No. 157 MEDICAL PROBLEMS AT HIGH-ALTITUDE SITES AND THE MOUNT LOGAN, YUKON, HIGH CAMP

by I. DRUMMOND RENNIE, M.D.
Rush-Presbyterian St. Luke's Medical Center, Chicago

September 8, 1970

1. Organization and Accessibility of Mount Logan High Camp

For more than a decade the Arctic Institute of North America (A.I.N.A.) has run a research facility at the southeastern end of Lake Kluane (61°0′ N, 138°25′ W) at Mile 1054 on the Alaskan Highway in the Yukon Territory of Canada. The facility, which consists of huts, cook house, radio shack, and an air strip, has acted as the base camp for a large number of temporary camps set up in the surrounding mountains and glaciers and manned by glaciologists, climatologists, geologists, botanists, zoologists, and limnologists. The highest of the temporary camps used to be at Divide (8,500 ft; 60°43′ N, 140°0′ W) on the Kaskawulsh Glacier which at that point is some 1,300 ft deep. All the camps were served by light planes, equipped with skis, flying out of the Kluane Base.

In 1967, Dr. Charles Houston, Professor of Community Medicine at the University of Vermont, planned and organized the setting up of a further subsidiary camp on the high plateau of Mount Logan (60°36′ N, 140°32′ W; 70 miles by air from Kluane). Logan High Camp, which has been in operation every summer since 1967, is at 5,300 m (17,600 ft) altitude. Dr. Houston is a high-altitude physiologist, and it was for physiological studies that it was primarily intended, though in the years of its opera-

tion, studies in glaciology and meteorology have also been done. Though there were several other such research stations already in operation, none were as high as Logan High Camp. This extra height is important because of the extra stress it puts upon the body. There is good evidence, for example, that on abrupt exposure of unacclimatized people to high altitudes there is no mental deterioration (disorder of thinking, calculation, etc.) until after a height of 16,000 ft has been attained (Mc Farland, 1969). It is of interest that the sigmoid of the oxyhemoglobin dissociation curve keeps up the oxygen saturation of the blood, but at the altitude of Mount Logan the latter falls off rapidly. Physiologically, then, there is a considerably greater increase in stress on going from 14,000 ft up to 18,000 ft, than going from 10,000 to 14,000 ft.

The practical importance of this is the corresponding increase in the frequency and severity of symptoms to be expected when an unacclimatized person flies from Kluane up to the High Camp on Logan — a height differential of approximately 15,000 ft. There is also good evidence that Logan High Camp is situated at about the highest altitude to which satisfactory acclimatization is possible. Higher up, there is a steady deterioration in general health (Pugh, 1964; Dill, 1968).

Logan High Camp is remote and isolated, on a large mountain, exposed to severe weather. Clearly, its use is justified only if the risks are manageable. Four years' experience has shown that they are.

The *accessibility* of Logan High Camp must be considered, because of the occasional need for medical evacuations. Arctic Institute camps are served by two Heliocouriers, one of which is supercharged and is able to land and take off on the high plateau. The pilot, Mr. Philip Upton, has now made more than 100 landings at High Camp without mishap. The flight up takes 50 minutes. The Heliocourier is unloaded and reloaded at High Camp very rapidly and never stays there more than a few minutes. It can carry up to 600 lb. weight, but the size of the cargo is obviously limited by the dimensions of the door and of the cabin. This is adequate to take a stretcher patient and an attendant.

For the past two years, the Canadian Forces taking part in the physiological experiments have been brought to Kluane in a large STOL transport Buffalo together with their equipment and a jeep. This aircraft has had no difficulty with the Kluane air strip. Air drops of heavy supplies have twice been made at High Camp with recovery undamaged of some eighteen out of twenty of the supply bundles and their parachutes.

Efficient radio communication is maintained by small, portable single-sideband transceivers with a few watts of power output.

There is an efficient modern hospital at Whitehorse. An arrangement has been made whereby in an emergency, supercharged Bell Helicopters at Whitehorse Airport, belonging to Trans North, may be hired (by telephone or radio), though this would cost some $500 for the round trip (at $250 per hour). So far they have not been required, but one of these helicopters has landed and taken off from the plateau without difficulty.

Logan High Camp can, practically speaking, be serviced by air. Kluane itself, 136 miles from Whitehorse, is easily accessible via the Alaskan Highway, and frequent jet passenger flights link Whitehorse with Vancouver and Edmonton.

