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EDITORIAL

MAN AND THE MOUNTAINS

The important geographical landmark of Nepal is the high mountains on its north side. The mountains have always attracted the attention and the imagination of man. The 'Third Pole' is what G. O. Dyhrenfurth has called the highest mountain in the world. To climb the high peaks has always been the dream and desire of many mountaineers. Our mountains in the north not only stand as a challenge to human ingenuity and endurance, but in the past have played important role in the commercial and political life and relation between Nepal and Tibet. And consequently the problem of high altitude and its effect to health has always been with us though poorly understood and never properly studied. Kuti and Kerung situated at the height of 14,000 feet (4,268 m) and 9,000 ft (2,743 m) respectively were once very important trading posts at the Nepal-Tibet boarder. Except for Rasuwa and Kodari (both at 6,000 ft, 1,829 m) all other trade routes to Tibet e. g. Nangpa La (19,050 ft, 5,807 m), Kang La (18,515 ft, 5,645 m) Tipta La (19,095 ft, 5,821 m) Bangwa (19,095 ft, 5,821 m) Larke (17,103 ft, 5,672 m) Mustang (10,200 ft, 3,060 m) etc are at high altitudes. Even wars were fought between Nepal and Tibet at high altitude at Nangpa La (19,050 ft, 5,807 m) Neylam (12,000 ft, 3,658 m) Bhairab Kund (12,000 ft, 3,658 m) Kerung 9,000 ft, (2,743 m) and Doju Gadhi (8,000 ft, 2,439 m) in 1789 and again in 1855. The problems of high altitude are not only of historical importance but equally and increasingly being pertinent to our present day life. We have permanent settlements at the heights of 13,000 ft (3,975 m) at Chala a salt traders village at the North-West corner of Nepal; 12,350 ft (3,764 m) at Manang. Perhaps Dolpa villages (16,000 ft, 4,878 m) are the settlements at the highest altitude in Nepal. Moreover, with increasing tourist inflow to Nepal

we have ever increasing number of people climbing and trekking to the heights of 13 to 14 thousand feet (3 to 4 thousand meter) within a few days of leaving the sea level. It is not uncommon for a visitor from America or Japan within a few days of arrival to Kathmandu to fly to Lukla (10,000 ft, 3,000 m) and trek up a couple of thousand of feet above.

The essential feature of visiting or residing at high altitude is the exposure to a lowered barometric pressure, and the hypoxia caused by the lowered pressure of the atmospheric oxygen. The composition of air at all altitude remains the same. But with increasing height the total barometric pressure falls progressively. The barometric pressure at sea-level is 760 mm Hg. which at 6,000 ft (1,800 m) becomes 610 mm Hg., at 14,000 ft (4,200 m) 450 mm Hg. and at the peak of the Mt. Sagarmatha (29,028 ft, 8,847 m) it is only 225 mm Hg. The total barometric pressure is the combined pressure exerted by O₂, N₂, CO₂ and water vapour. As far the diffusion of oxygen into the body is concerned we are more interested with the pressure these gases exert at the pulmonary alveoli. Carbon dioxide is excreted from the blood stream into alveoli and the partial pressure it exerts in the alveoli remains practically constant at 40 mm Hg. Another gas which is always present is the water vapour. The pressure it exerts is the saturation pressure of water vapour at body temperature. Since the body temperature remains constant the partial pressure of water vapour in the alveoli remains constant at 47 mm Hg. These two gases therefore exerts a combined pressure of approximately 90 mm Hg. The pressure of other gases at sea-level in the lung is thus (760-90) = 670 mm Hg. The percentage of oxygen in atmospheric air is unaffected by altitude and remains constant at 21. Since some of the inspired oxygen has been absorbed and metabolized the percentage of O₂ in a dry and CO₂ free alveolar gas sample is only 15%. So if air is breathed at the sea-level the PO₂ in the alveoli is 15% of (760-90) mm Hg = 100 mm Hg. At 6,000 ft (1,800 m) PO₂ in the alveoli is 15% of (610-90) mm Hg = 78 mm Hg. The ascents to high altitude however induces hyperventilation which lowers the PCO₂ from 40 mm Hg. to even 25-30 mm Hg. The combined pressure exerted by CO₂ and water vapour at the alveoli thus comes to about 70 mm Hg. The alveolar FO₂ at 14,000 ft (4,200 m) is about 57 mm Hg. And assuming only air is breathed at the peak of Mt. Sagarmatha the PO₂ is only 14 mm Hg. The PO₂ of the venous blood is 40 mm Hg. So the pressure difference of the O₂ in the alveoli and the venous blood is (100-40) = 60 mm Hg. at the sea-level, which is reduced to (57-40) = 17 mm Hg at 14,000 ft (4,200 m) and at 29,000 ft (8,857 m) is less than the PO₂ of the venous blood. Because of the shape of the Oxygen dissociation curve, the O₂ saturation falls off very gradually as the alveolar PO₂ is reduced, and then more rapidly. The altitude of 5,000 ft (1,500 m) causes no arterial hypoxia and from 5 to 10 thousand feet (1,500 to 3,000 m) there is slight hypoxia, but at higher altitude with successive increment in altitude there is increasingly greater hypoxia. Thus at 6,000 ft (1,829 m) the arterial oxygen saturation is 94.0%, whereas at 14,000 ft (4,268 m) it is 80%, at 15,000 ft (4,500 m) it becomes 78.0% and at 29,028 ft (8,847) the height of Sagarmatha only 22%.

