COLD SURVIVAL

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The basic consideration in survival in Scotland whether under mountain or water conditions is the same, an inability to maintain the body temperature. This occurs where the losses of heat are greater than the heat produced by body energy (metabolism). With cold water immersion or wet through clothing, a low temperature and a high wind velocity on mountains, this can occur even at high levels of activity, but usually danger only occurs when body energy production falls with the onset of physical exhaustion. Therefore, exposure is now more correctly referred to as the exhaustion/exposure syndrome. The main danger with a fall in body temperature (hypothermia) accompanying exhaustion/exposure is its insidious onset, for patients do not collapse until their body temperature has already dropped about 5° C and is over half way to the level at which death usually occurs. The methods of heat loss by the body are by conduction, convection, radiation and evaporation. All of these are minimised principally by clothing in cold environments and are increased by lowering of the temperature of surroundings, the velocity of the air or water and soaking or water-logging of clothing. Death from hypothermia usually occurs when body temperature falls to between 26 and 30° C (normal 37° C) and is commonly due to arrest of the circulation.

In addition to hypothermia other factors must be considered. For water immersion these are:

- (a) Heart irregularities due to "shock" and fear
- (b) Respiratory difficulty due to cold

For mountain exhaustion/exposure these are:

- (a) Loss of water and salt from the body
- (b) Heart irregularities due to fear
- (c) Frost bite and trench foot
- (d) Snow blindness

Prevention and first aid measures should be based on an adequate appreciation of the factors in cold exposure which are potentially lethal and the normal body and other mechanisms used to combat them.

"Exposure" - its Cause, Prevention and Emergency First Aid

The classification of the Scottish Highlands for mountaineering is 'sub-arctic', and the only serious disagreement with this is as to whether it is too lenient: for much of the year, between October and March, the

conditions above 3,000 ft are as severe as any experienced under polar conditions. This is shown by the annual toll of life and injury necessitating calling out mountain rescue teams. With more people taking part in outdoor activities and ease of access to high ground provided by ski lifts, this source of death and hospital treatment is likely to increase. The major problem about which something can be done is the general group of conditions known as 'exposure': for these are the most common cause of death, more so than climbing accidents, and can be prevented or minimised by adequate knowledge and precautions.

'Exposure' is not a single entity and in considering the effects of the environment on the individual in the Scottish mountains four separate conditions must be recognised:—

Local effects

- (a) Sunburn and snow blindness
- (b) Frost bite and trench foot

General effects

- (c) Dehydration and salt depletion
- (d) Exhaustion/exposure (Hypothermia)

All of these are related to a breakdown in the physiological processes by which the body temperature is kept at a constant level of 98.4° F (37° C) and before considering the abnormal factors in exposure states the general body temperature regulating mechanisms will be reviewed.

Body Temperature Regulation

The body is continually producing heat and losing heat, and if body temperature is to remain constant these two must be equal, any difference will give rise either to a rise in body temperature (hyperthermia) or a fall (hypothermia). In simple mathematical terms this can be represented as:—

Body heat production =

Body heat loss + Change in body temperature.

This can be further expanded by defining the sources of heat production and heat loss. There is only one factor affecting heat production - the release of energy by body metabolism.

Three physical methods exist for heat loss

- (a) Conduction and convection
- (b) Radiation
- (c) Evaporation

but only evaporation will always produce loss of heat: conduction, convection and radiation can serve to raise the temperature of the body under certain conditions. Therefore our original heat balance equations may be expanded to:—

$$M = E \pm C \pm R + t.$$

(*M = Metabolic heat: E = Evaporation: C = Conduction and Convection: R = Radiation: t = Change in Body Temperature*).

