DYNAMIC STRUCTURE OF THE BLOOD FLOW IN THE SMALLEST CEREBRAL VEINS

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With respect to its composition and the properties of its individual components, blood is a very complex liquid. Its motion in different blood vessels is therefore very complex in character, and it has attracted the attention of research workers for a long time. However, the available techniques for intravascular observations are very limited. Special methods are needed for such observations to be made. In the investigation described below a contact optical system and video technique were used. In this way hitherto unknown features of the dynamic structure of the blood flow in the veins could be observed.

EXPERIMENTAL METHOD

Experiments were conducted on seven albino rats weighing 180-230 g. The animals were anesthetized with pentobarbital (50 mg/kg, intraperitoneally). The animal's head was fixed in a stereotaxic frame. Two rectangular burr-holes measuring 4 × 6 mm were drilled in the parietal bone of the skull on both sides of the sagittal sinus. The dura was removed. The brain suface was continuously irrigated with Krebs–Henseliet solution at 37°C. For direct observation and for filming a contact epiobjective was used, and placed in contact with the brain surface in order to study and take motion pictures of the moving blood. A thin layer of Krebs–Henseleit solution was always present between the lens of the epiobject and the brain surface. This movement of the erythrocytes was an indicator of the absence of mechanical pressure of the frontal lens on the brain surface. The epiobjective was warmed to 36-37°C. The image of the vessels was projected by means of a mirror obturator and prism into the frame window of the motion picture camera and on the transmitting tube of the television system. Choice of the visual field and direct monitoring of the visual image were carried out on the television screen, and the motion picture camera was used to record the picture observed periodically. A technique using motion-picture and television methods, with the corresponding detailed schemes was described by the writers previously [1].

To improve the picture of the blood flow in the vessels, hemodilution was carried out. For this purpose, a thin polyethylene catheter was inserted into the femoral vein of the animals, and a 7% solution of albumin infused through it into the vascular bed. The blood escaped through a catheter inserted into the femoral artery. Gradual isovolemic hemodilution was carried out until the hematocrit index was 20-25% over a period of 60-80 min. Throughout the experiment the animals' blood pressure remained between 100 and 120 mm Hg. The body temperature in the rectum remained at 36-37°C.

EXPERIMENTAL RESULTS

Direct visual observations and analysis of single motion picture frames showed that the structure of the blood flow in very small pial veins (diameter 10-15 μ) is of a central (axial) flow of erythrocytes, between which and the vessel wall there is a thin, translucent layer of plasma. When these very small veins merge to form larger veins (diameter 50-100 μ) these flows still remain and form the unique dynamic structure of the blood flow. Thus in the large veins just mentioned several separate flow can be counted, and extend within the boundaries of the field of vision over a distance of 400-600 μ.

During observation on the flow of whole blood in the pial veins this picture, because of the high optical density of the blood, is difficult to distinguish. It was virtually impossible to record it on motion picture film sufficiently clearly. We therefore used hemodilution, i.e., dilution of the blood to a hematocrit index of 20-25% with the aid of