Man has climbed almost all the mountain peaks of the world but prolonged residence seems to be limited to areas at 18,000 ft (5,500m) or below. Whether man is exposed

to high altitude for a short period or for many years, the problem of acclimatization to the high altitude is that of adjustment to a diminished atmospheric oxygen tension. All the physiological processes in acclimatization are ultimately directed to one end: to keep the body adequately supplied with O₂. Several mechanisms are involved in maintaining oxygen supply to the cells of the body as one ascends to the high altitude. Some of the mechanism start immediately, while others take several days or weeks to achieve. Most people acclimatize to high altitude when they ascend gradually and when they undertake physical exertion during the ascent. Gaining height too rapidly if accompanied by over exertion soon after the ascent however may lead to acute mountain sickness within a few hours. The first and the rapid phase of acclimatization starts about 5000 ft (1500 m). The reduction of arterial PO₂ is first detected by the chemoreceptors at the Carotid bodies. It causes the respiratory centre to be stimulated and as a result the depth and frequency of breathing increases. This may be the first thing a mountaineer notices. The resulting fall in PCO₂ produces respiratory alkalosis which shifts O₂ haemoglobin dissociation curve to the left, increasing the affinity of haemoglobin for O₂. The O₂ uptake of haemoglobin in the lungs is therefore increased. The decrease in H⁺ concentration due to fall in arterial PCO₂ is compensated by the excretion of a less acid urine and the blood PH is maintained near normal. Permanent residents at high altitude have normal blood PH. The number of circulating red blood cells increases. This compensation takes some time to develop. The successful Italian expedition to Mt. Sagarmatha noted the haemoglobin value of about 23G% with the hematocrite of 67% to 70%, which it took 30 days to develop. Polycythemia increases the O₂ content of the blood. The other important adaptation mechanism is the increase in the cardiac output so that each 100 ml of blood loses less O₂. In the residents of the high altitude there is increase in number and diameter of the capillaries which makes possible a better uptake of the O₂ at pulmonary level and an easier diffusion to the tissues.

The effect of high altitude on the heart as distinct from the circulatory adjustment have been studied in the residents at 14,000 ft (4, 268 m) in the Andes. Cardiac output as studied by cardiac catheterization was found to be within normal limit (Penaloza et al, 1962). In the acclimatized mountaineers on the Himalayan Scientific Expedition of 1960-61 the cardiac output at 19,000 ft. (5, 800 m) were found normal at rest. The maximum output on exercise was however 25% lower than at sea-level (Pugh, 1962). Rise in pulmonary arterial constriction cause by hypoxia at high altitude has been demonstrated by catheter studies in the Andian and North American subjects (Rotta, A 1961). This is thought to be the explanation of the sometime quite severe right sidedness seen in ECG of the residents at high altitude, and of the hypertrophy of right ventricle and pulmonary artery musculature found at necropsy (Arias-Stella and Saldana, 1963; Recavarren and Arias-Stella, 1964). The right ventricular hypertrophy and the pulmonary hypertension are however not found below 11,000 ft (3,300 m) or below the level of O₂ saturation of 87% (Rotta et al, 1959).