Metabolism

When one considers a human in an environmental temperature below 28° C (82° F) the only source of body heat gain is by metabolism. This is produced by the various energy processes and consists of a basal component necessary for essential body functions, such as breathing and blood circulation, and an activity portion, the result of voluntary muscle activity under normal circumstances. When a person is inactive and the basal metabolism is insufficient to maintain body temperature the additional heat is produced involuntarily by the muscles as shivering. Whatever the source of the activity component of the body heat production it requires both the various food substances to act as energy sources, such as glucose and fatty acids, and also the body chemicals necessary in the energy production reactions, such as ATP (Adenosine triphosphate) and creatine phosphate. Unless both types of these essential substances are present in adequate amounts the body is chemically incapable of sufficient heat production. Physical exhaustion can be characterised by depletion of the components in the energy process, resulting in inability to maintain activity heat production. With this knowledge it is not surprising that in the majority of cases of 'exposure' physical exhaustion has proceeded or accompanied the more obvious hypothermia, so that it is now more common medically to talk of the 'exhaustion/exposure syndrome' rather than simply of 'exposure'.

Conduction and Convection

By conduction we mean the direct transfer of heat from the body to another material with which it is in contact. The rate of heat transfer will depend on:—

- (a) The temperature difference
- (b) The conductivity of the material (i.e. the rate at which it will conduct heat)
- (c) The area of contact

Convection refers to the same process with air which is not trapped, for hot air rises and is replaced by colder

air. Thus in convective heat loss the layer of air with which conduction of heat from the skin or clothing is occurring is continually replaced. As air must move for convective loss a further factor must be added to those for conduction:—

- (d) Wind speed

Water has a relatively high conductivity, as do many man made materials, but both wool and air have a very low conductivity. Because of this, clothing to give adequate insulation should be designed to trap air under an impervious layer, and the material trapping air should also have a low conductivity. This is the rationale of string vests and loose knit sweaters; but they must always have a wind-proof layer over them if they are to be effective. The heat loss due to conduction is immediately increased should the clothing become wet and convective losses from the surface may also be increased. It should be borne in mind that clothing can become wet not only by weather conditions or immersion, but also by sweating.

Radiation

In addition to visible light the radiation beyond both extremes of visibility must be considered. Those of short wave length are the ultra-violet, and those of long wave length the infra-red. Although only the infra-red is concerned with heat losses, the ultra-violet is also of importance to mountaineers. Ultra-violet rays are those responsible for sunburn and for snow blindness. Although the winter sunlight is weak, at altitude little ultra-violet light is filtered out, as it is under city conditions, and where there is snow cover there is additional danger from reflected ultra-violet. This gives sunburn in unsuspected sites, such as under the eyebrows and is probably a major source of radiation causing snow blindness.

Infra-red rays are radiant heat and transfer heat directly between surfaces with little loss to the intervening air. The factors governing radiant heat exchange are:—

- (a) The temperature of the surfaces (this is governed not by a simple temperature difference law but by a law of physics known as Henry's Law).
- (b) The emissive (absorptive) power of the surfaces.
- (c) The area available for radiant heat exchange.

The human skin, of whatever race or pigmentation, is both a good absorber and a good emitter of radiant heat, being over 98% efficient at both. This is important for heat loss in a cold environment where considerable heat loss can result from any exposed skin and particular care must be taken over protecting the head which constitutes 9% of the body area. With good trapped air insulation by dry clothing radiant heat losses from the

outer surface of the clothing is of little importance, but when clothing is wet or inadequate radiant heat losses can be considerable. As infra-red is not within the visible range the colour of clothing is not a good guide to the emissive power and the latter is related more to the nature of the material. Fortunately, man-made fibres such as nylon and terylene are poor emitters and most outer garments such as kagoules are made of poor emitters.

