FURTHER STUDIES OF HIGH ALTITUDE PULMONARY ŒDEMA

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During the past ten years there has been a growing awareness of the occasional occurrence of acute pulmonary œdema as a result of exposure to high altitude. Early observations were made in the Peruvian Andes where a large number of people constantly travel from sea coast to altitudes up to 15,000 ft. (Lundberg, 1952; Bardales, 1955; Lizarraga, 1955; Lizarraga, 1957). A case report of acute pulmonary œdema occurring in a cross-country skier at high altitude in the Continental United States has been published by Houston (1960). Recently the entire problem has been reviewed and 31 additional new cases have been described (Hultgren *et al.*, 1961). The data may be briefly summarized as follows: acute high altitude pulmonary œdema occurs in susceptible individuals who quickly go from sea level to altitudes of 9,000 to 15,000 feet. Acclimatized mountain residents who visit a low altitude area temporarily and then return to high altitude seem to be most susceptible. Most of the Peruvian patients were mountain residents who had spent from 1 to 4 weeks at sea level and then returned to the altitude. Young males under 19 and subjects who have experienced previous attacks of high altitude pulmonary œdema are also susceptible. Most of the episodes in mountaineers occurred upon initial exposure to high altitude, without adequate prior acclimatization. The symptoms usually consist of cough, dyspnœa, weakness and hæmoptysis beginning 12 to 36 hours after arrival at a high altitude. Physical signs include pulmonary râles, cyanosis and tachycardia. Signs of infection are absent. Roentgenograms reveal pulmonary exudates which may be patchy or occasionally diffuse. The central pulmonary vessels are prominent. Cardiac enlargement is not present. Bed rest, oxygen administration, or removal to a lower elevation result in clinical recovery and clearing of the pulmonary exudate in 24 to 48 hours.

Fatal cases have been described, particularly in mountaineers where oxygen has been unavailable. Undoubtedly, many cases of so-called "pneumonia" occurring in mountaineering parties have been instances of high altitude pulmonary œdema.

It is the purpose of this report to describe 8 cases of high altitude pulmonary œdema. These include 2 fatal cases occurring recently in the Continental United States with complete autopsy studies as well as 6 cases from the Peruvian Andes with reasonably adequate electrocardiographic studies.

The Peruvian cases were personally observed by one of the authors (C.L.) at the Chulec General Hospital, La Oroya, Peru, and the methods of study employed are similar to those of a previous report (Hultgren *et al.*, 1961).

Case Reports

Case 1 (*S. S.*). A 6-year old boy who resides at La Oroya (altitude 12,250 feet) entered the Chulec General Hospital on March 16, 1960 complaining of dyspnœa and restlessness. These symptoms had

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appeared during the journey to La Oroya from Lima (altitude 500 feet) where he had spent 2 weeks and had developed a mild cold with rhinitis.

Physical examination revealed a pale, anxious, dyspnœic boy. The heart rate was 170/min., the blood pressure 86/50 mm. Hg, the oral temperature 100°, and the respiratory rate 60/min. Crepitant râles were present over both lungs. No heart murmurs were noted. On March 17, hæmoglobin (Hb.) was 12·1 gm., packed cell volume (PCV) 39, white cell count (WBC) 9,100, and the corrected sedimentation rate 10 mm. The urine specific gravity was 1·019. There was no proteinuria and the urine sediment was normal. Chest roentgenograms taken on March 16 revealed numerous densities in both lungs. The heart was not enlarged (Fig. 1, A).