Contrary to the Andian and North American findings the study done among the Himalayan population living between 12 to 13 thousand feet (3,658 to 4, 016 m) in North Bhutan

in 1965 however revealed no clinical evidence of pulmonary hypertension and right sidedness in ECG (Jakson, Turner, and Ward 1967). No catheter study was done in this series.

ECG changes at high altitude have been extensively studied. Jakson and Davies (1960) described it in both European and Sherpa climbers of the British Solo Khumbu Expedition of 1959. The recordings of the ECG of 12 mountaineers at different altitude up to 19,150 ft (5,845 m) showed right axis deviation, and lowering or inversion of T wave in right precordial leads. Milledge (1963) in the study of serial ECG changes in the climbers during 1960-61 Himalayan Scientific and Mountaineering Expedition who spent approximately five months at 19,000 ft (5,800 m) and later for shorter periods at higher altitude up to 24,000 ft (7,316 m) on Makalu showed similar changes of right axis deviation and T wave inversion in the right precordial leads. There was also decrease in the amplitude of QRS voltage which reversed on oxygen breathing. 'The interesting finding was that similar ECG changes to those in the European climbers going from sea-level to the high altitude were seen to develop also in the Sherpas normal residents at 12,000 ft (3,658 m) who accompanied them to 19,000 ft (5,800 m) none of whom showed the commonly accepted changes of right ventricular hypertrophy in their tracing'. In all cases where the ECG was repeated after return to sea-level it had reversed to normal (Milledge, 1963).

So far the physiological study at high altitude has been limited to the study of the effect of lowered PO_2 caused by lowered barometric pressure and gross effect in the circulatory haemodynamics. Lowered barometric pressure may surely have some effect also on the interstitial fluid and tissue tension. This so far has not been studied. It may have some bearing in the development of the cerebral and pulmonary oedema in certain individual at high altitude.

HIGH ALTITUDE PULMONARY OEDEMA AND ACUTE MOUNTAIN SICKNESS

High Altitude Pulmonary Oedema (HOPA) and Acute Mountain Sickness (AMS) are probably clinical variants of the same disorder. These have long been known as hazards to mountain climbers. Occurrence of acute pulmonary oedema in healthy men exposed to high altitude was first described by Hurtado in 1937. But the phenomena did not gain general recognition, nor did it evoke interest of the research workers until the present time. In recent years the medical officers of the Indian Army have gathered much information from thousands of cases occurring among the troops transported from the plain to high altitude in the Himalayan stations. Houston (1960) a distinguished American mountaineer was probably the first to demonstrate high altitude pulmonary oedema by chest X-ray films. Physiological studies of POHA by Fred et al (1962), Hultgren et al (1964) and recently by Roy et al (1969) have contributed much to the understanding of the phenomena.

The disease occurred in those often young healthy subjects arriving at altitude between 11,000 ft (3,300 m) and 18,000 ft (5,500 m). There was a definite time lag of 6 to 96 hours between the arrival at high altitude and the onset of symptoms. During the time lag, the predisposed individual suffered from an antidiuresis, whereas the immune individual passed urine freely. The incidence in large group of men arriving at high altitude under identical circumstances varied from 1.01 to 83.33 per thousand (Madan Lal 1970). An individual predisposed to AMS or POHA invariably suffered from the illness on every subsequent trip to high altitude after a stay at sea level. As a matter of fact the incidence of POHA was higher among the people from the hills in comparison to the plainsmen (Singh et al, 1965). Among the 8 cases reported by Hultgren et al (1962) 6 were acclimatized to high altitude by virtue of their continuous residence (Peruvian-Andes). Pulmonary oedema occurred in them from 9 to 36 hours after returning to an altitude of 12,250 ft (3,734 m) from a stay at sea level which varied from 2 days to 2 months. Among the 101 cases reported by Menon (1965) 65 were those who had spent several months in high altitude, and were then returning after a period of stay in the plain which varied from 12 to 16 days.

