The Mountaineer at Extreme Altitude

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An increasing number of mountaineers now wish to climb the highest peaks in the world without supplementary oxygen, in small groups or alone, and sometimes in winter. This trend is accelerating and to prevent a high mortality several vital factors must be appreciated.

Oxygen lack and barometric pressure

The critical factor is barometric pressure. Oxygen lack at high altitude is due to the low pressure of oxygen in the atmosphere, and the pressure diminishes more the higher the climber goes. The barometric pressure determines the pressure of oxygen in the air, the lungs and finally in all the tissues and muscles, and this dictates the amount of exercise the mountaineer can take. At extreme altitude performance is exquisitely sensitive to even small changes of the pressure of the oxygen in the lungs, and oxygen pressure also determines heat production and mental performance.

Variation in atmospheric pressure

Considerable variations occur in the barometric pressure and therefore in the oxygen pressure in the body. At extreme altitude the most important is *seasonal change*. In summer the barometric pressure 'on the top of Everest' averages 255 Torr (mm Hg) (it was measured in 1981 and found to be 253 Torr), whilst in mid-winter it is 243 Torr. This means that on average the atmospheric pressure is 12 Torr (equivalent to a height loss of 300m) higher in summer. and for this reason alone Everest would then be easier to climb. In winter, because the pressure is lower, climbing at altitude will be more difficult and this will be as much a reason as low temperature and high winds for the paucity of winter ascents on peaks over 8000m without supplementary oxygen. Daily variation in pressure also occurs but the changes tend to be small.

Latitude also affects the barometric pressure. Everest lies relatively near the equator and as a result the barometric pressure for a given altitude is higher than it would be nearer the poles, as for instance on Mt McKinley in the Arctic. The reason for the high barometric pressure over the equator is that there is a large mass of cold air found in the troposphere. It seems that it is the relatively high barometric pressure on Everest, by virtue of its position near the equator, that makes it climbable without supplementary oxygen.

Oxygen pressure in the body

When air moves from the atmosphere to the depths of the lungs the oxygen pressure falls. A large fall in oxygen pressure occurs in the depths of the lungs where fresh air mixes with CO_2 which comes from cell function and which is removed when the individual breathes out. A slight fall occurs when oxygen diffuses through the walls of the lung into the blood vessels. In the tissues themselves there is a considerable fall, particularly if large quantities of oxygen are being used by working muscles.

Acclimatization to oxygen lack occurs at all levels in this chain, and its purpose is to deliver to the tissues as high a pressure of oxygen as possible. For instance, in the depths of the lung the fall in pressure is less and the actual pressure of oxygen is higher in the well-acclimatized, whilst in the unacclimatized the fall is greater and the oxygen pressure is lower. This particular adaptation takes about 20 days at 4000m.

Maximum oxygen uptake and delivery

Despite all efforts at acclimatization, the amount of oxygen delivered to the tissues is always less at altitude than at sea-level and there are other factors:

1. There is a limit to the amount of oxygen that diffuses through the lung to the vessels, and this is one key factor determining the amount of oxygen that gets to the cells. If there is any obstruction to the passage of oxygen, because of fluid in the lungs as occurs in infection or high-altitude pulmonary oedema, the patient becomes ill very quickly. Because the brain is so sensitive to oxygen lack, the first indication may be irrational behaviour – i.e. a lung condition may be present with mental symptoms which makes for confusion in diagnosis.

2. The heart does not function as well at extreme altitude as it does at sea-level, and when working at full stretch the amount of blood pumped each minute is less. In turn this means that less blood and therefore oxygen gets to the muscles.

3. Some people are able to breathe more deeply and rapidly than others, and this response to oxygen lack may well be important in attempting to identify those who can go high, but it is only one factor.

4. Oxygen that could be used for ascending may be squandered in fighting against the wind, slipping downhill on scree or soft snow, ploughing through powder snow or in many other ways. Efficiency of movement is of great importance in using available oxygen at extreme altitude.

5. Climbers normally go uphill continuously using about 50–60% of the maximum amount of oxygen that they can take in. To move continuously at great altitude means breathing more rapidly and more deeply, until at about 7400m, in order to move continuously, they would have to breathe maximally. It is impossible to breathe really maximally for more than about one minute, and so they have to move intermittently. Near the

top of Everest it is only possible to move continuously for very short distances, i.e. up to 30–40 steps at a time, and then rest is essential. It is like running a series of 100-yard races.

6. Whilst panting at this rate a considerable amount of both water and heat is lost from the lungs.

Cold

Whilst moving, the climber generates heat and keeps warm, but when he stops he will cool down. However, during the day radiation from the sun will keep him warm when stationary and indeed he may become so hot, even on the top of Everest, that he has to take off clothing to stop overheating. However, if the sky is overcast or after sunset, heat from radiation falls and he has to rely on heat from the muscles to keep him warm. If he is exhausted he may only be able to move slowly or not at all, heat production falls and he will cool rapidly even if fully clothed.