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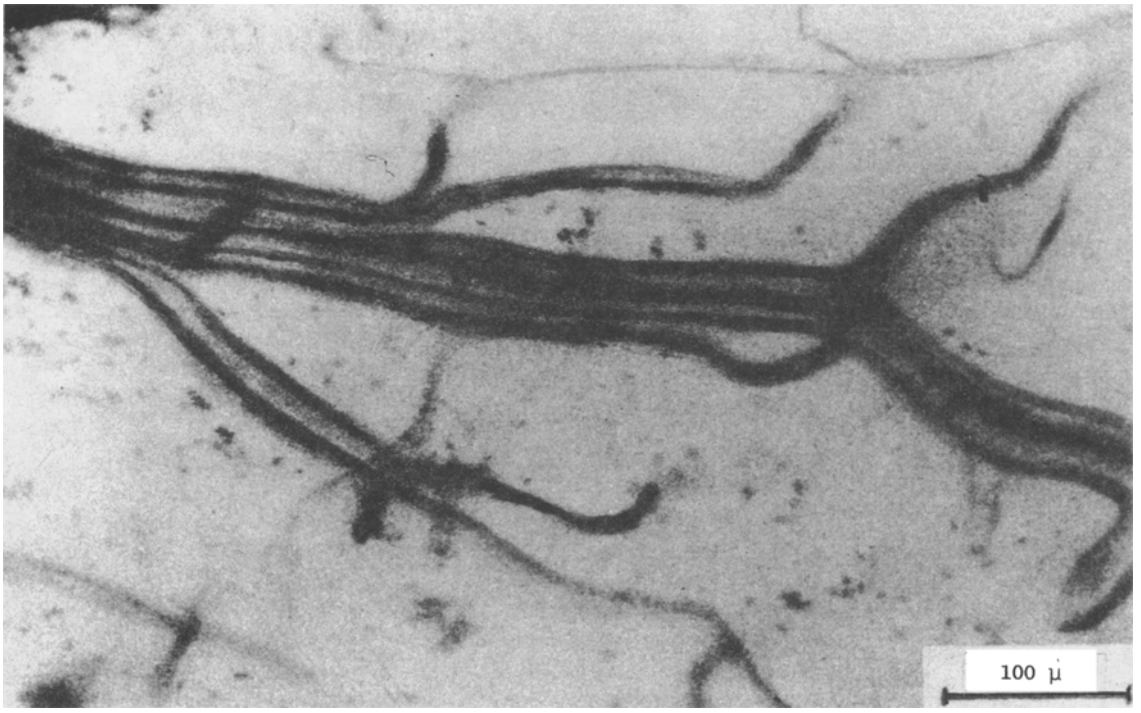

Fig. 1. Area of venous system of pia mater of rat brain. Filming speed 2 frame/sec. Exposure of frame 0.15 sec.

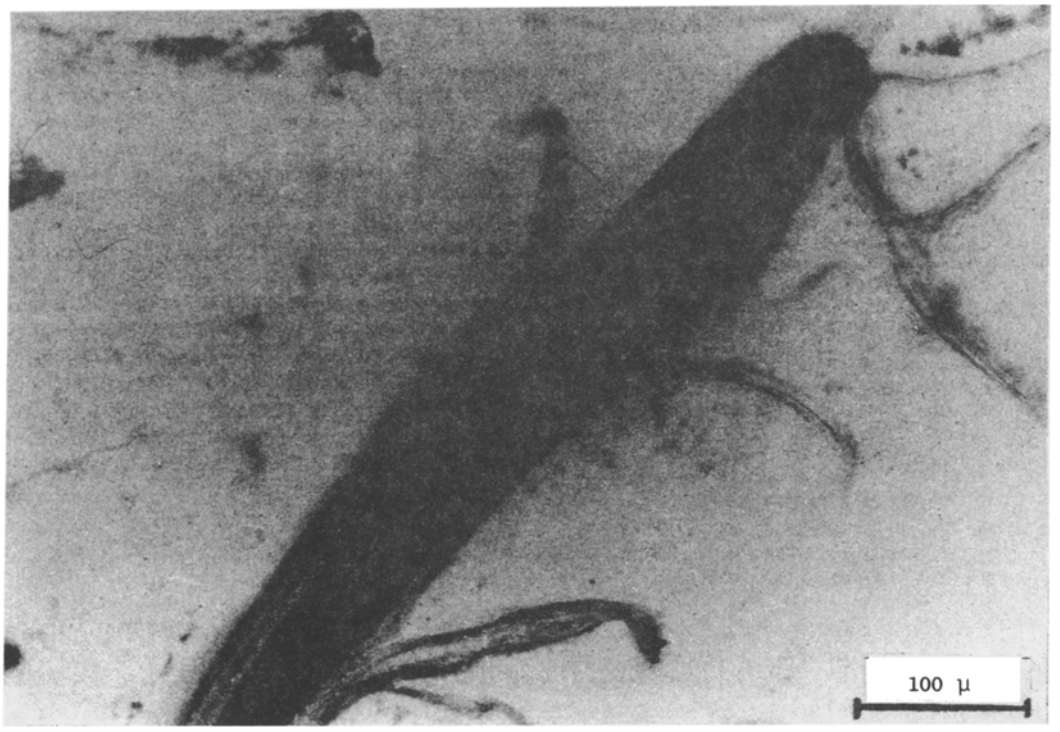

Fig. 2. Another area of venous system of pia mater of another rat. Filming speed and exposure the same as for Fig. 1.