Acute Mountain Sickness

(Hull et al, 1965; Harris et al 1966; Hultgren and Lundberg, 1962; Madan Lal 1970): Headache was the commonest and most persistent symptom. Other common symptoms were insomnia, vomiting, anorexia, giddiness, disinclination to work and lack of concentration. Patient may be apathetic, incoherent in speech. Hallucinations and hysterical outburst and other behaviour disorder have been reported especially in those exposed to exercise at heights above 14,500 ft (4,420 m). Blurring of vision, with engorgement of retinal vessels, frank papilloedema and vitreous haemorrhage has been observed (Madan Lal, 1970). Twenty four cases reported by Madan Lal (1970) developed increasing headache, failure of diuresis, increasing breathlessness severe papilloedema stupor, seizure, and ultimately coma and paralysis. The predominant findings in the postmortum in the three who died from this complication were cerebral and pulmonary oedema. Lumbar Puncture done in 34 cases during the illness and after recovery showed increase in the CSF pressure of 60 to 210 mm of water during the illness. Cytology and biochemistry of the CSF were normal.

Pulmonary Oedema of High Altitude (POHA):

Pulmonary oedema often occurs as a part of Acute Mountain Sickness. However, it may occur without any mountain sickness as a prelude. Characteristically, POHA begins with progressive cough and dyspnea. Cynosis may develop and rales are heard on one or both sides in the interscapular areas and spread upper zones. In the early stage the lung bases are usually spared. Heart rate and respiratory rate increase. During sleep breathing had a tendency to become irregular or

frankly Cheyne-Stokes in type, and the patient affected wakes up suddenly with a feeling of suffocation. In fulminating cases the patient feels chokkes, becomes moribund and haemorrhagic pleural effusion may occur at one or both sides (Nanda, 1970).

Chest X-ray films pulmonary densities, usually first confined to middle and upper zones, more predominant on right side. ECG may show evidence of right axis deviation, clockwise rotation and T inversion in precordial leads. At necropsy the main finding has been the oedema of lungs.

Haemodynamic study in patients with POHA showed the moderate increase of the pulmonary arterial systolic pressure (36 to 54 mm Hg), with normal pulmonary artery wedge pressure and left atrial pressure (Roy et al, 1969; Bhatia et al, 1970; Hultgren et al, 1964; Fred et al, 1962). Moreover the postmortum have shown no left atrial or left ventricular dilatation or other evidence of left ventricular failure.

The duration of the incapacitating illness due to AMS and POHA varies from 2 to 5 days. Complete recovery however may take long time 900 cases reported by Madan Lal (1970) 43% became symptom free within 3 days, 26% within 4 to 7 days, 13% in 8 to 14 days. Some took from 4 weeks to 150 days for complete recovery.

The pathophysiological mechanism of POHA and AMS still remains obscure. Arrias-Stella and Kruger (1963) and Roy et al (1965) have postulated that redistribution of blood volume with a shift from the peripheral to the pulmonary circulation in association with increased pulmonary arterial is important for the occurrence of pulmonary oedema at high altitude. It may be significant that 9,000 ft (2,743 m) is the altitude at which hypoxia begins to dominate the control of ventilation and at which arterial PCO₂ begins to fall Boothby et al, 1954). A low PCO₂ causes constriction of peripheral veins (Wood and Boy, 1970) and tends to dilate the pulmonary arterioles (Cross, 1965). Both these mechanisms would lead to a shift of fluid to pulmonary capillaries. Peripheral venoconstriction as a result of exposure to cold may be a contributory factor. It has also been suggested that hypoxic tissue damage to pulmonary alveoli may also be a contributory factor. An interesting feature of POHA is that when exposed to the hypoxic stimulus at high altitude under similar circumstances only a small proportion of person develops this condition. An individual predisposed to AMS and POHA invariably suffered from this illness on every subsequent trips to high altitude. And a significantly large number of cases occurring among persons who returned to the heights after staying in the plain for sometime. Prof. Viswanathan (1970) assumes that it is due to constitutional factor, the nature of which lies in the architecture of the pulmonary vasculature. He postulates that the development of POHA is an abnormal reaction of certain parts of pulmonary vasculature to low P_{O2} at high altitude in susceptible individuals, where as susceptibility may be determined genetically. It becomes manifest in the form of greater pulmonary resistance at precapillary level, presumably as a result of an increased amount of circular muscle fibres in the arterioles of certain areas within the lungs.