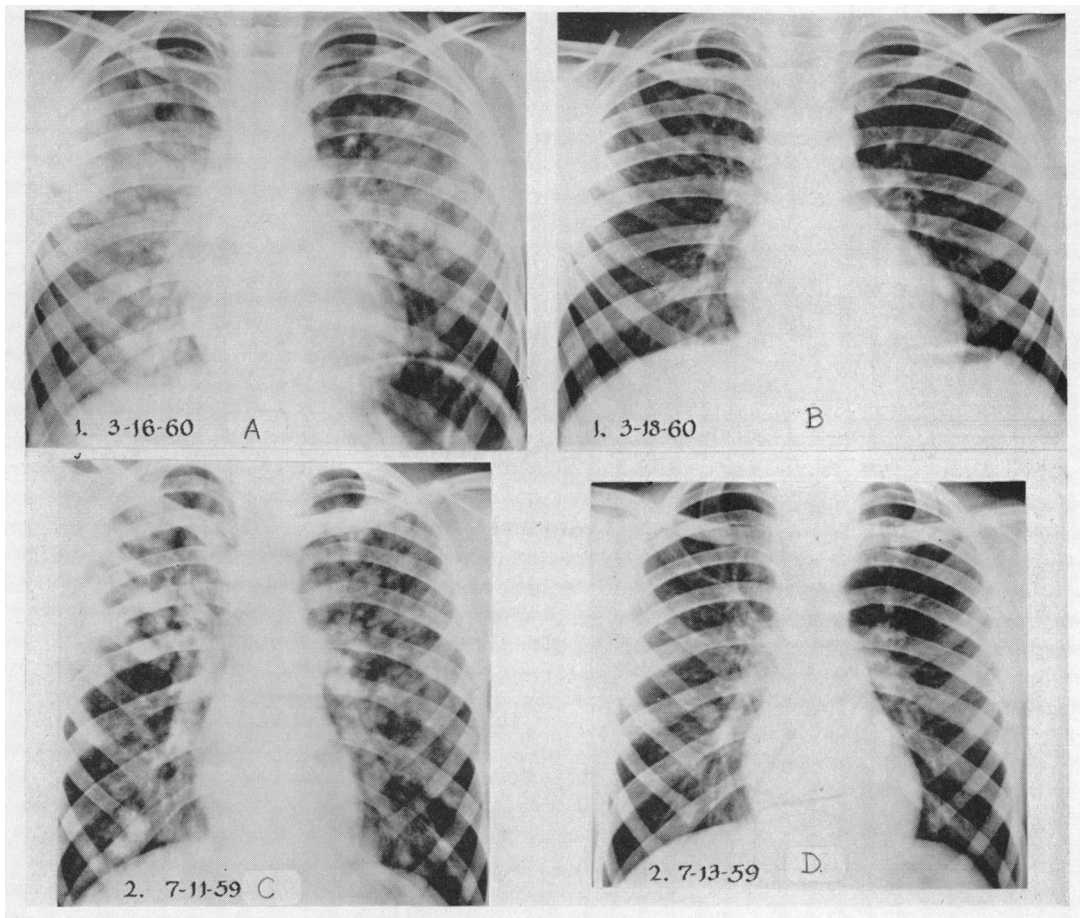

FIG. 1.—Roentgenograms from patients with acute high altitude pulmonary œdema. A and B refer to Case 1 before and after pulmonary œdema respectively. C and D refer to Case 2.

Bed rest, oxygen by tent, and analgesics were employed and the patient rapidly became asymptomatic. He was discharged on March 18. On that day X-rays of his chest revealed complete clearing of the œdema (Fig. 1, B). His hæmatocrit was 40 per cent.

Case 2 (*H. H.*). A 7-year old boy from La Oroya entered hospital on July 11, 1959 because of dyspnœa and chest pain beginning 20 hours after his arrival in La Oroya from Lima. He had spent 2 weeks in Lima on vacation. Initial symptoms consisted of cough, expectoration of yellow serous non-bloody sputum and aching pain in the chest and præcordium. The chest pain was made worse by coughing and deep breathing. Three hours after the onset of symptoms he was noted to be cyanotic.

Physical examination revealed a pale, slightly cyanotic boy in no acute distress. The heart rate was

110/min., the blood pressure 100/60 mm. Hg, the oral temperature 99·9° and the respiratory rate 36/min. The chest was clear to auscultation. No abnormal cardiac findings were noted. The Hb. was 15·4 gm., the WBC 19,100 with a differential leucocyte count of 83 per cent polymorphonuclear (PMN) and 14 per cent lymphocytes. Roentgenograms of the chest revealed densities in both lung fields (Fig. 1, C). An electrocardiogram revealed a heart rate of 136/min., peaked P waves in lead 2 and a pattern compatible with right ventricular hypertrophy. T wave inversion was present in leads V1 and V2.

