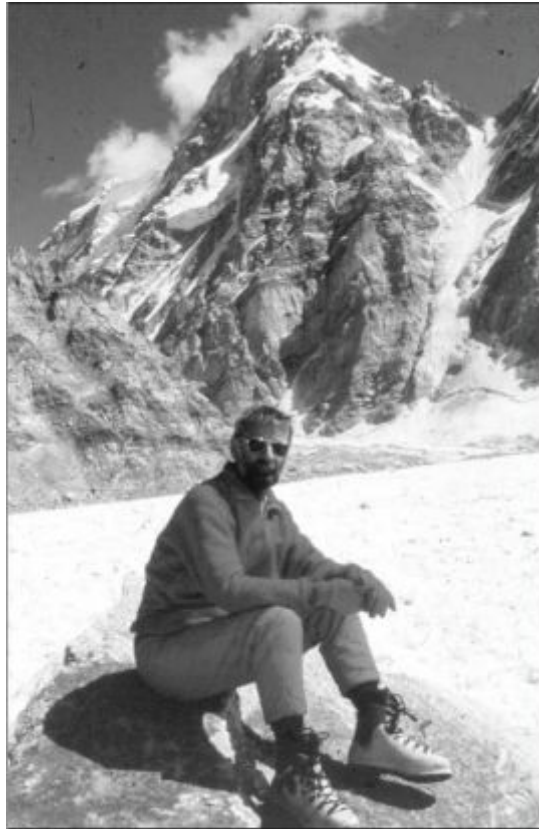


High Altitude Illness

Mike Townend



High altitude problems are often thought as being of interest mainly to climbers, but other groups of travellers may well be exposed to high altitude. Trekkers may reach altitudes of 5000m or more and package tourists, especially those travelling to destinations such as parts of South America, Nepal and Tibet may easily experience altitudes of 3-4000m or more. Business travellers may also find themselves at high altitude destinations.

Why are there problems?

Altitude problems are caused by hypoxia. There is just as much oxygen in the air at high altitude as there is at sea level but atmospheric pressure becomes lower as altitude increases. As a result the pressure driving oxygen from the alveoli into the blood is lower and the level of oxygenation falls.

Altitude definitions

Intermediate altitude is defined as altitudes of 1500-2500m. Arterial oxygen saturation at such altitudes is 90% or more.

High altitude is defined as altitudes of 2500-3500m. Altitude problems occur on rapid ascent at these altitudes

Very high altitude is defined as altitudes of 3500-5800m. Arterial oxygen saturation is less than 90%. Hypoxia occurs on exertion and altitude problems are common.

Extreme altitude is defined as altitudes of over 5800m. Here hypoxia occurs at rest. Further acclimatisation is not possible and it is impossible to survive indefinitely.

Acclimatisation to altitude

With increasing altitude there is an increase in pulmonary ventilation which leads to hypocapnia. This in turn leads to respiratory alkalosis, causing increased renal excretion of bicarbonate.

There is an initial increase in heart rate which is later followed by a gradual reduction in resting heart rate with acclimatisation, at least up to extreme altitude. At extreme altitude the resting heart approaches maximal heart rate

increased erythropoietin secretion leads to increased red blood cell production. This results in an increased haematocrit & haemoglobin concentration and increased blood viscosity

Limits of acclimatisation

Up to about 5500m acclimatisation is possible. it is no coincidence that there is no permanent human habitation above 5500m. Above 5500-5800m (extreme altitude) there is no further increase in acclimatisation. With increasing altitude above this level there is an increasing tendency to physical and mental deterioration due to chronic hypoxia, and above 8000m survival is not possible if exposure is prolonged.

Acute mountain sickness (AMS)

AMS is essentially a benign condition, but if ignored may progress to more severe altitude illness.

Incidence of acute mountain sickness

Studies have given various figures for the incidence of AMS depending on the altitude and the rate of ascent.

Table 1

<i>Altitude & site of study</i>	<i>Incidence of AMS</i>
3050m (Switzerland)	13%
3650m (Switzerland)	34%
4243m (Nepal)	43-53%
5400m (Nepal)	63%
6195m (Alaska)	30%
Trekking in Everest region	23-47%

Symptoms of AMS

Symptoms of AMS include headache, dizziness, anorexia, nausea, vomiting, lethargy and sleep disturbance. Peripheral oedema may occur and periodic breathing, especially during sleep, frequently occurs.

