CHANGES OF BLOOD CELLS AT HIGH ALTITUDE (II)

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THOSE who live at sea-level may suffer from mountain sickness when they go up suddenly to high altitudes. As one of the physiological responses to high altitude at this time, it is certified that red cell counts decrease and this is called a primary response of the physiological body to high altitudes. But they can reach high altitude without any complaints of mountain sickness, if they have a one week resting period at sea-level after they have previously stayed about one week or so at high altitude which has made them suffer from mountain sickness.

It was ascertained from our previous data¹ that RBC (red blood cell) counts in the blood increase at this second exposure to high altitude. This red cell increase is called a secondary response to high altitudes. As a serial study, it is now postulated whether it would be reasonable or not for acquiring a good acclimatization, when they move up to high altitudes immediately after they have returned from the first climb. Three healthy young adults were subjected to this study. One stayed in the Himalayas (5000 meters above sea-level) about three weeks, and one went on a one day trip to the top of Mt. Fuji (3776m) in Japan two weeks before the climb according to this plan.

The altitude which was planned was Mt. Kazbek (5030m) and Mt. Elbrus (5650m) which are located in USSR near the Black Sea, from July 27 to August 12. The author examined the red cell count, white cell count, platelet count, hematocrit, blood smear and as a blood coagulation factor, thrombotest. The author made the auscultation of the heart sound with a stethoscope and examined the splitting of the second

heart sound.

METHOD EMPLOYED

Blood was aspirated from the cubital vein with a plastic syringe from three healthy young adults. One of these returned to Japan after the first climb. RBC (red blood cell), WBC (white blood cell) and platelets were counted directly using a microscope (Nikon LH-101). Rees-Ecker's solution and Türk's solution were used. Blood smears were performed and fixed with methyl-alcohol, which were stained in Keio University Hospital after returning to Japan and differentially counted by a hematologist. Blood hematocrit was measured using a battery-driven electric razor which was modified by the author conveniently as in figure 1. The batteries were changed at each time of analysis and exactly ten minutes was required for the rotation of the micro hematocrit tube. Thrombotest was performed according to the Owen's method. Plastic tubes were used. As an anticoagulant, 0.5ml of 3.1% sodium citrate solution was used and 4.5ml of blood was aspirated into this tube. RBC and platelets were counted from this tube simultaneously.

RESULTS

<Symptom>

The subject who experienced the high altitude of the Himalayas one month before this plan, didn't developed mountain sickness at this time. The other two subjects suffered from nausea, headache, and anorexia when they first reached the height of 4200 meters. The second attempt to reach high altitude was performed by these two subjects including the author, immediately after returning to sea-level. Neither the author nor the man who experienced the height of the Himalayas complained of nausea or headache.

Key Words: High Altitude
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Fig.1. Blood hematocrit was measured using a battery-driven electric razor which was modified conveniently.

<Auscultation>

On auscultation at the sea-level there was no splitting of the second heart sound in any of the three subjects even after extreme exercise. With the first exposure to high altitude, two subjects other than the man who experienced the Himalayas recorded the splitting of the second heart sound when they first reached the height of 3000 meters above sea-level on July 29. On August 3, after descending from the height of 4200 meters down to that of 3000 meters, no splitting was heard in either subject. With the second attempt to the next altitude, on August 7, after slow movement from 3700 meters to 4100 meters, they all showed the splitting even after taking a rest of four hours. On August 8, they all showed splitting of the second heart sound about one hour after they climbed up from the base camp of 4100 meters to the point of 5000 meters and climbed down to the same camp. As they took a rest during the next 24 hours on August 9, the splitting disappeared and

they succeeded in the ascent to the summit of 5650 meters above sea-level.

<RBC Change>

The subject who experienced the Himalayan climb showed the increment of RBC count from the first exposure to the altitude in this plan, and showed a strong response to the second exposure, too. On the other hand, the remaining subjects showed a decrease in RBC count on the first climb. The author himself didn't show an increase in RBC at the second exposure to high altitude. (Fig. 2)

<Hematocrit>

While the subject who experienced the Himalayan climb showed an increment of hematocrit value, the other subjects showed a decrease of it. The difference between them was prominent. (Fig. 2)

<WBC>

All subjects showed a tendency toward leucopenia even after the descent from the second attempt. (Fig. 2). Blood smears revealed the

Fig. 2. Change of RBC (red blood cell) counts, Ht (hematocrit), WBC (white blood cell) counts were shown. Time schedule and height relationship are shown at the bottom of the figure.

