Altitude Illness—
Recent Advances in Knowledge

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LESS than thirty years ago the great Himalayan peaks in Nepal were opened for the first time to climbers, and the Karakoram ranges were re-opened. Since then all of the major peaks have been climbed, most of them several times. More than 70 persons have reached the summit of Everest, half a dozen without using oxygen for the final push. During the same period, floods of less experienced climbers and trekkers have surged high into areas which a few years ago were far beyond reach. Not surprisingly there have been many cases of altitude illness and too many deaths among enthusiasts. With this expansion of trekking and climbing has come renewed interest and research into the problems caused by lack of oxygen (hypoxia). The purpose of this brief paper is to outline some of what we know, and don't know, about high-altitude illness.

Definitions

Convenient though it may have been to classify altiude illness into neat categories, most people today would agree that Acute Mountain Sickness (AMS), High-Altitude Pulmonary Edema (HAPE), and Cerebral (brain) Edema (CE) are parts of a continuous spectrum of pathology manifested in different forms and combinations. Their root cause is oxygen lack and the body's responses to this, and the underlying abnormality is probably a disturbance in the distribution of salt and water within and between the body cells. Different people may prefer different terminology, some using the words benign or malignant depending on the seriousness of the problem. Others have more complicated classifications with sub-headings. Unlike many other diseases, however, the basic mechanisms of altitude illness are not well understood, and the main value of classification is to ensure that different observers are describing similar problems in similar terms. What the mountaineer needs is a clear understanding of the warning signals, and how best to prevent or treat them.

AMS is common after rapid ascent to over 5000 or 6000 feet; its symptoms of headache, nausea, and often vomiting, weakness and shortness of breath are familiar. Like a bad hangover, AMS lasts only a brief time and is very rarely fatal, though the victim often wishes it might be. HAPE is more serious, comes on rapidly, and may cause death in less than 40 hours after rushing to an altitude as low as 9000 feet. The symptoms are weakness, shortness of breath, and cough with blood-stained or frothy sputum. HAPE may proceed rapidly to coma and death, or may improve with equal speed if the victim goes down only a few thousand feet soon after symptoms begin. CE, less common but more serious, is characterized by severe headache, staggering gait, frequent and ominous hallucinations, coma and death. Though unusual below 14,000 feet, CE has killed healthy people at 10,000 feet.

Although headache is common even at low altitude, its exact cause is not clear. Most observers feel that lack of oxygen causes swelling of the brain within the rigid box-like skull, and this pressure causes headache. The greater the swelling the worse the headache and the more likely the appearance of other symptoms characteristic of brain edema. We know that all persons going above 17,500 feet, whether or not they are affected by altitude illness, show increased blood flow to the retina of the eye. More than a third of them will show retinal hemorrhages (HARH) which rarely cause symptoms and disappear within days or weeks even while at altitude. Occasionally HARH may occur in the macula of the retina where central vision is perceived, and in this unusual event the individual will notice a blurred or blind spot when looking straight ahead. Macular hemorrhages, fortunately uncommon, sometimes do leave a persistent blind spot, but others do not. We do not know whether or not such tiny hemorrhages occur in other parts of the body, and the cause and significance of retinal hemorrhages is still unknown.

Occurrence

Although a great deal has been learned since Ravenhill's classic description of these forms of altitude illness in 1913, many puzzles and blank spaces remain. For example, although most people stay well only if they take time to acclimatize while climbing above 6000 or 7000 feet, others are able to go from sea level to 9000 feet in one day and to continue higher much faster than the recommended rate of 1000 feet per day without difficulty. Of course individual variation is not surprising, and occurs in most human characteristics, but what is it due to? Thousands of skiers yo-yo up and down 12,000-foot mountains within a day after leaving sea level without difficulty, but quite a few have died a day or two after reaching even lower altitudes. Many people have symptoms on

one occasion but not on another for reasons that are obscure. At present we have no way of predicting who will and who will not have altitude sickness.

Is a person who has had one bout of HAPE or CE more likely to have another? We believe so, not because susceptibility has been increased by one attack, but because the underlying susceptibility has not changed. On the other hand many climbers have had one or more attacks of HAPE or CE and climbed again with no difficulty. Others who have gone down from a climb because of dangerous early warning signs have recovered and gone back to climb even higher a week or two later. Today we have no means of predicting vulnerability.

Is the long-term altitude resident, returning home after a stay in the low-lands, more likely to develop HAPE than is the new arrival? Ravenhill was undecided; Singh found that the risks were identical, but several groups have recently accumulated a variety of information which strongly suggests that reentrants are at greater risk. Though the jury is still out, we can say with confidence that persons returning to their permanent homes at altitude after a stay lower down should be more careful, because they may be slightly more vulnerable to HAPE, and possibly to CE as well. Even in this group however there is considerable variation: some individuals show a much greater increase in the pressure in the arteries going to the lungs than do others, and thus are presumed to be more susceptible to HAPE.