Bed rest and oxygen administration resulted in rapid clinical improvement. On July 13, the Hb. was 15·0 gm., the WBC 9,000 and the differential leucocyte count was normal. Roentgenograms of the chest revealed complete clearing except for residual congestion of the central pulmonary vessels (Fig. 1, D). The electrocardiogram revealed normal P waves and upright T waves in leads V1 and V2. The pattern of right ventricular hypertrophy persisted. He was discharged from the hospital on July 14.

Case 3 (L. P.). A 3½-year old girl entered the hospital on Nov. 11, 1959. She was born in Lima but had resided for 2 years in La Oroya. After spending a week in Lima, she returned to La Oroya on Nov. 9. The following night she developed dyspnœa, a mild cough, headache and aching pain in the chest and upper abdomen. Early the following morning she was given oxygen by mask at home for 2 hours with some relief but in the afternoon she became markedly dyspnœic and cyanotic. The parents noted audible rhonchi. The child felt cold and was sweating, but there had been no vomiting.

Physical examination revealed a dyspnœic, cyanotic child with audible respiratory rhonchi. The heart rate was 172/min., the oral temperature 99·8° and the respiratory rate 74/min. The blood pressure recorded the following day was 120/80 mm. Hg. Crepitant râles were heard over both lung fields. No abnormal cardiac findings were elicited.

On the day after entry the Hb. was 15·4 gm., the PVC 46 per cent and the WBC 10,700. The sedimentation rate was 6 mm. The urine specific gravity was 1·025 and a trace of protein was present. The total bilirubin was 0·6 mgm., the cephalin flocculation test was negative, and the thymol turbidity test was 0 units. The total serum proteins were 5·8 gm. (globulin 3·2 gm. and albumin 2·6 gm.). The blood urea was 17·6 mg. per 100 ml. On the following day the urine specific gravity was 1·012 and the trace of proteinuria was still present. Roentgenograms revealed diffuse, bilateral pulmonary densities.

Oxygen (100%) was administered by mask and 0·2 mg. cedilanid was given intravenously. In 24 hours clinical improvement was marked and the child was discharged from the hospital on Nov. 14 feeling perfectly well. On Nov. 20 the urine specific gravity was 1·021 and no protein was present.

Case 4 (H. M.). A 7-year old girl entered the hospital on April 4, 1960 because of dyspnœa and præcordial pain of 6 hours duration. She had been born in Ancash (10,100 feet) and at 4 months of age moved to Casapalca (13,700 feet). Two years later she moved to La Oroya. She had 2 attacks of pulmonary œdema the previous year. In the first of these, on March 31, 1959, she had returned to La Oroya after an 8-day stay in Lima. She had no appetite upon arrival at La Oroya and during the night she vomited and began to speak incoherently. At 3 a.m. she coughed up bloody sputum and was noted to be cyanotic, sweating, dyspnœic and extremely weak. She had visited Lima several times previously in the past and had experienced only moderate anorexia and nausea after arrival in La Oroya. Upon admission to the hospital at 5 a.m. on April 1 she was dyspnœic, cyanotic and "flaccid". The heart rate was 140/min., the blood pressure was 85/60 mm. Hg and the respiratory rate was 40/min. The temperature was subnormal. Râles were present throughout both lungs. The Hb. was 16·1 gm., PVC 49 per cent and WBC 12,000 with 83 per cent PMN leucocytes. The corrected sedimentation rate was 9 mm. The urine specific gravity was 1·030. No proteinuria was present. The antecubital venous pressure referred to the mid-chest was 143 mm. saline. Roentgenograms of the chest revealed diffuse densities throughout both lung fields. The P waves in the electrocardiogram were slightly peaked and the heart rate was 150/min.