It will be noticed in the heat balance equation that losses due to conduction, convection and radiation can be either positive or negative. A negative heat loss means that the body will gain heat from the environment, and as all these methods of loss are dependent on the temperature difference between the skin and the environment, the change from heat loss to heat gain will occur when the environmental temperature in contact with the skin is equal to the skin temperature: this point is usually in the region of 32°C . At environmental temperature below 28°C adjustments to body heat loss are almost entirely made by altering skin blood flow: thus affecting conduction, convection and radiation losses, and this region is referred to as the zone of vasomotor regulation. Between an environmental temperature of 28°C and 32°C the heat loss by conduction, convection and radiation is less than heat production by metabolism, and as has been stated, above 32°C the body would gain heat if another method of heat loss were not available. This is the third method, evaporation heat loss, and is always a source of loss of heat.

Evaporation

When any liquid evaporates it absorbs heat; this can be easily demonstrated by putting a volatile liquid such as surgical spirit on the skin and noticing the cold sensation produced. The body loses heat by the evaporation of water, to a small extent in the air we breathe out, but mainly from the skin. At low environmental temperatures we lose very little heat by this method, but when the skin temperature rises above a certain level we increase evaporative loss by starting to sweat, the specialised sweat glands secreting a dilute solution of salt and water.

Above an environmental temperature of $28 - 32^{\circ}\text{C}$ the body relies almost entirely upon evaporative loss to keep body temperature constant, and this is known as the zone of evaporative regulation. Sweating will only produce a heat loss if the sweat does evaporate; sweat which drips off or is absorbed by clothing produces no loss of heat to the body, but does represent a loss of water and salt. The factors which affect evaporative heat loss are:—

- (a) *The skin temperature.* It should be noted that in contrast to other methods of heat loss the

temperature difference between the skin and the environment is not a factor.

- (b) *The relative humidity of the air.* At any temperature air can only hold a certain amount of water as vapour, the more saturated the air the more difficult it is for sweat to evaporate. The latter is important in mountaineering for the air to be considered is that trapped in the clothing, when the clothing is dry.
- (c) *Air velocity.* This governs the rate at which water vapour is removed from proximity to the body and replaces it with air with a lesser percentage saturation. This is important in mountaineering when considering a person with wet clothing.

The precise physiological mechanisms by which changes are mediated are not important, for it is the factors in the environment which can be affected in the prevention or the treatment of exposure states.

Having considered the normal factors governing heat regulation the four types of mountain 'exposure' will be considered in turn and their prevention and treatment discussed.

(a) Sunburn and Snow Blindness

These are both the result of ultra-violet radiation. At altitude they are always a risk because although the sun may be weak, or even obscured by thin cloud, there is much less filtering out of ultra-violet than under urban conditions. If there is complete or extensive snow cover the risk is much increased, because reflected as well as direct ultra-violet must be considered, and sunburn will then affect areas of skin which face downwards, rather than the more usual areas of brow and nose. Prevention of snow blindness is by wearing glasses or goggles, and these should be chosen for their ultra-violet filtering ability rather than being simply darkened glass or plastic. When protective glasses are not worn the first signs of danger are a complaint of brightness or of paleness of colours, later spotting of vision and blurred vision occur leading eventually to complete blindness. Except in extreme cases recovery is likely eventually. In the Scottish mountains, when the signs of snow blindness begin to appear the best treatment is to protect the patient's eyes, possibly by using goggles or glasses from another member of the party, and getting on to ground where there is not continuous snow cover ahead. When mountain rescue is being carried out care should be taken that a patient being carried face up does not develop damage from direct ultra-violet, and on a long rescue in daylight when there is other than thick cloud cover the eyes should be protected preferably by goggles, or failing that by a scarf, cloth or bandage.

(b) Frost Bite and Trench Foot

These are due to the local effects of hypothermia, but

whereas frost bite is due to a below zero environmental temperature, usually on exposed tissues or on areas where the insulation of clothing is inadequate, trench foot can occur in temperatures up to 10°C provided the area is chilled by a good conductor, usually water. The danger of both these conditions is their insidious onset, for hypothermia blocks the passage of pain impulses by nerves, and they are therefore, not associated with pain. Tissue hypothermia does not necessarily result in cell death until the temperature of the tissue falls below -4°C when water begins to crystallise out as ice, and there is considerable evidence that in many instances potentially saveable tissue is damaged by over-vigorous attempts at first aid. However, when either frost bite or trench foot persists for any length of time, changes occur in the walls of the blood capillaries so that irreversible impairment of the local circulation takes place with cell death.