"Alpine style" climbs are now in vogue. Small, superbly skilled teams have reached many summits higher than 21,000 feet, and a few over 25,000 feet, after one or two days of very rapid climbing from an advance base at 14,000 or 15,000 feet. Most have returned safely although not unaffected. Others have died because of altitude, or because their climbing skill and judgment has been so badly affected that they have made foolish mistakes. Many rescuers have been jeopardized. The risks of "alpine style" ascents are very high for climbers and rescuers alike, and one wonders whether the rewards equal those which come from taking time to enjoy everything the mountains have to offer.

How altitude is measured becomes critically important on high mountains. To our bodies the "physiological" altitude is all that matters, and this is determined by the barometric pressure which decreases as altitude increases, and which changes with weather. Because the percentage of oxygen in air is everywhere 20.93%, the lower the barometric pressure the lower will be the pressure of oxygen available to the body. On summits whose altitude has been measured by observing the barometric pressure and transposing this to feet from standard tables, this is the "physiological" altitude. But if the height has been measured by triangulation, then mountains near the equator have a slightly higher barometric pressure and thus a lower "physiological" altitude than those of identical

linear height in the high latitudes. This is because the thin envelope of air which surrounds our slightly flattened globe is thicker at the equator than at the poles. Changes in barometric pressure during storm or fair weather cause changes in available oxygen and thus in "physiological" altitude. Recent careful calculations indicate that on the summit of Everest barometric pressure is at the absolute minimum which man can survive breathing air, regardless of how well or poorly he is acclimatized. This is because an irreducible minimum of atmospheric pressure within the lung is taken up by water vapor and carbon dioxide.

Prevention

We have no reliable way of predicting who may or who may not develop altitude illness, nor on which days one individual may be better or worse. Today we are less confident in recommending a "safe rate of climb" than we were a few years ago, because there is such tremendous individual variation, and even great variation in the same person from time to time. We do know that physical fitness has no direct correlation with susceptibility to altitude illness, but at the same time we realize that the fitter climber, moving more economically, uses and needs less oxygen than does the slob. It has been clearly proven that a pure carbohydrate diet gives an "altitude benefit" of about 2000 feet. However, without replacement of essential proteins and some fats, the body wastes away, so it is necessary to add these food stuffs occasionally. But when? Recently it has been shown that blood oxygen decreases in most people during sleep, due to derangements in breathing—the familiar Cheyne-Stokes respiration. One might say that the individual "goes up" a few thousand feet during sleep. Therefore, if one eats a mixed or high protein and fat diet at bedtime as has been the custom, the loss of the "altitude benefit" derived from carbohydrates, together with the decrease in oxygen due to sleep, is likely to make symptoms worse in the morning. Perhaps it would be wise to take a pure carbohydrate diet for all meals during several days of strenuous exertion, and a diet high in protein and fat during the following rest day. Several tragedies have indicated that the use of sedatives at altitudes above 18,000 to 20,000 feet increases the irregularity in breathing and thus decreases blood oxygen. Consequently we believe today that sedatives should not be used at great altitude. We have found however that agents which smooth out or regularize breathing, thus improving oxygen content of the blood, cause sounder and more restful sleep; acetazolamide (Diamox) and aminophyllin confer this benefit.

Other medications are being tested to improve adaptation to altitude or to decrease symptoms. Stimulants to blood formation, or extra iron, are not considered necessary because lack of oxygen is the strongest known stimulus for blood formation, and normal body stores are enough

to meet usual needs. Vitamins can of course be added to the somewhat restricted diet without ill-effects, but excess vitamins give no added benefit at altitude. Medications which stimulate breathing are effective, but have limited use: Medroxyprogesterone (Provera) does stimulate breathing and reduce symptoms, but because it is a female sex hormone, has undesirable side effects for men and women alike. Antacids (in particular Rolaids) have been advocated, but there is only slender theoretical basis and inadequate experimental evidence for their benefit. Acetazolamide (Diamox) has been in use for more than fifteen years; theoretically it should be helpful and safe, and in fact it is widely used and well established as effective for most—but not for all—individuals. Diamox can be recommended with confidence that it will prevent many symptoms in people who must go rapidly to altitudes as high as 10,000 feet and even higher. It will not work for everyone, and it will not protect those who go too rapidly to even greater heights.