The fact that Logan is in a friendly, cooperative country has been of great importance to us, no difficulties being experienced with customs and considerable assistance having been given to the project by, for example, the Canadian Forces.

2. *Season*

The High Camp has been open for physiological studies only in July, though it is intended to lengthen the period from three to six weeks in 1972.

TABLE 1

FLIGHTS TO LOGAN DURING THREE-WEEK PERIODS IN JULY, OVER 4 YEARS. THESE PERIODS WERE SELECTED AS COVERING THE PHYSIOLOGICAL EXPERIMENT 'SEASON.'

YEAR	NUMBER OF FLIGHTS TO LOGAN HIGH	NUMBER OF DAYS WHEN FLYING WAS IMPOSSIBLE	NUMBER OF 2-DAY PERIODS WHEN FLYING WAS IMPOSSIBLE
1967	25	7	3
1968	18	4	0
1969	25	5	1
1970	23	6	1
Total	91	22 (33%)	

From Table 1 it can be seen that flying was possible on ⅔ of the days. 91 flights were made on these 41 flying days. It was rare for flying to be impossible for two consecutive days.

3. *Facilities at Mount Logan High Camp*

In 1970, three Versadome tents were in use, each large enough to house 8 or 9 people on cots. One is used for cooking and as a mess tent, and for the two radio transmitters. Another houses the support team

(9); the third, three scientists who use it also as a laboratory. In 1971, a fourth Versadome will be added. These tents are capacious, sturdy, and wind resistant (up to 100 miles an hour). They are warmed by propane space heaters and pleasant to live in, unlike the 1967 hut, which became dark and cramped and encouraged lethargy. Each tent has a wooden floor and is well lit, electricity being supplied by a propane-power generator housed 20 yards away next to the latrine (the generator keeps this, and the propane cylinders, conveniently warm).

An additional 8-man Canadian Army tent houses the 5 experimental subjects, and there are three 2-4 man Bishop tents ready pitched, some distance from the main camp, for use in any emergency such as fire.

The original hut, put up in 1967, is now deeply buried beneath the snow and is used for food storage. Thirty man-days of oxygen and about ten days of propane supply are always kept at High Camp, as well as considerable stocks of food.

The camp is situated about 300 yards from the NW col, at the upper end of a large snow field which slopes away to the East, where the Helicourier lands. It is sheltered by peaks on three sides (N, W, and S) and is well protected from the weather. The camp is pitched on snow and so is slowly shifting.

Logan High is set up and maintained by a team of young climbers (college students), the leader and some members of which have had several seasons on Mount Logan. In late May, the climbers are taken by Heliocourier and dropped at about 10,000 ft, at 'Trench,' a snow field west of Logan. They spend about 10 days climbing up to Logan High Camp, acclimatizing steadily. Once there, they dig out the previous year's caches and, serviced by the Helicourier, set up the Camp.

The support group is self-sufficient and resourceful. They operate the meteorological station on Logan High, and radio down weather reports to Kluane every three hours. They frequently have their own scientific projects as well, usually glaciology. Their primary task, however, is to look after the camp and the experimental subjects and scientists, and to assist with the experiments, setting up equipment, taking readings, etc. Some chores, such as loading and unloading the aircraft, and clearing snow, are very arduous at that height. They have repeatedly proved both their ability and reliability; because they are well acclimatized, they are invaluable research aides, as well as medical assistants when someone needs constant attention. They are a major factor in the safety of the operations on Logan.

Because, under the present arrangement, all servicing of High Camp is done by one Heliocourier, it is important for reasons of safety to keep the number of people — especially unacclimatized people — down to a minimum.

4. Physiological Considerations

The partial pressure of oxygen at Logan High Camp is approximately 80 mm Hg (normal, 150 mm). This is below the normal sea-level arterial partial pressure of oxygen (about 90 mm Hg); on Logan the latter is about 40–45 mm Hg.

The respiratory center of the brain responds to this hypoxia by increasing ventilation — the depth and rate of breathing — and this has the effect of blowing off CO_2. Normally, CO_2 is constantly produced by the metabolizing cells of the body. By the excessive ventilation the CO_2 level in the blood is rapidly lowered and this profoundly affects the flow of blood to the brain (which is diminished), the alkalinity of blood (which is increased), and the respiratory center itself (which becomes irregular).