The first requirement in prevention is adequate clothing. Particular care should be paid to the protection afforded to feet, hands and ears. With feet the two chief dangers are insufficient insulation between the sole of the foot and the ground, and water soaking inside the boot. A subsidiary cause of trouble is pressure giving rise to local interference with blood flow either by incorrect fitting or too tight lacing. Leather or Vibron in the thickness used in most boots are only moderate insulators and for adequate insulation a layer of trapped air is also advisable: this can be either built into the boots, as with the case of the uppers of good mountain boots, or can be in the form of a good cellular insole. Where an insole is used it should not collapse readily under pressure or the insulating effect will be lost over the main weight bearing areas of the heel and the ball of the foot. In addition to the insulation of the boot, with or without an insole further insulation should be obtained by wearing thick socks of wool or a wool and man made fibre mixture; nylon or terylene by themselves are not adequate. Provided adequate boots are worn the only place that water can penetrate is over the top. The main danger is not of complete immersion, but of snow thawing and penetrating down the socks by a wick effect; this can be prevented by the use of waterproof leggings. Good puttees are also of use; but are not so satisfactory.

The problems with hands are again those of insulation and water-proofing, and again trapped air is the agent of choice for insulation. To minimise the area available for surface loss, mittens, rather than gloves, should be worn and they should be waterproof as well as insulating: fleece or fur will give adequate insulation. Where the hands are likely to be used with fine movement a pair of work gloves should be worn inside the mittens and care taken that the gloves do not become wet during use, if the latter occurs the gloves should be removed before the hands are replaced in the mittens. Some protection

must be on the hands when touching good conductors such as metal when they are at about 0°C or lower.

The ears, and indeed the whole head, are often neglected when it comes to adequate insulation. Most anoraks and even some parkas have wind-proofing and waterproofing without insulation of the hood, and often further protection by a woollen hat covering the ears should be worn.

Assuming adequate clothing is worn the prevention of both these complications is either by the leader being responsible for checking all members of the party at regular intervals, usually at each halt, or with more experienced parties, by pairing the members, each being responsible for the other. The drill is to check for numbness of exposed areas of skin, particularly ears, nose and cheeks, and of the extremities, that is fingers and toes.

(c) Water and Salt Depletion

Excessive loss of water and sodium (salt) as a result of sweating is usually associated with a hot environment and the clinical syndrome of heat exhaustion. Such a state can also arise in a cold environment, and can in this situation be more dangerous because of ignorance of or delay in recognising its occurrence. As was mentioned in the basic heat balance equation where metabolic heat production is not balanced predominantly by conduction, convection and radiation losses, body core temperature is only maintained (i.e. prevented from rising) by the evaporative loss of sweating. When a person is adequately clothed for a mountain environment in Scotland, conduction, convection and radiation losses are minimised, principally by the insulation of entrapped air. Because of this, if metabolic heat production is much increased by severe exercise, the rate of conduction of heat from the skin to the outer surface of the clothes often is not sufficient to prevent a rise of skin temperature above that at which active sweating commences. For sweating to result in heat loss it must evaporate; initially this will occur until the entrapped air becomes saturated, but thereafter unless water vapour can escape from the clothing, further sweat will not evaporate but be absorbed by the clothing resulting in a loss of water and salt without a loss of heat. For the latter not to occur either the outer garments, although preventing soaking from external conditions, must allow outward passage of water vapour, or some method must exist for escape of water vapour in openings in the outer clothing. The former possibility is used with some of the new 'ventilatory' fabrics, but these are expensive and are a long way from being in general use for mountaineering. The latter solution is the one usually adopted; the majority of anoraks are only showerproof and will allow outward passage of water vapour. Where complete waterproofing is required a

