Problems of high altitude

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In order to define the levels of altitude at which problems are likely to occur the following definitions are generally accepted:

Intermediate altitude
1500-2500 metres. Arterial oxygen saturation in normal individuals is above 90%; problems are unlikely to occur.

High altitude
2500-3500 metres. Altitude problems are likely if ascent is rapid.

Very high altitude
3500-5800 metres. Arterial oxygen saturation is below 90%; hypoxia occurs on exertion; altitude problems are common; acclimatisation is possible.

Extreme altitude
Above 5800 metres. Hypoxia occurs at rest; further acclimatisation is not possible. There is no permanent human habitation above this altitude and prolonged periods at such altitudes lead to a gradual deterioration in physical and mental performance. Survival for long periods is not possible at higher altitudes, and above 8000 metres (the so-called "death zone") even a relatively brief stay may prove fatal.

Why are there problems at altitude?

Altitude problems are caused by hypoxia, which means a lack of oxygen in the blood. There is just as much oxygen in the air at high altitude as there is at sea level (approximately 21%), but the higher one goes there the lower is the atmospheric pressure driving oxygen into the blood in the lungs. Problems do not usually begin until an altitude of 2500 to 3000 metres (8000 to 10000 feet) is reached, where the pressure is low enough to reduce the amount of oxygen in the blood, though the altitude at which problems begin varies a little from person to person.

Acclimatisation

It is possible for the body to acclimatise to the lower atmospheric pressure, at least up to very high altitude (i.e. up to 5800 metres). Higher altitudes than this are unlikely to be encountered by anyone except high altitude climbers.

On initial ascent to high altitude there is an increase in pulmonary ventilation leading to hypocapnia and respiratory alkalosis, compensated for by increased renal excretion of bicarbonate and a bicarbonate diuresis. A rise in heart rate also occurs but the heart rate

gradually reduces again as acclimatisation occurs, though at extreme altitude the resting heart rate remains high. Over a longer period erythropoietin secretion increases, leading to increased red blood cell production and a consequent raised haemoglobin concentration and haematocrit. This in turn leads to increased blood viscosity and an increased tendency towards thrombosis.

Acclimatisation can be assisted in the following ways:

- ***Gradual slow ascent.*** It is often recommended that the net height gain in a day (that is the gain in height from one sleeping place to the next sleeping place ignoring any ups and downs en route) should be no more than 300 metres (1000 feet) per day. This is empirically a safe rate of ascent for almost everyone, though it may be possible for some people to ascend more than this in a day without any problems and a few individuals may encounter problems even at this rate of ascent. The problem here is that everyone has his or her individual rate of ascent before the body encounters difficulty, and what is the right rate of ascent for most members of a group may produce symptoms in a minority of a group of equally fit and healthy people. On an organised trek, for example, a rate of ascent is usually chosen that is likely to be safe for the group, but even then a few people in a group may develop altitude symptoms. When flying into a high altitude airport symptoms may also occur because in these circumstances there is no time for acclimatisation to occur, though acclimatisation will begin within a few days after arrival
- ***Avoiding over-exertion.*** Over-exertion is known to increase the chance of developing altitude problems Youth and fitness do not help to prevent altitude problems. In fact, it has been suggested that older people are less prone to altitude sickness, as they are less likely to over-exert themselves. A useful philosophy on a mountain trek or when walking up to the base camp for a high altitude expedition is that there are no prizes for getting there first. Those who try to set a fast pace to prove their fitness are inviting trouble. A slow and steady pace is what is needed.
- ***Adequate fluid intake.*** Dehydration has long been thought to increase the chance of developing altitude problems, though the evidence for this no longer appears to be very strong. Fluid loss increases at higher altitudes, partly because of sweating due to exertion and partly due to evaporation from the mouth, throat and lungs due to the drier air and it is important to avoid dehydration by drinking plenty of water whether or not it helps to prevent altitude problems. Tea, coffee and alcohol are diuretics and make the body lose more water than it gains from them. Fluid intake must not be taken to extremes as drinking too much water may cause hyponatraemia.
- ***Acetazolamide (Diamox).*** The use of acetazolamide, (Diamox) has been shown in many research studies to improve the body's uptake of oxygen by adjusting the body chemistry and to help either to prevent or to treat altitude symptoms. It treats the cause of the problem and does not simply mask its symptoms. Acetazolamide is a carbonic anhydrase inhibitor which causes the kidney to increase its excretion of bicarbonate ions. This causes a metabolic acidosis and in order to compensate for this pulmonary ventilation is increased, increasing excretion of carbonic acid (H_2CO3, i.e. $H_20 + CO_2$) via the lungs, The result of increased ventilation is that oxygen uptake in the lungs is increased, thereby reducing hypoxia. This cannot be achieved by voluntary hyperventilating without using acetazolamide as this would cause acute