Every organ and tissue in the body is affected by these initial changes in oxygen and CO_2, because these, in ever-widening ripples, cause secondary changes. Fluids shift between the circulating blood and the body cells, and powerful electrolytic changes occur; blood is diverted from some organs to others. Gradually, the process of acclimatization begins. Basically, this can be seen as consisting of thousands of ways of increasing oxygen delivery to the tissues. Thus, ventilation of the lungs is increased, as is the oxygen-carrying capacity of the blood, and the density of the capillaries in the tissues; these processes all take varying amounts of time to complete. In general their severity is proportional to the altitude (or the atmospheric hypoxia); they are all prevented by giving extra oxygen and are reversed by descent to sea-level.

5. Acute Mountain Sickness

Acute Mountain Sickness (A.M.S.) ('soroche') is an acute, self-limiting syndrome, or collection of subjective symptoms; and objective signs of illness, occurring in individuals abruptly exposed to high altitudes. None of the features alone is specific or diagnostic in the way that a rash or a temperature fluctuation may be diagnostic, but taken together they are characteristic.

The incidence is very variable between individuals and even from one exposure to the next in the same individual but, in general, both the incidence

and the severity increase with the altitude, and susceptible subjects tend to develop A.M.S. on further exposure to high altitude. Few persons develop symptoms as low as 7,000 ft, whereas everyone develops them at 17,600 ft on Logan, and occasionally these are severe enough to require evacuation. Cold may, and exercise does, aggravate the illness.

Typically, the newcomer feels very well for a few hours, apart from a striking breathlessness on the least exertion, and occasionally a feeling of faintness. Some 8 to 24 hours after arrival he begins to feel tired and lazy, yet he sleeps poorly, with frequent nightmares. A headache is usual, and may be very severe. On walking, he tends to lose his balance and stagger; he feels nauseated and does not wish to eat or drink, so that dehydration adds to his weakness. He may be depressed and listless or occasionally confused. He may be conscious of his uneven breathing and his breathlessness may become severe at rest because of fluid accumulation in the tiny alveolar air spaces of the lung (pulmonary edema). Rarely, severe headache may precede gradual loss of consciousness, with or without convulsions associated with generalized swelling of the brain (cerebral edema).

The illness usually passes off rapidly and after 2–3 days the newcomer begins to take an interest in his surroundings, to eat and drink and to become active, and to sleep. If pulmonary or cerebral edema occurs, continuous oxygen must be administered, and diuretics (drugs to increase the elimination of fluid through the kidneys) may be required. Evacuation will probably be necessary, as is usual if any symptom (ataxia, vomiting) is very severe and persistent. It probably takes several weeks before full acclimatization occurs.

6. *Medical Problems*

Any medical problem that may afflict previously-healthy persons at sea level may, of course, also occur at altitude. It is scarcely relevant to discuss these wide possibilities, except to say that it is the responsibility of the physicians at Logan High to carry first-aid supplies, and supplies of analgesics, antibiotics, ointments, decongestants, dressings, etc., to deal with minor ailments. If necessary, the physician can order evacuation to Kluane and to Whitehorse Hospital. In four years, this last has been necessary only once.

Some disorders occur particularly frequently at Logan High Camp:

a) Persistent dry cough, and nasal crusting and stuffiness. In 1970, several members of the support group had colds early-on, and were left with persistent dry coughs. This is a feature of life at very high altitudes, described by numerous climbers, and is probably associated with the low absolute humidity and the cold. No satisfactory treatment for this irritating complaint has been devised. Vasoconstricting nasal drops may be needed.

b) Painful external hemorrhoids tend to occur at high altitudes and may warrant laxatives and Anusol suppositories.

c) Insomnia is common, and barbiturates (e.g., Seconal or Doriden) are useful.

d) Snow blindness, due to the intense sun, reflected off the snow, the cold and the wind, is easily avoided with very dark goggles which should always be worn outside.

Venous thromboses have not been seen on Logan, but occur in climbers well acclimatized to very high altitudes (Houston, 1955; Clegg, 1956) who have achieved a huge increase in blood thickness.