Bed rest and oxygen administration by tent was accompanied by clinical improvement with disappearance of the cyanosis and dyspnœa. On April 3 she was entirely well and was discharged from the hospital. A repeat examination on April 4 revealed a heart rate of 100/min. and a blood pressure of 100/60 mm. Hg. The chest was clear to auscultation. The urine specific gravity was 1·016. An electrocardiogram recorded on April 29 was normal for this altitude. The second attack, in October 1959, occurred on returning to La Oroya after spending only 2 days in Lima. The findings were similar but milder than on the previous occasion. Bed rest and oxygen administration was accompanied by rapid improvement and the child was discharged from the hospital 24 hours after entry.

Prior to her most recent entry, she had spent 8 days in Lima and on the drive up to the mountains, she was given oxygen by mask for 5 to 15 minutes at Casapalca, Ticlio, Morococha and also upon her arrival at La Oroya at 6 p.m. April 3. She had been somewhat drowsy since leaving Ticlio (15,200 feet). At

3 a.m. on April 4, she developed an increasingly severe dry cough and at 5 a.m. she was dyspnœic but not cyanotic. At 7 a.m. she complained of nausea and præcordial pain and she was brought to the hospital.

Physical examination revealed a restless, dyspnœic child with mild cyanosis. The heart rate was 150/min. and the respiratory rate 46/min. Crepitant râles were present over all lung fields. The Hb. was 14·8 gm., the PCV 44 per cent and the WBC 8700. The corrected sedimentation rate was 15 mm. The urine specific gravity was 1·020. No proteinuria was present. Roentgenograms of the chest revealed bilateral pulmonary densities, more prominent on the left. The P waves in all leads of the electrocardiogram were slightly peaked and the heart rate was 120/min.

Bed rest and oxygen administration by tent was accompanied by prompt clinical improvement. On April 5 she was discharged from the hospital. The PCV was 44 per cent and the P waves in the electrocardiogram had become normal. Roentgenograms of the chest revealed complete clearing of the œdema.

Case 5 (*T. M.*). A 6-year old boy who had lived in La Oroya all his life entered the hospital on July 25, 1959. He had visited Lima for a 3-week vacation and returned to his home on July 24. While in Lima he had noted a slight cough but he had been otherwise well. On the morning after arrival in La Oroya he developed a persistent cough.

Physical examination revealed a pale, slightly cyanotic boy with moderately enlarged slightly erythematous tonsils. There were no other signs of upper respiratory tract infection. The heart rate was 128/min., the oral temperature 100° and the respiratory rate 32/min. Roentgenograms of the chest revealed diffuse densities in the right lung and a few central patches of exudate in the left lung. Bed rest and oxygen by tent resulted in rapid improvement and the patient was discharged from the hospital on July 27.

Case 6 (*J. T.*). A 45-year old Norwegian-born worker in the zinc plant in La Oroya entered the hospital on Nov. 20, 1955. Two days previously he returned to La Oroya from a 2-month vacation in Norway. He had been unable to sleep for the past 2 nights and on the day of entry he developed pain in the left chest and began to cough up frothy pink sputum.

On entry the pulse was 88/min. and the oral temperature was 99·8°. The Hb. was 16·8 gm. and the PCV 48 per cent. The WBC was 8,900 and the corrected sedimentation rate was 3 mm. The urine specific gravity was 1·035. Roentgenograms revealed bilateral fullness of the pulmonary vessels, a small area of increased density adjacent to the lower right mediastinum and diffuse cloudiness of the left middle and lower lung. Bed rest and oxygen administration by tent resulted in rapid improvement and he was discharged from the hospital on Nov. 22.