respiratory alkalosis with dizziness, paraesthesiae and eventually loss of consciousness. For prevention, acetazolamide should be taken in a dose of 125 to 250 mg twice a day, starting 1 to 2 days before reaching 3000 metres. A higher dose is used for treatment of established symptoms. A general opinion amongst most altitude experts is that it is not necessary for everyone going to high altitude to take acetazolamide. It is probably best reserved for

- those who have been to altitude previously and did not acclimatise well in spitre of adequate precautions
- treks or expeditions in which the lie of the land means that height gains may exceed the recommended levels per day
- flying in to altitudes of 3000 metres or more with no opportunity to acclimatise

Acetazolamide is a prescription-only drug, therefore it requires a prescription signed by a registered medical practitioner. In addition it does not have a product licence for use for high altitude problems, so that it has to be prescribed "off-licence". Drugs prescribed on a "just in case" basis for travel are not covered by the NHS and the doctor should issue a private prescription. Some GPs are not willing to prescribe acetazolamide for travellers, and if an individual encounters difficulty with this it may be possible to consult a specialist travel clinic. It is also to buy acetazolamide over the counter in some other countries but care must be taken as drugs obtained in this way may be time-expired or counterfeit. Other "altitude remedies" on sale tend to contain little more than aspirin or paracetamol, perhaps with a little caffeine or other ingredients. They may help with headache but they will not help to prevent or treat the real problem.

Adverse effects of acetazolamide. Acetazolamide often causes tingling in the hands and feet or elsewhere at the extremities. This is a nuisance if it occurs but is not dangerous. It is also a mild diuretic, and care should be taken to ensure an adequate fluid intake. It is also often said that carbonated drinks taste flat when taking acetazolamide. This who have a drug sensitivity to sulfa drugs should not take acetazolamide, though these drugs are not commonly used nowadays.

- ***Other methods.*** Residents of the Andean countries chew coca leaves as a protection against altitude problems. This is a centuries-old custom, though its effectiveness has never been scientifically tested. Coca leaf tea is often recommended, but again has not been properly evaluated. It seems unlikely to have much effect as it is usually brewed very weak, but at the very least it will probably help to avoid dehydration. Gingko biloba was thought to be helpful by some people but a recent trial showed it to have little or no effect. There is no evidence that any other remedies such as herbal or homeopathic remedies have any effect in either prevention or treatment, and their use may distract the user from taking other more important measures.

Acute mountain sickness

The commonest form of altitude sickness is acute mountain sickness (AMS). Its incidence has varied in different studies from 13% to 63% of lowland dwellers ascending to high altitude. These variations may be accounted for by differences in the rate of ascent in different studies, individual variation between subjects or groups of subjects studied and differences in the criteria used for diagnosis of AMS.

Symptoms of AMS

The main symptoms and signs of AMS are some or all of the following

- Headache
- Nausea
- Vomiting
- Fatigue
- Loss of appetite
- Dizziness
- Sleep disturbance
- Peripheral oedema

The symptoms of AMS have often been compared with having a "hangover" from drinking alcohol.