As he begins to cool, the blood supply to the extremities is cut off by constriction of the peripheral skin vessels. As the temperature continues to fall, shunts between the arteries and veins which are normally closed open up so that warm arterial blood is diverted to the veins without going to the skin vessels. This is a protective mechanism because it means that cold blood does not return to the brain and cool the cells in the brain concerned with regulation of the temperature for, if it did, the core temperature of the body would fall rapidly. However, because of this mechanism the skin is deprived of warm blood, cools rapidly and, if the air temperature is below freezing, it will freeze and become gangrenous (frostbite). It must be stressed that this can occur despite adequate clothing. In effect, the hands and feet are being sacrificed for the good of the whole. If the core temperature continues to fall despite this protective mechanism, hypothermia occurs.

It is likely that mountaineers who 'die from exhaustion' in fact do so from hypothermia, when all body functions, including heart rate, slow down with a low central core temperature. An individual may therefore appear dead when he is not. Attempts at resuscitation should always be made and individuals warmed up even if they appear cold and dead.

Wind is very important and even in above-freezing temperatures exposed skin can be frozen and frostbitten because of a high wind – the 'wind-chill effect'. A gale at below-zero temperatures may be so much of a hazard at extreme altitude that no movement outside the shelter of a tent or snow-hole is possible.

Dehydration

Some degree of dehydration appears inevitable at extreme altitude owing, in the main, to water loss from the lungs, the result of overbreathing. The mountaineer too may not feel that he is sweating because of the rapid evaporation of sweat in the dry air, whereas, in fact, he is losing a considerable amount of fluid.

The sensation of thirst also is blunted and, if to these factors is added the practical difficulty of melting snow, then it is not surprising that fluid replacement is inadequate.

As dehydration increases blood becomes thicker and more viscous. This is accentuated by the increase in red cells, which is an important factor in acclimatization. The tendency of the blood to clot is increased and strokes have occurred in fit young men at moderate altitude.

The extent to which dehydration occurs is still underestimated, and it may be extremely severe. Mountaineers who have been for even a few days at extreme altitude can look emaciated, but recover in a few hours after drinking a lot of water. The importance of fluid is emphasized by the fact that individuals can live for only six days without water, whereas without food they live for six weeks.

Food

Poor appetite, and difficulties in preparation which are inevitable at extreme altitude, can result in a considerable calorie deficit. Food must be easy to prepare, palatable at altitude, and of good calorie value. This combination seems from experience to be almost impossible to achieve. On pre-war Everest expeditions great trouble was taken with buying tasty food, and the food halls of Harrods and Fortnum and Mason were favourite shopping places. Now the local supermarket can provide pretty well all that is necessary. As a general rule, fresh food is always more palatable than processed food, and for the few days at extreme altitude high calorie fluids and foods should be taken, but tested at sea-level, as they can cause diarrhoea.

Brain function

Mountaineers still do not appreciate fully the effect of oxygen lack on the brain. Even at 1500m some minimal changes occur to vision. The higher centres that are concerned with reasoning and memory are the first affected, and acts that require innovation tend to be less well carried out than those that are well rehearsed. The history of high-altitude mountaineering is redolent with glaring examples of impaired judgement where wrong decisions have been fatal. Fixity of purpose is another feature of oxygen lack and, when allied to an obsessive desire to complete an ascent, may be lethal. At extreme altitude the climber is at the limits of tolerance to oxygen lack and mental function is greatly depressed. Oxygen lack not only stops the works but it wrecks the machinery, and this is as obvious in high-altitude mountaineering as it is in medicine and anaesthesia.

Drugs

Drugs are increasingly used by mountaineers, and all have some side effects; as a general rule, the fit and well-acclimatized do not need them to improve performance. In addition, the effect of drugs on an individual at sea-level may not be the same as at altitude. Antibiotics, too, can produce unpleasant side

effects such as diarrhoea, kidney damage and skin complaints.

Aspirin is a mild pain-killer and decreases the liability of blood to clot, but it can also cause irritation of the mucous lining of the stomach and severe bleeding may occur with blood being vomited up.

Diamox (acetazolimide) increases the excretion of urine but it also acts mainly as a stimulus to respiration and the evidence for its preventing acute mountain sickness is good. It is a safe drug and its side effects, tingling of the fingers and toes, are not serious. It is being used more often as climbers can fly to quite high areas now before setting up camp.

Dexamethasone, a steroid, has recently been shown to decrease symptoms of severe mountain sickness and its use has enabled individuals to descend by their own efforts.

Non-steroidal anti-inflammatory agents, like Ibrufen, have also been used with success for altitude headache.

Adequate vitamins are available in fresh food and there is no evidence that deficiency occurs on an expedition of normal length.

Dilution of the blood has been advocated to counteract vascular episodes and decrease the work of the heart in pushing thick blood around the vessels, but again there is no evidence that this is beneficial and there are dangers.

At extreme altitude the relentless combination of oxygen lack, cold, dehydration, starvation and mental torpor can lead easily to exhaustion and death. The main chances of success and survival lie in thoroughly understanding the hazards to the mind and body together with the dangers of the environment, and learning how these interact. Survival depends on being fit and well acclimatized and appreciating how lethal extreme altitude can be. Here the mountaineer is on a biological knife-edge and the 'death zone' is well named.