Case 7 (*C. B.*). A 40-year old white American geologist climbed to Camp Muir (10,000 feet) on Mount Rainier on August 24, 1958. He had experienced moderate acute mountain sickness while climbing Mt. Shuksan (9,038 feet) 2 weeks previously. He spent two nights at this camp, but on August 26 descended to sea level to take care of his wife who had influenza. He returned to 10,000 feet without difficulty, where he camped. Between 3rd and 5th September, he gradually developed a slight cough, blood-tinged sputum, insomnia and dyspnœa. On the morning of September 5 he was unable to talk without difficulty, his breathing was rasping with an expiratory grunt. Upon the advice of a physician a diagnosis of pneumonia was made and he was given penicillin intramuscularly and he became semicomatose, the temperature rose to 101° and he died without regaining consciousness on the morning of September 6. Autopsy showed the following. The heart weighed 450 gm.; the right atrium was markedly distended with post-mortem clotted blood, and the right ventricle was moderately distended. All branches of the coronary arteries were thin-walled and uniform except for a tiny hyaline plaque in the left anterior descending branch. The myocardium was normal. There was no evidence of infarction. The right lung weighed 1,300 gm. and the left 1,100 gm. Both lungs were boggy and œdematous and the cut surfaces exuded frothy fluid. No emboli were seen in the dissected branches of the pulmonary arteries. The liver weighed 1,800 gm. and appeared normal. Microscopic examination of the lungs revealed in all sections filling of the alveoli with red cells and pink œdema fluid, and in many alveoli strands of fibrin were present. A diffuse PMN exudate was present not only in the interstitial tissue but in the alveolar exudate. Only a moderate number of mononuclear cells were seen. No hyaline membranes were present. The vessels were distended and congested and thrombi were seen in many of the small branches of the pulmonary artery. In many of the dilated capillaries organized thrombi were present. These thrombi consisted of masses of platelets, fibrin, leucocytes and erythrocytes (Fig. 2 and 3). The small bronchi showed an infiltration of neutrophils in the mucosa. The basement membrane was intact but the epithelium was denuded. In the areas of pneumonitis some of the nucleoli of the white cells were smudged, suggestive of hæmatoxylin bodies. Numerous megakaryocytes were present. A tiny area of lymphocytic interstitial myocarditis was noted in the right upper myocardium. The liver and spleen were normal except for passive congestion. Cultures of the lung revealed no pneumococci but the

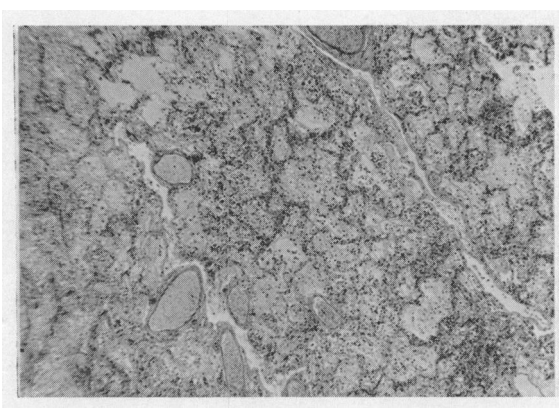

FIG. 2.—Acute pulmonary œdema in case 7 (C.B.). Note congested vessels and inflammatory exudate. Dark streaks are thrombosed small vessels.

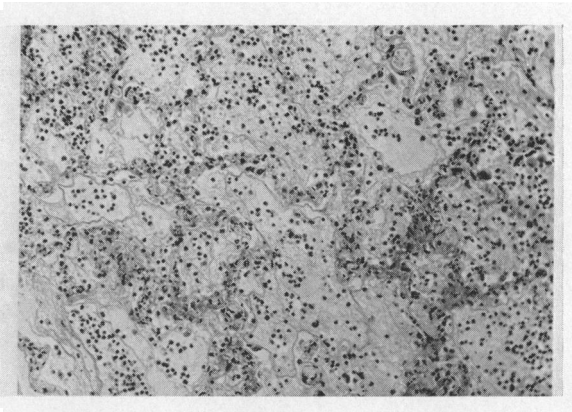

FIG. 3.—High power view of acute pulmonary œdema in case 7 (C.B.) showing pneumonitis. Darker linear masses are thrombosed vessels.

patient had received penicillin prior to death. The autopsy diagnoses were: 1. Pneumonitis, acute, diffuse 2. Pulmonary œdema. 3. Cor pulmonale, acute. 4. Thrombosis of small pulmonary arteries. 5. Bronchitis, acute.

