, implying that death is caused by hypothermia.

The lack of knowledge in the field of general hypothermia makes it impossible to provide clear definitions or a clear-cut guide to therapy.

HISTORICAL REMARKS

Although some effects of cold were recognized in antiquity and were described by Hippocrates and others, it does not appear that cold injuries, as such, were recognized. Perhaps the temperature in Greece and in Italy was not low enough. It appears that the first human investigations on the effect of cold exposure were carried out in England and published in 1805. The first authoritative account on mass casualties due to cold exposure was published by Baron de Larrey, who accompanied Napoleon's army to Russia in 1812. This remarkable report is frequently quoted even in the modern medical literature. Various attempts have been made to summarize the experiences made during World War II.⁴⁻⁶ Further information in the non-medical literature deals with episodes in wars or disasters like the sinking of the *Titanic*. Pugh⁷ recently described several deaths due to hypothermia in young hikers in Great Britain.

CLASSIFICATION

With induced hypothermia the body temperature can be decreased to low levels with subsequent recovery. Experimentally the temperature of small animals can be lowered even more, with survival of a certain percentage. While carrying out such experiments one is struck by the fact that, during the cold phase, one cannot predict which will die. From a practical standpoint every casualty showing signs of life, regardless of body temperature, must be considered a possible survivor. In principle, there is no "expectant" group—that is, those in whom death is considered probable.

CASUALTY CARE AT FIRST, SECOND AND THIRD ECHELONS

I. First Echelon (*Casualty Collecting Unit*)

It is unfortunate that probably the most difficult problem presented by hypothermia is first encountered by the first-aider who is least well equipped to deal with it; that is, the decision whether, in a victim of accidental hypothermia, life has ceased. Contrary to popular opinion, death is not easy to define clinically even under much more favourable circumstances. The condition—apparent death—is referred to as *Scheintod* in the German literature; and "anabiosis" in the Russian. The condition can best be illustrated in rat experiments. Under proper

conditions these animals can be supercooled—the body temperature falls to below 0° C.—then rewarmed and survive. During these experiments the rats are without respiration and without pulse for about an hour. This is the true anabiosis, as first observed in insects. It is conceivable that there is a similar state in man; if so, the conventional signs of death are not applicable here. Death then must be defined as “failure to revive on rewarming”. From a practical standpoint in disaster work this type of apparent death can be ignored. Even in the experiments the mortality rate was high and, in men, we have no adequate treatment in any event.

The first-aider should check certain vital signs: heart beat, respiration, pupillary reflex; and, in the absence of these, the patient should be presumed dead. However, even on this basis the recognition of death may be difficult. Occasionally persons pronounced dead by medical doctors have shown signs of life later on. The frequency and importance of this occurrence is exaggerated in the non-medical press, but nevertheless death can be misdiagnosed. If this can happen to an experienced medical practitioner, what should the first-aider do at the site of a major disaster in freezing temperatures? If an accident victim is hypothermic, respirations may be extremely shallow and slow, almost imperceptible, peripheral pulses may be absent and the apex beat slow, feeble, and also difficult to detect. In deep hypothermia, the pupillary reflex may be absent and at somewhat higher temperature it may be sluggish.

Obviously the first-aider may find himself in a terrible dilemma. A number of tricks have been proposed to aid him, but unfortunately none are reliable. A paramedical source has suggested, for instance, that when doubt exists an incision should be made through the skin. If it bleeds, the patient lives; if it does not, he is dead. In the intense peripheral vasoconstriction associated with general hypothermia following exposure, this maneuver is completely valueless. The practice of making incisions into people, living or dead, at the site of an accident must be emphatically discouraged.

The first-aider should know the following facts about severe hypothermia. The victim may be deeply unconscious owing to the low temperature, but as long as signs of life can be demonstrated, he should be evacuated. In view of the difficulties outlined above, the results of the simple testing of vital signs may be equivocal. Whenever there is any doubt, the victim should be evacuated. The patients should be prepared for transportation in the same way as other

unconscious patients. Immediate attempts at rewarming are probably not practical and are of doubtful value. No treatment is required, but the victim should be insulated to prevent further cooling. Local cold injuries may be difficult to diagnose. These and other additional injuries should be treated. Very likely these patients will not feel pain. Because of delayed absorption and the danger of subsequent accumulation, drugs should not be administered during this period.