— The subject who experienced the high altitude of the Himalayas one month before this plan
 ---- The subject who went on a one day trip to the top of Mt. Fuji (3776 m) in Japan two weeks before this plan
 - - - The author

increment of the four and five segmented leucocytes. This change of segmentation number (so called the left shift) was indicated as an index ($\text{seg3} + \text{seg4} + \text{seg5} / \text{stab} + \text{seg2}$), which is originated by the author. (Fig. 3) The percentage change of lymphocytes, monocytes and eosinocytes showed no remarkable change. (Fig. 3)

<Platelets>

At the first and second exposure to high altitude, they all showed a thrombocytopenic tendency. (Fig. 4)

<Thrombotest>

The percentage value of thrombotest decreased at high altitude in all subjects, that is to say, defects of coagulation factors (II, VII, IX, X) occurred at high altitude. (Fig. 4)

DISCUSSION

The subject who experienced the height of the Himalayas three weeks before this plan, showed the increment of RBC count. Other subjects

showed an anemic tendency during the first exposure to the altitude. This anemic tendency is called the primary response. After returning to sea-level, because they did not take a rest and immediately started the next climb, there never arose the secondary response to high altitude, except in the man with Himalayan climbing experience. It was clear that, to attempt the next altitude, more than one week rest would be required after the ascent of the first mountain. It was the same tendency as the author's previous report¹ that leucopenia arose at high altitude, but it was still unknown why the segments of white cells showed the left shift. For the estimation of platelet count, a quick measurement and the use of plastic tubes was necessary. *E. Genton*² demonstrated an increased tendency of the platelet adhesiveness and a decrease of platelet count at high altitude. It is also shown in this present paper that platelet count decreased according to the altitude.

Fig. 3. The index $[(\text{seg 3} + \text{seg 4} + \text{seg 5})/(\text{stab} + \text{seg 2})]$ was introduced to indicate the change of the segmentation number (so called the left shift). The percentage change of lymphocytes, monocytes and eosinocytes showed no remarkable change.

— The subject who experienced the high altitude of the Himalayas one month before this plan
 The subject who went on a one day trip to the top of Mt. Fuji (3776 m) in Japan two weeks before this plan
 --- The author

As a coagulation factor, the author has selected to use the thrombotest. Coagulation factors (II, VII, IX, X) can be checked by this method. A prolongation of these factors at high altitude occurred. This may be a reasonable response for avoiding hypercoagulability of those who reached a state of polycythemia at high altitude. *J. Somerville*³ reported patients with cyanotic congenital heart disease showed polycythemia, thrombocytopenia and some coagulation defects.

The splitting of the second heart sound can not be accepted in healthy adults on auscultation, but as in the patient of atrial septal defect in whom shunt-flow across the atrial septum occurs, the pulmonary blood flow is more than the systemic flow, so the pulmonary valve closes slower than the aortic valve, and then the splitting occurs. It is supposed in this author's report that the pulmonary blood volume is

increased more than the systemic blood volume as a result of adaptational response in the human body to high altitude. There are some reports^{4,5} that a shift of the blood volume to the pulmonary circuit occurs in those who have symptoms of high altitude pulmonary edema. It was clear from my auscultation that all subjects in this present paper were not in a state of pulmonary hypertension, because the pulmonary component in the splitted second heart sound was not high pitched.

CONCLUSION

1. After descent from the first mountain, a term of resting (more than one week) would be necessary prior to the succeeding attempt at high altitude.
2. Platelet count decreases at high altitudes.
3. As a coagulation factor, the value of thrombotest decreases at high altitude.

Fig. 4. Change of platelet counts and thrombotest value was shown.

- The subject who experienced the high altitude of the Himalayas one month before this plan
- The subject who went on a one day trip to the top of Mt. Fuji (3776 m) in Japan two weeks before this plan
- - - The author

4. The splitting of the second heart sound occurs at high altitude, which indicates an increase of the lung blood volume over the systemic blood volume.

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