Causes of AMS

AMS may occur at altitudes above 2,500-3,000m, (8-10,000ft). it is a sign of lack of acclimatisation associated with too rapid ascent, for the individual concerned. Each individual has his or her own capacity for acclimatisation and what is a suitable rate of ascent for one person may be too rapid for another. This may be a problem for groups with a fixed itinerary, for example commercially organised trekking groups. Over-exertion before becoming fully acclimatised also predisposes to the development of AMS and travellers going to high altitude should be advised to "take it easy", on arrival until they are acclimatised. Dehydration probably predisposes to AMS but the evidence for this is not strong. in any event, an increased fluid intake is needed at high altitude as there an increase in fluid loss, especially from the respiratory tract, because of the low partial pressure of water vapour in the atmosphere as altitude increases. Youth and fitness offer no protection against AMS and older people may acclimatise better. This may well be because younger people are more prone to over-exert themselves whilst older people are more likely to pace themselves. Constitutional or genetic factors may be involved in making some individuals more susceptible to AMS.

Mechanisms of AMS

Hypoxia causes an increase in cerebral blood flow whilst hypocapnia decreases cerebral blood flow. At high altitude the effect of hypoxia predominates. Hypoxia also results in damage to capillary endothelium which causes the capillary walls to become more permeable. In addition sodium & water retention occur due to a variety of physiological processes including the renin/angiotensin mechanism and atrial natriuretic peptide. There is also an intracellular to extracellular fluid shift. All these changes lead to a slight increase in intracranial pressure which is thought to be the mechanism producing the symptoms of AMS. Retinal haemorrhages also occur but they are usually symptomless and of little clinical significance.

Prevention of AMS

The best method of prevention is acclimatisation following the "rules of three".

Box 1
<i>The "rules of three"</i>
Above 3,000 metres
Ascend no more than 300 metres/day
Rest at same altitude every 3 days

There is little evidence to support the "rules of three" but as empirical rules they appear to represent a safe rate of ascent for most people and may be exceeded by some without harm. An often quoted policy is to "climb high and sleep low", i.e. limit the gain in sleeping altitude as above but climb higher than this during the day. It is the change in sleeping altitude that is critical and not height gained and lost again during the day.

Acetazolamide (Diamox) assists the process of acclimatisation. It does not simply obscure the symptoms of AMS as is sometimes claimed. It is a carbonic anhydrase inhibitor which causes a bicarbonate diuresis, leading to an imbalance in the carbonic acid/bicarbonate buffer system. This requires increased excretion of carbonic acid, which is achieved by increasing pulmonary ventilation and thereby increasing the excretion of carbon dioxide. This increase in ventilation has the effect of increasing oxygenation and therefore reducing the degree of hypoxia and reducing the likelihood of the development of AMS. Acetazolamide may be taken prophylactically, especially if the lie of the land precludes a safe rate of ascent, if flying from low altitude into a high altitude airport with no opportunity to acclimatise gradually, or if acclimatisation has been poor on previous exposure to high altitude in spite of taking reasonable pre-cautions. See Table 2 for dosage.

Treatment of AMS

Resting at same altitude with no further height gain will lead to the resolution of symptoms of AMS in most cases. Acetazolamide may be used to treat established symptoms as well as for prophylaxis. Dexamethasone may also be used (see Table 2 for dosage of both drugs). If symptoms persist or become worse in spite of resting at the same altitude, descent of at least 300 metres will usually be successful and may then be followed by cautious re-ascent.

High altitude pulmonary oedema (HAPE)

Whilst AMS is a benign condition which resolves if acclimatisation is allowed to proceed at a rate suitable for the individual concerned, HAPE is a serious and potentially life-threatening condition demanding urgent action.

Incidence of HAPE

HAPE is more likely to occur at very high altitude, in excess of 3,500 metres. Estimates of its incidence are usually in the region of 1-2% of travellers to such altitudes.

Symptoms of HAPE

Symptoms include breathlessness (especially at rest), cough and frothy white sputum which may become pink or bloodstained. Widespread scattered moist sounds may be heard on auscultation of the chest. Diagnosis may be difficult as breathlessness is the norm on exertion at high altitude and cough is also a common symptom due to the dryness of the air. Breathlessness on exertion which does not resolve following resting or breathlessness occurring at rest is highly suggestive of the development of HAPE.

Mechanisms of HAPE

Hypoxia leads to an increase in pulmonary artery pressure. Hypoxia also results in damage to capillary endothelium which causes the capillary walls to become more permeable. Some vascular channels in the lung become extremely constricted and there is therefore high pressure hyper-perfusion of remaining channels. In conjunction with increased capillary permeability this leads to scattered areas of extravasation of fluid into the alveoli. More recently the presence of free oxygen radicals in the lungs has been associated with cell membrane damage and increase capillary permeability. There has also been found to be a release of inflammatory mediators such as cytokines but this is thought to be a result rather than a cause of damage. Nitric oxide also plays a role in HAPE. It is a pulmonary vasodilator, and decreased production or bioavailability of nitric oxide is associated with a rise in pulmonary artery pressure.