Small retinal hemorrhages occur, almost always symptomless and transient (Frayser *et al.*, 1970). They will not be found unless looked for and may be related to strenuous exertion. They occurred in 9 out of 25 persons in 1969 and in 3 out of 28 in 1970. At least 3 members of the support group had these hemorrhages. It should be pointed out that in only one case did they cause symptoms. Such hemorrhages occur in 20–40% of new-born babies.

7. *Avoidance of Acute Mountain Sickness*

So far, no satisfactory way has been found of predicting who will get A.M.S. Nevertheless, *selection* of persons to go onto Logan is important. To the non-mountaineer (who tends *not* to appreciate the cot-beds, the warm and roomy Versadomes, the excellent food and the protective and solicitous support group, because he contrasts conditions at High Camp with life at home, and not with bivouacs on other mountains), Logan High Camp may seem a somewhat remote, friendless and austere place. People who are worried about themselves and their health, and who are frightened of going up to Logan should not do so. Our experience has been that such people tend to suffer severe symptoms (vomiting, etc.), some of which are made worse by their mental attitude, while their worries may prove contagious.

At the present state of our knowledge it would be foolish to send up to Logan anyone with more than

mild hypertension, or someone who has suffered from a myocardial infarct, but there is definitely no correlation whatsoever (negative or positive) between A.M.S. and physical fitness, nor is there any known sex difference in A.M.S. Anyone with abnormal hemoglobins (e.g., sickle-cell disease) would be at great risk on Logan.

In general, the unacclimatized person sent straight up to Logan will perform his mental and physical tasks slowly and with mistakes; it is therefore logical, both from the point of view of science and for their health, to attempt prior acclimatization. This can be done best by walking up from Trench (10,000 ft) accompanied by an experienced mountaineer and taking 7–10 days over it. The next best alternative is to fly to Divide Camp (8,500 ft), stay there 3 or 4 days, and then fly to Logan. This has worked well in the past, the hypoxic stimulus at 8,500 ft being adequate to start the whole process of acclimatization without producing symptoms (except in rare cases).

There is a problem with unacclimatized people who wish to go to High Camp for only an hour or two, in order, for example, to set up or adjust a scientific instrument. This can be done, but the person will have to take oxygen from a portable Sky Ox bottle in order to perform well, and he has to be prepared to stay longer in the event of changes in the weather forcing the cancellation of the return flight. He must therefore be passed medically fit.

There is evidence from studies by others (Forwand *et al.*, 1968) and from our own experience, that acetazolamide (Diamox) which inhibits the enzyme carbonic anhydrase, and which to some extent prevents the development of the alkaline blood that occurs at high altitude, is useful in preventing or diminishing A.M.S. It is therefore usual for all unacclimatized people to take this for 3 days before and for 2–3 days after ascent to high altitude, even if they are being staged through Divide Camp.

The next phase in the prevention of A.M.S. starts on arrival. There is evidence (Singh *et al.*, 1969) that physical activity increases the severity of A.M.S. and so it is the practice at Logan High Camp to rest the newcomer as much as possible for 24–48 hours, any work during this time being discouraged. It is essential that he force himself (or be forced) to drink large quantities of fluid as dehydration is a rapid consequence of distaste for food and the increased (and considerable) insensible water loss at altitude from the lungs (Pugh, 1965).

The newcomer must be examined at least daily by an acclimatized physician well-familiar with high-altitude problems. This is an essential qualification, since judging the physical condition of people at altitude is not easy, especially when the physician himself (as happens at altitude) is unusually tired. The Mt. Logan physician has several radio discussions daily with another physician, also experienced in high-altitude work, at Kluane; in fact, there are usually two physicians at High Camp. It is imperative that the Kluane physician have the final say in any decision. Often he relies on *how* things are said, or what is *not* said, to determine the situation.

Oxygen: thirty man-day supplies of oxygen are kept at High Camp. Oxygen may be given as either 100%, from large or portable cylinders; or mixed with air to an amount of oxygen equal to that in sea-level air, using demand delivery.

Evacuation is done by the Heliocourier, after discussions between the physicians at Kluane and Logan.

Our experience so far has shown that use of prophylactic diamox, insistence on proper hydration and frequent medical examinations have reduced the incidence and severity of acute mountain sickness. We have become much more expert and confident in its prevention and management.

In 1967 all 6 of the support group were ill and 2 were evacuated. In 1969 and 1970 there were 8 and 9 support personnel respectively, and none were ill.