Thus AMS and POHA are caused by certain changes in the body caused by exposure to hypoxia, hypobaric condition and hypocapnia which affect principally the lungs, the brain and the kidneys. CNS symptoms are attributed to combination of increased cerebral blood volume, increased CSF pressure and cerebral oedema (Arki and Robinson, 1970). Increased cerebral blood flow in men made acutely hypoxic with 10% oxygen had been observed (Kety and Schmidt, 1948). Similar increase in cerebral blood flow in the individuals exposed to hypoxia at 12,000 ft (3,658 m) has been noted by Roy et al (1970). White et al (1942) demonstrated actual brain swelling in anoxic animal. Madan Lal (1970) and Singh et al [1959] have demonstrated histological evidence of cerebral oedema in patients dying of AMS. Increased cerebral blood flow and increased cerebral oedema may account for the rise in CSF pressure.

Treatment: Mild cases of headache may require only analgesics. Only those with severe headache, vomiting, anorexia and breathlessness require active treatment. Induced diuresis is the main stay of treatment. Frusemide, morphine, and betmethasone has been used with considerable benefit. It is generally agreed that the patient should be removed to lower altitude as soon as possible. And if the qualified medical help is available morphine as well as frusemide should be given parentally. The beneficial effect of morphine might partly be due to the reduction of pulmonary blood volume due to redistribution of blood to the periphery (Roy et al, 1965). Morphine also augment frusemide diuresis in HOPA (Singh et al, 1967). Betmethasone is administered to relieve cerebral oedema. Other measures include bed rest, warmth and immediate administration of 100% oxygen. Complete clinical and radiological clearance of the lungs is attained within three days. When both pulmonary oedema and acute mountain sickness are present together they were benefited more or less simultaneously in each case [Singh, 1970]. It is suggested that the positive-pressure artificial ventilation, which among other thing will raise the pulmonary interstitial fluid pressure may be of real help in severe cases (BMJ, 1972). Indian army has found that a single dose of Frusemide 80mg. given immediately on arrival at high altitude and for two successive morning has a preventive value in AMS and POHA. In a few individuals who pass too much urine after using frusemide and develop weakness, giddiness and cramps the dose is reduced to 40mg. The frusemide cover is not recommended at altitude below 11,000 ft. (3,300m). perhaps it is unnecessary to suggest frusemide cover to all the people going to high altitude except in condition of mass movement like army. But it must be made clear that if one develops symptoms of AMS or POHA the individual should take frusemide 80mg. four hourly until medical help is available. Simple education of the people visiting high mountain as to the dangers of ascending too rapidly, of over exertion, of exposure to cold and of starting up the mountain while suffering from cough and cold might go a long way in preventing this disorder. Knowledge of the symptoms of AMS and POHA and the value of frusemide therapy and the need for the patients to be evacuated to lower altitude might save many lives. Availability of emergency stretchers, oxygen and frusemide with clear instruction in their use in huts at high altitude will allow effectual first aid to be carried out (BMJ, 1972).

In this context of preventing high altitude sickness it is of interest to note the suggestion of Dr. John Dickenson for setting up of a reading room in Kathmandu containing relevant articles where doctors especially those who come as medical officers to high altitude trekking or mountaineering groups will be able to study these disease. This perhaps would best be done by Nepal Medical Association. It may also collect information and stimulate interest in high altitude physiology. Recently we were pleased to have Prof. Paul Cerretelli and Dr. Miserocchi of the department of Physiology, Milan University, both members of the successful Italian Expedition to Mt. Sagarmatha speak to NMA on the subject. I hope this mutually beneficial intercommunication between NMA and the doctors of the mountaineering or trekking group will continue.

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