Case 8 (D. C.). A 9-year old boy died during the night while on a camping trip in the Sierra Nevada mountains, California, at an elevation of 9,400 feet. His only childhood illness had been attacks of "croup" for which he had been given calcidrine. He had experienced no attacks for the preceding 2 years. There was no history of asthma. He had been in good health except for a sore throat on July 23, 1960, for which he was given aspirin on the two subsequent days. On July 24 he ascended to 9,400 feet where a camp was made. The following afternoon during a hike he complained of some dyspnœa. Upon returning to camp he seemed well, ate a good meal and retired to his tent. At midnight, however, he awakened suddenly with breathlessness which increased over the next 2 hours until he died.

At autopsy, the lungs were heavy with diffuse pulmonary œdema with occasional areas of focal hæmorrhage. Blood-tinged, frothy fluid was present in the bronchial tree, but there was no evidence of bronchial obstruction apart from the œdema fluid. A 2·5 cm. right hilar lymph node contained a soft caseous centre. The spleen was moderately enlarged.

Histological studies demonstrated marked pulmonary œdema with capillary congestion, stasis and some focal hæmorrhages, but no evidence of pneumonitis. As in the previous case, numerous megakaryocytes were present. The bronchial mucosa was the site of an acute bronchitis with denudation of the mucosa in several areas and heavy infiltrate of mononuclear cells and lymphocytes. The hilar lymph node was a typical caseous node of tuberculous origin. Acute passive congestion of the liver was present. There were numerous focal areas of acute interstitial myocarditis confined to the myocardium of the right ventricle. The inflammatory cells consisted of PMN leucocytes, and numerous mononuclear cells with probably a moderate number of eosinophils. There was little evidence of muscle cell destruction. Multiple sections of the left ventricle, septum and atrial myocardium revealed no inflammatory changes in these areas. The endocardium and valves were normal. Careful examination of all the other organs including the brain revealed no evidence of a systemic arteritis. Unfortunately organ weights were not determined.

DISCUSSION

Six of the 8 patients were acclimatized to high altitude by virtue of continuous residence in the area either since birth or for at least the preceding 2 years.

The attacks of pulmonary œdema in the 6 Peruvian patients occurred from 9 to 36 hours after returning to an altitude of 12,250 feet from a stay at sea level. The sea level stay varied from 2 days to 2 months. Case 7 also had spent 5 days at sea level prior to his return to 14,000 feet, but he previously had spent only 2 nights at 10,000 feet which may have been insufficient time for acclimatization.

Two patients had electrocardiograms recorded during 3 attacks of acute pulmonary œdema and following recovery. One record (Case 2) was characteristic of, and another (Case 4) suggestive of right ventricular hypertrophy. During acute pulmonary œdema, sinus tachycardia and prominence of the P waves, particularly in leads II, AVL and V2, was observed. Following recovery the heart rate slowed, P waves decreased in amplitude (mean decrease in 3 episodes 0·5 mm.), R waves in V1 became lower and a slight decrease in the degree of right axis deviation occurred. These transient changes are similar to those observed in other cases of acute pulmonary œdema (Hultgren *et al.*, 1961), and are compatible with an acute increase in pulmonary artery pressure during the acute illness.

X-ray studies in the 8 episodes of pulmonary œdema in Peru revealed the occurrence of bilateral pulmonary densities with prominence of the central pulmonary vessels in all cases. Complete clearing of the process was evident in 2 to 3 days. Cardiac enlargement as manifested by a cardiothoracic ratio of greater than 50 per cent. was not present in any patient. Clearing of the œdema was not associated with any consistent change in heart size. In 2 instances (Cases 1 and 8) rather obvious *increases* in heart size occurred upon recovery. Recurrent episodes may occur indicating an individual predisposition to the development of acute high altitude pulmonary œdema. Case 4 had 3 episodes.