For a long time it has been known that exposure to high altitude causes an increase in the number of red cells and the amount of hemoglobin in the blood. An immediate increase is due to concentration of blood while the later slower increase is due to formation of new red blood cells. Although this expanded transport capability of the blood is beneficial, when the increase is excessive, blood becomes too thick to move rapidly and effectively through tiny capillaries. Red blood cells tend to "stack" and thus lose oxygen less readily, and blood clots more readily. Consequently, although modest increase in red blood cells is desirable, too great an increase is dangerous. From this it follows that "diluting" the blood when it is too thick should be beneficial. Based on these theoretical considerations, doctors on a number of recent Himalayan expeditions have withdrawn one or two pints of blood from well acclimatized climbers whose blood appears to be "too thick" replacing the withdrawn blood with a physiological solution. Although there are no controlled studies to prove the benefits, this procedure seems to be helpful, and certainly deserves further examination. These changes in blood also suggest a slightly different approach for the individual who wishes to go higher than he should in a short space of time: if one or two pints of blood are removed several weeks before a climb, the body will replace these red cells, and the stored blood may then be re-injected at the time of the climb, giving an artificial boost to the oxygen carrying capability of the blood. Unfortunately stored blood cells lose some of their transport capability, and this "auto transfusion," although it has been used in Olympic athletes, is not recommended for mountaineers.

The need for rigorously controlled studies of methods for changing altitude tolerance and susceptibility to altitude illness is particularly great because of the notoriously subjective nature of altitude symptoms. Whatever procedure or drug is advocated for prevention or treatment must

be strictly compared to a placebo (inactive medication) in such a setting that neither subject nor investigator knows which is being used until the data have been analyzed. Few studies today have met this criteria.

Treatment

It is tiresome but necessary to repeat that the best management for altitude illness is to *get down* as soon as the problem has become clear and before it has become serious. Improvement is almost always dramatic after descending only a few thousand feet. If not, then a complicating condition should be suspected. Using oxygen or bedrest while remaining high may help, but it greatly increases the risks—risk that bad weather may prevent a later descent, risk that a walking patient may become a litter case, risk that the condition may suddenly worsen and move toward death. Although it has been suggested that bedrest in a hospital setting with full medical resources at 12,000 feet will result in improvement of HAPE, this measure can only be condemned in a mountain setting.

We have learned recently that fluid may accumulate within the lungs only a few hours after arrival at altitude before any signs or symptoms appear. This fluid seeps between the air sacs (alveoli) of the lung and the blood capillaries. It may be re-absorbed without ever causing symptoms, or it may increase, leak into the air sacs, and develop into frank HAPE, depending on circumstances which we understood only poorly. Oxygen is certainly helpful in the early stages, but it becomes less helpful as more fluid accumulates and blocks the diffusion of oxygen from alveoli into blood. It would be dangerous to rely on oxygen on a mountain. A diuretic which stimulates kidney function (Lasix is the most popular), is believed to be helpful, although there are certain risks, and although no controlled studies have proven its value. Although Digitalis—a heart stimulant—is used in some regions, most physicians do not believe it is useful if the heart is normal as it is in most mountaineers, because the heart is already working with optimal force. Small doses of morphine are certainly helpful, but also carry important risks. Adrenal hormones such as dexamethasone have theoretical value in CE, and limited observations suggest that they do have benefits, though these appear only after six hours or longer. Although a number of other drugs or procedures have been tried, none have gone beyond the experimental stage and cannot be recommended today.

As regards retinal hemorrhages, their exact cause is not understood, and neither treatment nor preventive is known. In fact little is necessary, since the majority disappear without a trace. Strenuous exertion does seem to be associated with a slight increase in risk of retinal hemorrhage, and there is also a weak association between number or size of HARH

and illness or wellness and with speed of ascent. Thousands of climbers have gone to high altitudes where more than a third are likely to have HARH. Present evidence suggests that retinal hemorrhages carry no risk unless they appear in the region of central vision (the macula) where persistent visual defects may result. Our present state of knowledge does not indicate that HARH alone are reason for descent, or a reason not to climb again. We have seen HARH disappear during a stay at altitude. Individuals have had HARH on one trip to a given altitude, but not on others. Macular hemorrhages are more serious, and if present, probably do justify descent. At the present time we have no idea whether or not these tiny hemorrhages occur elsewhere in the body.

Careful scientific research has taught us a great deal about the evolution of altitude illness, and has produced many suggestions for management. But physicians need to know how to recognize and when and how to treat the various forms of altitude illness. Doctors who go on organized trips or expeditions surprisingly often are completely ignorant of even the simplest aspects of altitude illness. This is inexcusable. Any doctor who ventures to an altitude above 12,000 or 14,000 feet should know what the possibilities are. Education of the climbing and trekking public has been very rewarding, and has sharply decreased altitude illness on Mount Kenya, Mount McKinley, and in the Everest region. A thorough understanding of the risks (and pleasures) of altitude should be as much a part of mountain craft as is the use of rope and hardware.