Mild hypothermia presents an entirely different picture. As the temperature falls progressively, the following changes are observed:⁷ abnormal behaviour, slowing, stumbling, weakness, repeated falling, collapse, stupor, unconsciousness and death. In the stages before the collapse, the victims are able to walk. They may or may not shiver. These individuals should not be left unattended, as mild hypothermia is a dangerous condition that has a high mortality. The majority of these patients are able to rewarm themselves spontaneously if further heat loss can be minimized. As long as they can walk, they should be encouraged to walk to the next echelon if satisfactory clothing can be provided. An important point to remember is that their judgment may be impaired and that under no circumstances should even mild cases be sent on their way alone. Additional injuries are treated according to the usual routines. If the casualty-collecting unit is warm, it is not dangerous to expose the hypothermia victims temporarily to this warm environment. If they are able to drink, warm fluids in small quantities including alcohol are not contraindicated.

II. *Second Echelon (Advanced Treatment Centre)*

With doctors and nurses available, the victims of severe hypothermia should be sorted in as detailed a manner as circumstances permit. If questionable cases are brought in by first-aid personnel, death should be verified. Low-registering rectal thermometers are not available and consequently the severity of the hypothermia in individual victims is difficult to assess. All of the unconscious patients should be sent to the Emergency Hospital, on a high-priority basis. When everyone cannot be evacuated, it may be necessary to classify as “expectant” those who clinically have the most severe injuries, and leave them until the last. Resuscitation is limited to obvious measures such as clearing of the airway. Severe hypothermia is associated with low blood pressure; consequently this finding does not call for plasma expanders. Again, no analgesic drugs should be given. Some of these patients may be

able to rewarm spontaneously. In any event, further heat loss should be avoided.

Victims of milder hypothermia who were able to walk to the advanced treatment centre may well be on the way to recovery. Shivering, under these circumstances, is probably a good sign. These patients do not require any specific treatment. They can be in a warm environment without risk. They should be kept under supervision because their mental abilities may still be impaired.

The condition of patients with other degrees of hypothermia may deteriorate on the way to the centre. Here treatment is urgently required. If the facilities for rapid rewarming are available (warm bath), the patient may be rewarmed and then sent to the Emergency Hospital for further assessment. If the facilities are not available, the patient should be evacuated with a high priority as a stretcher case; further heat loss should be avoided because the prognosis is fairly good.

III. *Third Echelon (Emergency Hospital)*

The main problems at this level are the victims of severe hypothermia who survive transportation to hospital. Even now they may appear dead: they may have impalpable pulse, unobtainable blood pressure, shallow respiration, unreactive pupils, and no response to painful stimuli. The patients are carefully examined for additional injuries, especially cerebral injuries. Cardiac arrhythmias are a serious sign.

An attempt should be made to determine the rectal temperature. Because the body temperature is below the scale on clinical thermometers, another, such as a laboratory thermometer, must be used. In humans, death occurs at 28-26° C., probably owing to respiratory failure. Under the influence of drugs (anesthesia, alcohol) lower temperatures can be tolerated.

The purpose of treatment is to elevate body temperature. The old controversy between slow rewarming and rapid rewarming has not yet been resolved. In 1812, Baron de Larrey observed that victims of cold exposure often died when they were brought close to a campfire. At that time he improvised a slow-warming method in which the victims were rubbed with snow. On his authority this notion has persisted since that time, although its value has never been proved. It is not recommended.

In severe hypothermia, oxygen consumption and, therefore, heat production may be depressed to such a degree that spontaneous rewarming may be impossible or extremely slow. Extraneous heat may be applied by exposing the patient to room temperature, covered with blankets (slow

rewarming) or by immersing the patient in a warm bath (40° C.) (rapid rewarming). The dangers of immersing an unconscious patient in a bath are well recognized. In addition, the danger of rewarming shock may be increased. Sudden shock, during or at the end of the rewarming phase, is an ill-understood entity that carries a high mortality. It has been observed both in men and in animals. Slow rewarming is a time-consuming procedure which also carries a certain mortality. For many years animal experiments have been conducted to determine the optimal rewarming speed. The results obtained usually favour rapid rewarming. However, it must be recognized that these findings are not directly applicable to the situation under discussion. Almost all the experiments were carried out on animals under anesthesia, which alters the cold tolerance. The majority of the experiments were of short duration. Recent studies in our laboratory appear to confirm the previously expressed opinion that duration of hypothermia has to be considered as well as depth of hypothermia. Whereas, following a short period of hypothermia, the survival rate was improved by rapid rewarming, this difference could not be demonstrated following prolonged hypothermia.

Although this question must remain unanswered for the time being, the experimental findings may provide useful guidelines. Victims of severe hypothermia arriving at the emergency hospital are likely to have been hypothermic for a considerable time, and their condition is complicated by exhaustion. If it is accepted that these patients do not benefit from rapid rewarming, it will mean that facilities for immersion need not be provided at the third echelon.

