Acta orthop. Scandinav. 37, 117–121, 1966.

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ACID-BASE STATUS OF THE INTRAMEDULLARY BLOOD IN IMMOBILIZED EXTREMITIES

A Preliminary Report

By

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Received 27.viii.65

When an extremity is immobilized, osteopenia appears in the bone tissue and atrophy in the musculature. This is a generally known fact, which has been the subject of much research. It is commonly believed that immobilization leads to circulatory stasis, with reduction of the pH, and that the increased acidity favours increased bone resorption (*Neuman & Neuman* 1958, *Nordin* 1960). But it has been shown that the rate of new bone formation appears to be normal in immobilization (*Engström & Amprino* 1950, *Slack* 1954, *Heaney & Whedon* 1958). The resorption, on the other hand, is increased, which explains the loss of bone substance.

The present investigation was carried out in order to demonstrate possible changes in the acid-base status of the intra-osseous blood from an immobilized extremity. The blood was obtained from holes drilled into the marrow cavity of the tibia near the distal metaphyseal area. This blood is a composite blood, containing arterial, capillary (from the sinusoids) and venous blood (from the great collecting vein in the centre of the marrow canal). It is not the blood which is in closest contact with the bone surfaces, where resorption takes place or new bone is formed, but it would seem to be closely related to this blood. We have no exact knowledge as to the cortical flow in the diaphysis of a long bone, but it is possible that the direction of flow through the vascular canals of the cortex varies according to whether the musculature is at rest or at work (*Valderrama & Trueta* 1965). The blood which reaches the marrow cavity via the nutrient artery has a constant direction of flow but varies in quantity.

MATERIAL AND METHODS

Rabbits weighing about 2 kg were used. The left hind leg was immobilized in one of the following ways: resection of one centimetre of the calcaneus tendon, resection of the sciatic nerve, or fixation of the leg in plaster of Paris, with the knee joint in the flexed position and the ankle joint in the intermediate position. After periods of immobilization varying from 4 days to 4 weeks, the animals were anaesthetized with Nembutal® and heparinized. They were then connected via a tracheotomy to a respirator and breathed atmospheric air. The common carotid artery was prepared free and a catheter was introduced, through which arterial blood was obtained. Holes were drilled with a dentist's drill through the corticalis into the marrow cavity at exactly the same points distally of the front sides of both tibiae. Heparinized capillary tubes were used for sampling; they held about 50 microliters and were introduced into the marrow cavity through the holes. The blood in the first tube was discarded on account of its content of fat and cells from the bone marrow. From each tibia and from the art. carotis, three or four capillary tubes full of blood were taken.

Astrup's technique was used in analysing the blood samples. It permits the determination of the actual pH and, after equilibration with known CO_2 mixtures, of the actual pCO_2 and the standard bicarbonate in small volumes of blood *(Siggaard-Andersen et al.* 1960, *Siggaard-Andersen* 1962).

RESULTS

The results reported here refer to our preliminary experiments and the investigation is being continued by one of us (Semb) for the purpose of obtaining more information about the blood changes found.

The actual pH was obtained in all the experimental animals, though at the beginning of the series of experiments the blood samples were not always equilibrated. As regards the actual pH in the blood from each leg, the results are best shown in the diagram in Figure 1, which illustrates the pH differences in blood from immobilized and free tibiae, after the tibia had been immobilized for different periods. The pH in the control tibia was made equal to 0. The diagram shows a clear tendency to higher pH values in intramedullary blood from the immobilized tibia for periods of immobilization longer than 10 days. The standard bicarbonate values in blood from the right and left tibiae showed no certain variations. The differences in pH were due to the fact that the pCO_2 was lower on the immobilized side. See the diagram in Figure 2, which shows the relations between the actual pH and the pCO_2 in blood from immobilized and free tibiae.

In four cases the right sciatic nerve was prepared free on a level with the hip joint (after the above-mentioned analyses had been performed) and the nerve was subjected to Faradic stimulation for 2

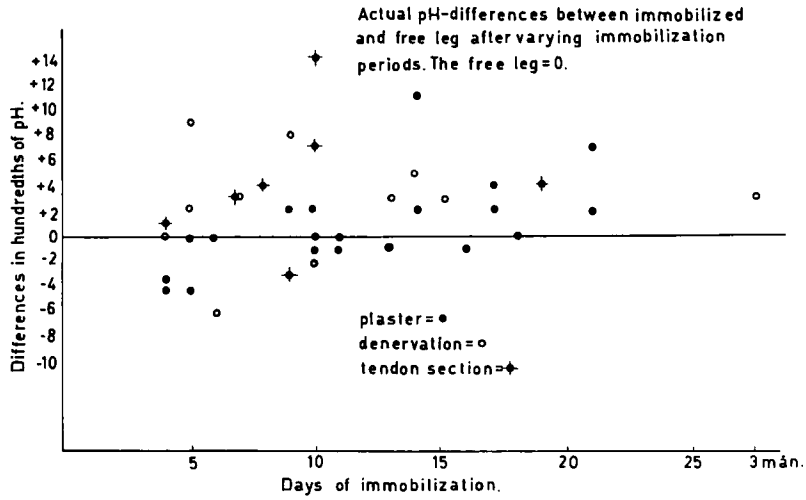

Figure 1.