Kagoule is worn and this should be loose fitting around the body so that the water vapour escapes by convection between it and the other clothing. It is useful when exerting oneself to remember that hot air even when saturated with water, tends to rise, so, unless it is raining, loosening of clothing around the neck greatly assists in evaporative regulation of body temperature. In the untrained individual the efficiency of body movement is less than in the trained and therefore the metabolic heat production for a given task is increased; it is therefore the less experienced members of parties who are liable to excessive fluid and salt losses, although the levels of exercise involved may not be severe enough to produce physical exhaustion or discomfort. If adequate fluid is carried and drunk, but without salt replacement, salt depletion, similar to that seen in foundry or furnace workers, can occur, the most common symptom being muscle cramps. These can progress to the stage of disabling the sufferer from further activity. In addition to the more obvious cramps, salt depletion also leads to muscle weakness, again reducing the sufferer's ability to reach assistance. Treatment is by giving salt and fluid, and the best first aid item for this is a self-heating can of soup, as this is far more palatable than either salt tablets or salt water. Prevention is by carrying adequate food with contained or added salt; bars of chocolate and a water bottle are quite inadequate by themselves. Where water is not carried or obtained a far more serious situation with water and salt loss may result. The loss of water leads to concentration of the blood with a reduced circulation. The clinical picture is the same as heat exhaustion, the sufferer showing collapse and weakness with a dry mouth and tongue, sunken eyes and a weak thready pulse; even in a cold environment the body temperature may be raised. Both salt and water must be given as treatment, for if water alone is given the salt depletion is made worse. Again soup is probably the most efficient first aid measure before skilled assistance is available. In practice this situation should never arise for it means both that the sufferer has been pushed beyond his capability and training, and that the individual or group has left inadequately equipped in terms of food and fluid. Even where safe water from burns is expected it is always wise to carry some form of fluid, and food carried should always contain salt and not just be judged in terms of readily available calories (energy).

(d)Exhaustion/Exposure (Hypothermia)

Although the last of the clinical states produced by mountain exposure usually comes under most consideration because it is the one which is lethal, the previous three conditions should be considered of equal importance for they can be the precipitating factor which leads to death from hypothermia. From the basic heat balance equation it is apparent that body cooling or hypothermia will only occur when the body heat losses

are greater than the metabolic heat production. Under most circumstances and with dry clothing, it is possible to balance an increased heat loss by an increase in body activity or by shivering: indeed, as was shown in the previous section, at high levels of activity, even in severe mountain conditions, heat losses to match the metabolic heat may present a problem. Therefore, in the majority of persons in whom hypothermia occurs, the ability to produce metabolic heat must first be reduced, that is he must be exhausted. The most important factor which will give rise to increased heat loss is loss of the insulation of trapped air in clothing, and this normally means water soaking: if the wind velocity is high this will give not only more conduction to the surface, but also to greater evaporative heat loss from the surface.

When the body temperature begins to fall from the normal level of 37 - 38° C, there is at first little obviously wrong with the sufferer. They become slower and tend to lag, and there is loss of concentration or even a euphoric, light-hearted attitude, but serious symptoms with collapse and loss of consciousness do not occur until the body temperature has dropped to about 32 - 34° C. Only slightly below this temperature irregular heart beats begin to occur and death from heart failure occurs in most cases at a body temperature only a few degrees below 30° C. Thus the margin between collapse and death is small, and it is important for survival that, as far as possible, cases should be diagnosed and first aid treatment started before collapse and loss of consciousness occurs.