DISCUSSION

Death due to cold exposure has been known for a long time, yet the condition is not discussed intensively in the medical literature. There are many references to cold exposure in the non-medical literature, but these deal mainly with local cold injuries. Death occurs when the temperature drops below a critical level. Death also occurs during the rewarming phase—so-called "rewarming shock". The nature of the rewarming shock has not definitely been established but it appears to be a real and dangerous entity.

Within the present state of our knowledge, it is difficult to make definite recommendations that are of value in practice. Available evidence indicates that, following a short period of hypothermia, rapid rewarming gives the best chances of survival. This implies that general

hypothermia is no contraindication to the treatment of frostbite by rapid thawing.

Following a long period of hypothermia, which inevitably is associated with exhaustion and starvation, slow rewarming may be just as efficacious. A high mortality rate must be expected with either method. In any event, the method of rewarming depends on the facilities available, and patients have to be carefully supervised whichever method is chosen. Experimentally, it is well established that the central organs should be warmed before the periphery. Various methods of applying diathermy or different types of waves to warm the deep-seated organs have been tried, but none are yet practical. Intravenous fluids should be used sparingly to avoid overloading a cold or cold-injured heart.

Drugs should only be given with care. Under hypothermia, whether drugs are given by mouth or by injection, absorption will be slow. In addition, since many drug effects are temperature-dependent, the effect of a particular drug is unpredictable. It is agreed, however, that a clear airway must be established and maintained. Since the immediate cause of death in hypothermia is respiratory failure, mouth-to-mouth respiration as a first-aid measure and respirator care in the hospital may be indicated in severe cases. The monitoring of the blood gases is useful under these circumstances. The majority of investigators recommend oxygen during the rewarming phase, for instance through a nasal catheter, while others have warned against the administration of pure oxygen. If cardiac arrhythmias persist, intravenous administration of procaine or quinidine is indicated. Ventricular tachycardia is a danger signal because it may be followed by ventricular fibrillation. Other drugs that have been used during recovery from accidental hypothermia include corticosteroids and thyroid hormone. As in other forms of starvation, the judicious use of intravenous glucose solutions is helpful. All intravenous solutions should be warmed to body temperature and given slowly, with due consideration of the risk of subsequent renal failure. There may be other

late complications. Clinical and experimental experience has shown that death may occur several days after normal body temperature has been reached. Bronchopneumonia has been described as a contributing factor in the death of these individuals; in others, the cause of death was unknown.

Finally, something should be said about prophylaxis of cold injuries. The necessity for adequate protection against cold is self-evident. Most measures of self-protection are matters of common sense, but it appears that, even with a slight fall in body temperature, some mental facilities are impaired and the victim may not use his common sense. Thus, patients left without supervision may take unnecessary risks.

SUMMARY AND CONCLUSIONS

The various changes produced by a lowering of the body temperature differ from patient to patient. Even the lowest temperature compatible with life is not uniform; it depends on a number of factors.

For these reasons and because in a major disaster the measurement of the rectal temperature is impractical, little consideration is given in this paper to the body temperature. From a practical standpoint the conscious hypothermia victim and the unconscious patient can be differentiated. In the former hypothermia is relatively mild and of short duration, while in the latter the temperature is lower for a longer period of time. Rewarming may spontaneously occur in both groups, but it is more likely in mild hypothermia. If the facilities are available, rapid rewarming in a water bath is the treatment of choice in the mild cases. The value of rapid rewarming in the severe cases is questionable, but it does not appear to be contraindicated. All patients need close supervision until the normal body temperature is reached and probably for some time thereafter.

REFERENCES

1. WEBSTER, D. R. AND BIGELOW, W. G.: *Canad. Med. Ass. J.*, **67**: 534, 1952.
2. ZINGG, W. AND HILDES, J. A.: *Ibid.*, **87**: 1196, 1962.
3. ZINGG, W.: *Med. Serv. J. Canada*, **22**: 399, 1966.
4. MCCANCE, R. A. et al.: *Med. Res. Counc. Spec. Rep. (London)*, No. 291: 1, 1956.
5. MOLNAR, G. W.: *J. A. M. A.*, **131**: 1046, 1946.
6. KILLIAIN, H.: *Der Kaelte-Unfall. Allgemeine Unterkuehlung*. Dustril Verlag, Muenchen-Deisenhofen, 1966.
7. PUGH, L. G. C. E.: *Brit. Med. J.*, **1**: 123, 1966.