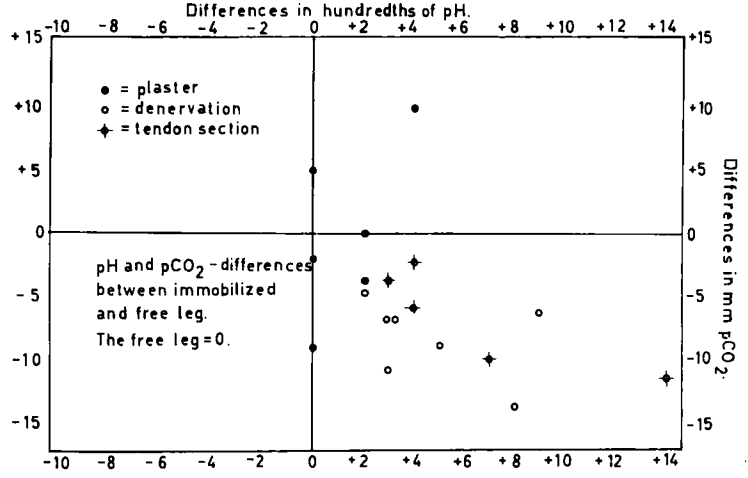

Figure 2.

minutes. A tonic cramp arose in the musculature of the extremity. Immediately after this cramp, fresh blood samples were taken from the marrow cavity of the right tibia. Owing to the muscular cramp, there was a displacement of the standard buffer line to the left, on account of a reduced standard bicarbonate, indicating a metabolic acidosis. In a couple of cases there arose a general metabolic acidosis, which could be observed in the arterial blood as well.

DISCUSSION

This investigation has shown that, when an extremity is immobilized, there will be increased alkalinity in the intramedullary blood. The rise in pH is connected with the lower carbon-dioxide tension in the same blood. This change in the acid-base status of the blood cannot be explained in specific terms, but some views may be quoted. Owing to the fact that the musculature on the immobilized side is inactive, its blood flow is reduced to a minimum. For this reason, it is possible that relatively more arterial blood is shunted through the bone. A more rapid flow results in a more rapid removal of carbon dioxide and less use of the oxygen in the blood. In order to shed more light on these problems, the 0_2 saturation of the blood should also be determined and an investigation of this kind has been commenced by one of us (Semb).

However, the investigations reported in the introduction argue against less use of the blood; they showed that in immobilization osteopenia there seems to be normal formation of bone in combination with increased resorption. Both new formation and resorption imply high metabolic activity.

The pH observed in the marrow cavity, however, is not necessarily equivalent to the pH at the site of the metabolically active processes in the actual bone tissue. Large pH gradients may exist. However, it is interesting to note that the pH is so much higher in the marrow cavity with mobilization, as one might have expected that it would have been normal or even lower than normal, owing to the addition of acid venous blood from resorption foci in the bone tissue.

The experiments have yielded results which cannot yet be completely explained but at any rate they have not confirmed the theory that the bone resorption in inactivity osteoporosis is caused by local acidosis in the bone tissue. The experiments primarily involve a new approach to the investigation of the pathophysiology of bone tissue.

SUMMARY

The pH and pCO_2 of intramedullary blood from the tibiae of rabbits were investigated by Astrup's micro-method. One of the hind legs of each rabbit was immobilized in different ways (nerve resection, tendon resection and fixation in plaster of Paris). It was then possible to observe that immobilization leads to increasing alkalinity of the blood in the tibia on the immobilized side, owing to a lower pCO_2. The results are discussed.

RESUME

Le pH et le pCO_2 du sang intramédullaire du tibia de lapin a été examiné par la micro-méthode d'Astrup. Une des pattes arrière de chaque lapin a été immobilisée de différentes manières (résection de nerf, résection de tendon et fixation dans la plâtre de Paris). Il a été alors possible d'observer que l'immobilisation conduit à une alcalinité accrue du sang dans le tibia du côté immobilisé due à un pCO_2 plus bas. Discussion des résultats.

ZUSAMMENFASSUNG

Der pH und pCO_2 intramedullären Blut der Tibia von Kaninchen wurde mittels Astrups Mikromethode untersucht. Einer der Hinterfüsse jedes Kaninchens wurde in verschiedener Weise ruhiggestellt (Nervresektion, Sehnenresektion und Gipsverband). Es war dann möglich zu beobachten, dass Ruhigstellung zu einer erhöhten Alkalinitet des Blutes in der Tibia auf der ruhiggestellten Seite wegen eines herabgestzten pCO_2 führte. Die Ergebnisse werden besprochen.

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