There are two main types of preventive measures: those against exhaustion and those against heat loss. The prevention of exhaustion is largely a question of adequate planning and route selection. The idea of "pushing people to the limit" as being "good for character development" borders on the suicidal in the Scottish mountains. Adequate escape routes must be planned on all expeditions and the decision to take individuals to shelter should be taken when signs of exhaustion with a tendency to lag behind first appear. The other exposure states of snow blindness, frost bite and dehydration must be guarded against and looked for, as they will all impair performance and may precipitate exhaustion. Adequate water, salt and sources of calories must be carried and regular rests in shelter should be taken. The prevention of excessive heat loss is a question of adequate clothing. All types of heat loss are a function of the area available for heat exchange; although most persons have adequate protection over the trunk, it is forgotten that this constitutes only 36% of the body area and that the legs are also 36% and the head nearly 10%. Therefore, adequate woollen trousers and "long-john" underpants are required, the jeans worn by many walkers being quite inadequate, and as has been stated, when considering frost bite the head should be

properly protected. Waterlogging of clothing either from without or within must, as far as possible, be protected, and this means waterproof outer garments, either of a ventilatory fabric or over-trousers and a Kagoule.

If hypothermia becomes established and a person in a party begins to show signs of collapse, treatment should be immediate. It is allowable to move the patient a short distance, if by this either good shelter or a considerable loss of altitude can be achieved: otherwise all cases should be treated where they occur. At the same time as treatment is started help must be sent for. The immediate first aid measure is to prevent further heat loss, and this means placing the patient first in a sleeping bag and then in a thick polythene survival bag. The place chosen should, as far as possible, be shielded from the wind and the head, as well as the rest of the body, should be covered. Fluid, sugar and salt may be given, but alcohol should never be given. Many persons with hypothermia will continue to lose body heat despite these measures and some method of body heating may be required. In the survival situation this is best provided by another body, and a fit member of the party should be put in the bag with the patient. When mountain-rescue assistance arrives the first aid measures are the same as should already have been started and the rescuers will attempt to remove the patient to hospital as rapidly as is consistent with safety. The only additional resuscitative measures which may be employed are the giving of water and salt by intravenous

drip and the new method of body heating being examined of heating the air breathed in. If a person suffering from exhaustion/exposure is got to habitation they can be placed in a hot bath, but careful watching is required, as too rapid heating can be dangerous.

If hypothermia is diagnosed as early as possible and the correct first aid measures instituted on the spot, the chances of survival are very good; if, on the other hand, the party tries to press on and get the sufferer to walk to habitation and treatment, the risk of death is high

Conclusions

The Scottish mountains offer unrivalled facilities for physical exercise, but they must be treated with respect and the sub-arctic nature of the climate recognised.

The complications of mountain exposure should be guarded against by adequate planning before any expedition, knowledge of the capabilities and limitations of the members of the party, and experienced mountain leadership during the expedition.

Diagnosis and treatment of the complications of mountain exposure when these occur should be early and prompt. Any attempt to walk out to help rather than treatment on the spot is likely to result in further complication and maybe death.

ANNOTATION

BLOOD GLUCOSE MEASUREMENTS IN FIELD TRIALS

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Blood sampling in the field presents many problems, such as site of sampling, size of sample, how to prepare the blood sample, the effect of storage and the analytical method.

In the light of our experiences, in many different sports situations, the procedure we have adopted to give maximal accuracy may be of interest.

1. Generally, finger incisions by sterile lancet are most satisfactory.
2. 0.1 ml blood is adequate.
3. Zinc uranyl acetate (0.16% w/v), ready prepared by Boehringer & Co. (URAC), is the most suitable

deproteinizing reagent.

4. Proteinaceous matter should be separated by centrifugation immediately after precipitation.

5. Storage of the deep-frozen supernatant leads to decreasing values and minimum storage is desirable. When comparisons are to be made, the time of storage should be standardised.

6. B-d-glucose, is determined by using an automated glucose oxidase-peroxide method.

By analysis of variance, 27 samples using this procedure, gave a standard deviation of ± 1.03 mg/100 ml within duplicates.