In spite of the available clinical data and autopsy information, the ætiology of high altitude pulmonary œdema is unknown. The pathology of high altitude pulmonary œdema either in man or experimental animals has not been described. The observations of Kritzler (1944) are pertinent to this problem. He reported on a necropsy study of 27 cases of acute high altitude anoxia. These aircrew members had experienced failure of oxygen equipment at altitudes between 24,000 and 31,500 feet. In most instances the period of anoxia was short but in 7 cases the duration was possibly 90 minutes or longer. Congestion of the pulmonary circulation was the most constant pathological change in the lungs. It was severe and diffuse in 62 per cent. Dilatation of the right ventricle was present in 74 per cent but in no instance was dilatation of the left ventricle observed. Pulmonary œdema was extensive in 4 cases and noted microscopically only in 13 cases (48%). In 8 cases the combined weight of the lungs exceeded 1600 gm. No areas of pneumonitis or myocarditis were noted. In only one case was a demonstrable organic disease noted and that consisted of severe coronary arteriosclerosis. Similar data have been reported by Mueller and Rotter (1942).

On the basis of the information presented in this paper and experimental studies of the mechanism of production of acute pulmonary œdema, either acute elevation of left ventricular diastolic pressure or pulmonary venous constriction could be ætiologic factors. The following factors may also be important in causing the syndrome: (*a*) peripheral vasoconstriction and shift of blood volume to the thorax due to anoxia; (*b*) increase in blood volume; (*c*) increased cardiac output due to anoxia; (*d*) undue physical activity; (*e*) myocardial anoxia; (*f*) increased capillary permeability due to infection or hypoxia.

A possible objection to the presence of an elevated left ventricular diastolic pressure in these patients could be the observation that heart size was not increased during the acute attack and that heart size did not consistently decrease upon recovery. However, Jackson (1951) has noted that there may be little change in heart size or shape during pulmonary œdema and with recovery.

If high altitude pulmonary œdema were due entirely to an elevation of left ventricular diastolic pressure without myocardial dysfunction, one should probably not consider the situation one of ordinary left ventricular failure. Considerable evidence has now accumulated to indicate that left ventricular filling pressures may be elevated to levels capable of producing pulmonary œdema by hypervolæmia and increased work loads with preservation of normal myocardial function. Such filling pressure elevations are adaptive changes to meet increased cardiac work rather than manifestations of myocardial weakness. Experimental data to establish this concept have been obtained in animals (Sarnoff and Sarnoff, 1952) and man (Eichna *et al.*, 1954), and the clinical counterpart probably is present in acute glomerulonephritis (De Fazio *et al.*, 1959). The existence of a similar

situation in high altitude pulmonary œdema remains to be examined by appropriate hæmodynamic studies.

If left ventricular failure due to myocardial weakness or overload is present in acute high altitude pulmonary œdema, the administration of rapidly acting digitalis glycosides should result in some improvement, for digitalis has been shown to be effective in acute heart failure produced in a previously normal heart (Selzer *et al.*, 1953). The evidence on this point so far has been difficult to evaluate. In a previous study (Hultgren *et al.*, 1961), a digitalis preparation was administered during 5 episodes. In 3 patients, digitalis preparations were given without demonstrable effect, and in 2 instances, possible beneficial effects were observed. Case 3 in the present report was given cedilanid but the subsequent improvement could have been due to the oxygen and bed rest.

It is possible, however, that pulmonary venous constriction induced by hypoxia may be the fundamental causative mechanism. This would result in elevation of pulmonary capillary pressure without elevation of left ventricular diastolic pressure. The experimental evidence supporting such a possibility has been examined in a previous report (Hultgren *et al.*, 1961).

An infectious pneumonitis, bacterial or viral, while it may predispose an individual to pulmonary œdema, does not seem to be a causal factor in most of the reported cases for the following reasons: (*a*) lack of a history of a pre-existing upper respiratory tract infection in a majority of cases; (*b*) infrequency of clinical evidence of infection such as chills, high fever, leucocytosis or purulent sputum; (*c*) complete clearing of the œdema with bed rest and oxygen alone and ineffectiveness of antibiotics in situations where oxygen was not available; and (*d*) frequent occurrence of acute pulmonary œdema in mountaineers who had been in remote areas for many days where chances of exposure to an infected person were unlikely.