Of the unacclimatized people, the same is true, some evacuations are inevitable (there were 2 in both 1969 and 1970, because of severe acute mountain sickness, out of a total of about 30). Every person evacuated to Kluane has recovered rapidly.

8. The Icefield Ranges Research Project

The Icefield Ranges Research Project has, over the years, gathered a vast amount of data (physical and biological) in studies done in the huge area around Logan. It is clear that much of this work could be of use to any new research project, in whatever discipline.

9. Conclusions

From what has been said above, the following suggestions are offered to those wishing to carry out work at Logan High Camp.

a) Much work — heavy and scientific — can be done by the support group, who may be well qualified to do this work. Some may be given a short training course before they go to the Yukon.

b) Heavy work can only be done by acclimatized people, and even then it takes longer to do than at sea level.
c) Accurate scientific work is *far* better done after 2–3-days' stay.
d) Walking up from Trench, or staging through Divide, are strongly recommended.
e) Installations that need to be fixed on rock may be placed on one of the rocky out-crops above the camp. These are, however, much more exposed to the weather; and as all equipment will have to be hauled up from the Heliocourier landing site, this will almost certainly require the provision of a snowmobile to pull the toboggans, as the distance (⅓ mile), the deep snow, the altitude (17,600 ft), and the height difference (ca. 1,000 ft) would make this a fairly major undertaking.
f) Whenever possible, experiments should be devised that can be run with automatic equipment, or with only one observer — if possible one of the support team — at Logan High.
g) All personnel must be passed physically fit by the physician in charge, before they are allowed up to Logan High.
h) Scientists must be expected to provide money for their own experiments and contribute towards the cost of the entire project. In addition, a charge of $20 daily per person is levied (at Kluane or Logan), while each flight from Kluane to Logan costs $95. The support group are paid, so that any lengthening of the period at which High Camp is open means higher costs, and possible difficulties with college semesters, etc.
i) To prevent overcrowding, confusion, and over-use of the support group, it is obviously important to arrange, where possible, to have different projects going on at different times. It is undesirable, during the short period (mid-July) when there are 10 or more unacclimatized people at Logan High concerned with physiological experiments, that much attention should have to be devoted to other projects. For example, constant hourly meteorological readings are better arranged before and after this short period. No more than 18 people should be at High Camp at one time, and of these, 6 to 8 will be support group.
j) Special equipment needed by the experimenter must be within the dimensions and weight units of the Heliocourier, or must be landed at High Camp by some other means (for example, helicopter). No equipment part should be so bulky that it cannot be handled by the support team using, if necessary, winches, pulleys, a snowmobile, etc.
k) People taken up to Logan High (including scientists and support group) are expected to cooperate as subjects in simple physiological tests.

Acknowledgments: My thanks are due to Dr. Charles Houston for help in the preparation of this communication.

REFERENCES

Clegg, J. 1956, in *Kangchenjunga the Untrodden Peak,* by C. Evans (London: Hodder and Stoughton).

Dill, D. B. 1968, "Physiological Adjustments to Altitude Changes," *J.A.M.A.*, 205, 123–129.

Forwand, S. A., Landowne, M., Follansbee, J. N., Hansen, J. E. 1968, "Effect of Acetazolamide on Acute Mountain Sickness," *New Eng. J. Med.*, 279, 839–845.

Houston, C. 1955, *K2 The Savage Mountain Collins,* London.

McFarland, R. A. 1969, "Review of Experimental Findings in Sensory and Ventral Functions," in *Biomedicine Problems of High Terrestrial Elevations,* U.S. Army R&D Command, ed. A. H. Hegnauer, pp. 250–265.

Pugh, L.G.C.E. 1964, *Man at High Altitude.* Studies Carried out in the Himalaya. Scientific Basis of Medicine Annual Review. British Postgraduate Medical Federation, pp. 33–54.

Pugh, L.G.C.E. 1965, "Metabolic Problems of High Altitude Operation," in *Aerospace Medical Div., Arctic Aeromedical Lab., Nutritional Requirements for Survival in the Cold and at Altitude,* ed. D. A. Vaughan, Fort Wainwright, Alaska, pp. 299–341.

Singh, I., Khanna, P. K., Srivastava, M. C., Lal, M., Roy, S. B., Subramanyam, C.S.V. 1969, "Acute Mountain Sickness," *New Eng. J. Med.*, 280, 175–184.