Prevention of AMS

As the development of AMS signifies that the individual has failed to acclimatise properly the measures likely to assist in its prevention are those listed above as assisting acclimatisation, namely:

- Gradual slow ascent
- Avoiding over-exertion
- Adequate fluid intake
- Acetazolamide 125-250mg twice a day

Treatment of AMS

- It is essential for the affected individual to tell the tour or expedition leader or doctor or some other responsible person that he or she is having problems
- Rest at the same altitude, avoiding any unnecessary exertion and do not ascend higher until symptoms have improved
- Go down to a lower altitude, preferably at least 300 metres, if symptoms do not improve or if they becomebecome worse.
- Acetazolamide 250 mg 2 or 3 times a day

High altitude pulmonary oedema (**HAPE**)

Hypoxia causes a rise in the pulmonary artery pressure and damage to capillary endothelium in the lungs. Fluid is then forced out of the capillaries causing fluid to accumulate in the alveoli, resulting in pulmonary oedema.

Symptoms of HAPE

Symptoms and signs of HAPE may include:

- Breathlessness; this is an important early warning symptom. Everyone is more breathless on exertion at high altitude than they are at sea level but an important early warning sign of HAPE is breathlessness that does not settle easily on resting
- Reduced exercise tolerance. The affected person finds that exertion, particularly going uphill, becomes more and more difficult
- Tightness in the chest

- Cough. This may be a dry cough at first but eventually sputum is coughed up which may become pink or more obviously blood stained
- Scattered areas of crepitation on auscultation of the chest
- Central cyanosis
- Raised respiratory and/or heart rate

Prevention of HAPE

Proper acclimatisation as for AMS is likely to reduce the likelihood of developing HAPE but it is important to realise that HAPE may develop without there having been any prior symptoms suggesting AMS.

Treatment of HAPE

- This is a life-threatening situation and descent is essential, as far as possible as fast as possible, preferably at least 300 metres, until an atmospheric pressure is reached at which the body can take in more oxygen and the pulmonary artery pressure falls
- Oxygen is useful if available
- Nifedipine helps to reduce pulmonary artery pressure. A 10mg capsule can be held in the mouth and bitten open for rapid effect if available, and the drug is then given in a dose of 20mg every 6 hours
- Sildenafil (Viagra) also lowers pulmonary artery pressure and has been suggested as a possible treatment for HAPE
- A Gamow or similar pressurised inflatable bag may be used to increase the effective atmospheric pressure surrounding the patient.
- NONE OF THESE TREATMENTS IS A SUBSTITUTE FOR DESCENT TO A LOWER ALTITUDE AND NONE SHOULD BE USED TO TRY TO ENABLE TO AFFECTED PERSON TO GO HIGHER.

High altitude cerebral oedema (HACE)

Hypoxia causes an increase in the flow of blood to the brain and damage to capillary endothelium in the brain. Fluid is then forced out of the capillaries causing cerebral oedema

Symptoms of HACE

Symptoms of HACE may include:

- Changes in behaviour, for example becoming more irritable or behaving strangely. This is often an important early warning symptom
- Unsteadiness on the feet, possibly first appearing as stumbling more frequently that usual. This too is often an important early warning symptom
- Hallucinations
- Disorientation, not appearing to be fully aware of one's surroundings
- Mental confusion
- Eventually there may be a lowered level of consciousness and even coma, but these are a late and very worrying signs and the condition should be suspected long before this stage.

Prevention of HACE

Proper acclimatisation as for AMS is likely to reduce the likelihood of developing HACE. The symptoms of AMS are probably caused by physiological changes similar to those causing HACE. Whilst AMS symptoms may be followed by the onset of HACE, especially if inadequately recognised or managed, HACE may sometimes develop rapidly without any prior recognition of symptoms of AMS.

Treatment of HACE

- This is a life-threatening situation and descent is essential, as far as possible as fast as possible, preferably at least 300 metres, until a pressure is reached at which the body can take in more oxygen.
- Oxygen is useful if available.
- Dexamethasone (a potent corticosteroid) helps to reduce intracranial pressure. It is given in an initial dose of 8mg followed by 4mg every 6 hours. It can be given by injection if the patient is unconscious
- A Gamow or similar pressurised inflatable bag may be used to increase the effective atmospheric pressure surrounding the patient.
- NONE OF THESE TREATMENTS IS A SUBSTITUTE FOR DESCENT TO A LOWER ALTITUDE AND NONE SHOULD BE USED TO TRY TO ENABLE TO AFFECTED PERSON TO GO HIGHER.