Treatment of HAPE

The essential treatment of HAPE is descent to a higher atmospheric pressure. Descent should be as far as possible, as fast as possible, and preferably at least 300 metres. Other treatments are simply an adjunct to descent or buy time while descent is being arranged. Oxygen should be given if available. Nifedipine is useful in reducing pulmonary artery pressure (see Table 2 for dosage). The use of a pressurised bag such as the Gamow bag, into which the patient is sealed and which is then pressurised by means of a foot pump is useful to provide what is effectively a rise in atmospheric (and therefore oxygen) pressure. This should be regarded as a temporary measure and not a substitute for descent or a means of allowing further ascent, e.g. to allow the crossing of a mountain pass before descent on the other side. There is little evidence concerning the use of diuretics e.g. furosemide in the treatment of HAPE but, as dehydration is common at high altitude, their use is probably not advisable. More recently Sildenafil (Viagra) has been found to reduce pulmonary artery pressure (see Table 2 for dosage) and Salmeterol to reduce the incidence of HAPE when inhaled prophylactically.

Predisposition to HAPE

HAPE may occur as a "one-off" event and not recur on subsequent exposure to high altitude. In some individuals it does recur on subsequent re-exposure. There may be a constitutional or genetic predisposition in those who experience recurrence. Some individuals who develop HAPE have a low hypoxic ventilatory response (the reflex increase in ventilation in response to hypoxia) but it is not necessarily a good predictor of the occurrence of HAPE. It has been suggested that those who have suffered perinatal hypoxia are more prone to develop raised pulmonary artery pressure when exposed to hypoxia later in life and that this could be one of the predisposing factors for the development of HAPE.

Re-ascent after HAPE

There are documented cases of individuals who have shown symptoms of HAPE on re-ascent, either during the same trip after a period of descent to allow resolution of symptoms, or on subsequent trips. Some of these individuals experience recurrence on each subsequent exposure to altitude and some do not. The important question for the future is whether the "repeat offenders" are the same individuals who have a constitutional predisposition and if so whether it will be possible to predict susceptibility to HAPE before travel to high altitude if the appropriate characteristics can be identified.

Prevention of HAPE

As for AMS, careful acclimatisation is necessary, but HAPE may occur without previous warning signs of AMS.

High altitude cerebral oedema (HACE)

Like HAPE, HACE is a serious and potentially life-threatening condition demanding urgent action.

Incidence of HACE

HACE is more likely to occur at very high altitude, in excess of 3,500 metres. Estimates of its incidence are usually in the region of 1-2% of travellers to such altitudes.

Symptoms of HACE

Symptoms include severe headache, irrational behaviour, errors of judgement, hallucinations, ataxia and apathy. Later, convulsions and loss of consciousness may occur. These, together with abnormal neurological signs such as extensor plantar response, paresis or papilloedema, are bad prognostic signs and indicate imminent death. The condition may develop and progress extremely rapidly and early recognition is vital. Early indications may be subtle changes in behaviour or personality or a tendency to stumbling in a previously sure-footed individual.

Mechanisms of HACE

HACE is the result of similar mechanisms to those occurring in AMS, namely increased cerebral blood flow caused by hypoxia, increased capillary permeability caused by hypoxic damage to cerebral capillary endothelium, sodium & water retention and intracellular to extracellular fluid shift. All these changes lead to increased intracranial pressure

Treatment of HACE

The essential treatment of HACE is descent to a higher atmospheric pressure. Descent should be as far as possible, as fast as possible, and preferably at least 300 metres. Other treatments are simply an adjunct to descent or buy time while descent is being arranged. Oxygen should be given if available. Dexamethasone is useful in reducing intracranial pressure (see Table 2 for dosage); the initial dose may be given by injection in the presence of vomiting. Again the pressurised bag is useful but as in the treatment of HAPE it should be regarded as a temporary measure and not a substitute for descent or a means of allowing further ascent, e.g. to allow the crossing of a pass before descent on the other side.

Prevention of HACE

As HACE is essentially a further progression of the same processes causing AMS, prevention follows the same principles. Careful acclimatisation is necessary, but HACE may occur without significant warning signs of AMS

Re-ascent after HACE

Recurrence of HACE on subsequent exposure is less predictable than recurrence of HAPE. Some individuals experience recurrence on re-exposure and some do not.

Table 2

Dosage of drugs used for altitude problems

<i>Drug</i>	<i>Dosage</i>
Acetazolamide	(single dose or divided dose x2)
Prophylaxis	250mg daily
Treatment	500mg daily
Dexamethasone	8mg stat 4mg 4-6 hourly
Nifedipine	20mg 6-8 hourly
Sildenafil	50mg tds used in one study

Other problems of high altitude

There are many other conditions which may occur at high altitude but they are outside the scope of this article. They include hypothermia, cold injury, snow blindness (ultraviolet keratoconjunctivitis), thromboembolic disease, high altitude deterioration (physical & mental deterioration occurring after spending long periods at very high or extreme altitude), dehydration, weight loss and trauma.

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