It would appear that the myocarditis noted in Case 8 was an incidental finding not ætiologically related to the occurrence of the acute pulmonary œdema because the areas of myocarditis were focal and were confined to the right myocardium and there was no gross evidence of myocarditis or unusual dilatation of the left ventricle or left atrium. It is possible that the focal myocarditis was of viral origin and related to an upper respiratory infection prior to death.

The data presented in this paper demonstrate that pulmonary œdema can be a serious and fatal complication of rapid exposure to high altitude and that it may occur in the Continental United States at elevations as low as 9,000 feet. Physicians and mountaineers should be aware of the early symptoms and signs. Susceptibility is high in individuals who have had prior episodes of high altitude pulmonary œdema, acclimatized residents of high altitude areas who have spent from 1 to 4 weeks at sea level, young males under 19, and any individual who rapidly ascends to an altitude in excess of 9,000 feet and immediately upon arrival engages in vigorous physical activity. Since the role of infection remains unknown, trips to high elevations should not be made by persons suffering from viral infections or pneumonitis. Gradual acclimatization should be observed. Undue physical exertion at a high altitude should be avoided for the first 48 hours after arrival. The appearance of early signs and symptoms of acute pulmonary œdema should dictate prompt evacuation to a lower altitude. If this is not possible, absolute bed rest and continuous oxygen administration are indicated.

Despite the lack of evidence for their beneficial effect, the following additional measures may also be employed:

1. Parenteral rapidly-acting digitalis preparations such as ouabain, digoxin, or cedilanid.
2. Parenteral penicillin, or a broad spectrum antibiotic.
3. Parenteral mercurial diuretics such as thiomerin.

Morphine and codeine are probably contra-indicated because they depress the respiratory centre, and the application of tourniquets to produce a "bloodless venesection" because of the hypotension found in most of the patients.

SUMMARY

Six patients with acute high altitude pulmonary œdema are described; they were 5 children and one adult, residents of the Peruvian Andes.

All were acclimatized to a 12,250 ft. elevation but developed pulmonary œdema upon return from a stay at sea level varying from 2 days to 3 months.

Clinical symptoms appeared from 9 to 36 hours after arrival and consisted of dyspnœa, cough, nausea, vomiting, chest discomfort and hæmoptysis.

Physical findings included cyanosis, tachycardia, hypotension, pulmonary râles but no evidence of heart failure or pneumonia.

Roentgenograms revealed pulmonary vascular congestion and patchy pulmonary densities. Cardiac enlargement or a consistent decrease in heart size with recovery was not seen.

Electrocardiograms which were suggestive of acute right heart strain at the time of entry became normal upon recovery.

Bed rest and oxygen administration resulted in prompt, complete recovery with clearing of the roentgenological signs in 24 to 72 hours.

Two fatal instances of probable acute high altitude pulmonary œdema occurring at elevations of 9,400 feet and 14,000 feet are described with a report of the autopsy findings.

One patient demonstrated, in addition to severe confluent pulmonary œdema, a diffuse pneumonitis and thrombi in small pulmonary arteries and capillaries. The histological findings suggested the possibility of a viral pneumonitis facilitating the occurrence of the pulmonary œdema.

The mechanism of acute high altitude pulmonary œdema is unknown. In the majority of cases there is no evidence of an underlying pneumonia.

Mountaineers, previously acclimatized residents of high altitude areas, especially children, returning to the altitude after a short stay at sea level, and subjects who have experienced previous attacks should be aware of the possibility of acute high altitude pulmonary œdema whenever a rapid ascent is made to an altitude in excess of 9,000 feet.

Gradual acclimatization should prevent most attacks. Treatment should consist of prompt removal to a lower elevation, absolute bed rest and oxygen administration.

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Addendum

Since the preparation of this report, catheterization studies in one subject with acute high altitude pulmonary œdema revealed pulmonary hypertension with a normal left atial pressure. Pulmonary artery wedge pressures could not be determined. This observation suggests that left ventricular failure may not be an important causative factor.