7% albumin solution. This procedure caused no visible disturbances of the circulation or changes in blood pressure. However, the dynamic structure of the blood flow in the smallest (diameter 10-15 μ) and larger (diameter 50-100 μ) pial veins stood out clearly after hemodilution and could be recorded on motion picture film. Two different veins with internal diameters of about 75 and 50 μ, respectively, into which smaller veins emptied, can be seen in Figs. 1 and 2. Filming in this case was carried out with a speed of 2 frames/sec. With this speed of motion picture filming, the picture corresponded exactly to that of visual

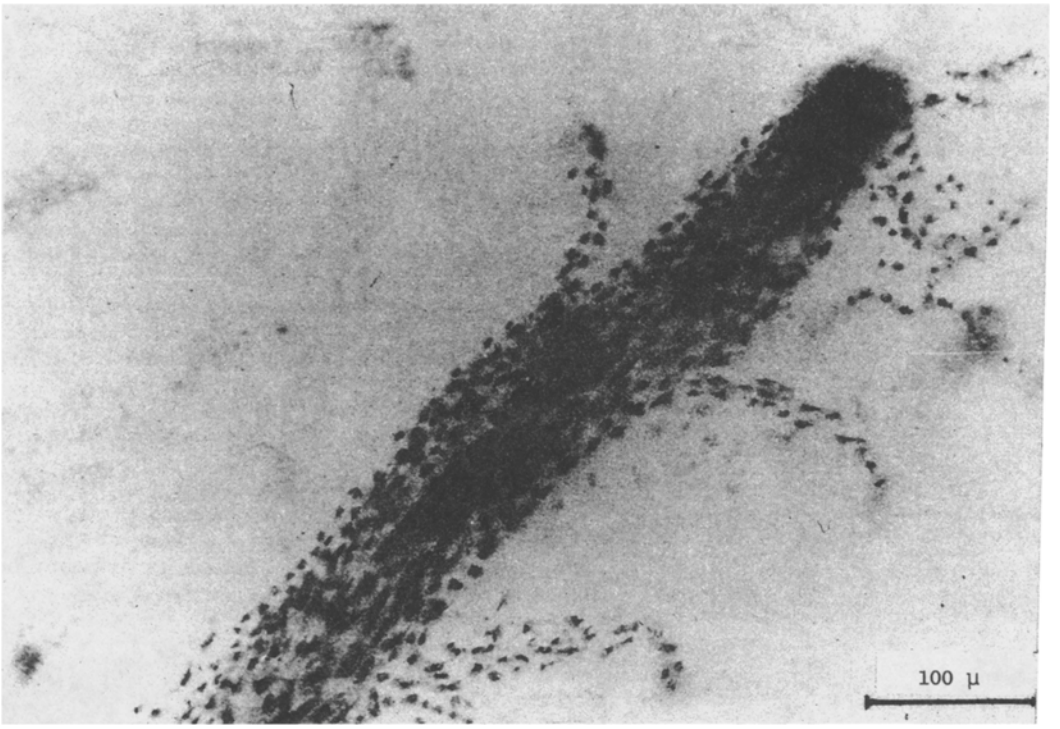

Fig. 3. Area of venous system illustrated in Fig. 2 but filmed at a speed of 40 frames/sec and with an exposure of 0.004 sec. Outlines of separate erythrocytes can be seen: distinct in peripheral flows and indistinct in central flows.

observation of the blood flow on the television screen. Where the veins join together to form a larger vessel these flows still persist, so that in a view 50-100 μ in diameter as many as 4-6 separate flows of cells, separated by translucent layers of plasma, visible throughout the field of vision, can be counted.

For a more detailed analysis of the dynamic structure of the blood flow in the veins, in similar experiments we used faster filming with a frequency of 40 frames/sec. Whereas with a filming speed of 2 frames/sec the exposure of each frame was 0.15 sec, at a filming speed of 40 frames/sec and with corresponding stopping down of the obturator, exposure was reduced to 0.004 sec. With such an exposure the outlines of separate erythrocytes could be identified (Fig. 3). Important details of the dynamic structure of the blood flow were thus clearly brought to light. As can be seen in Fig. 3, erythrocytes at the periphery and in the center of the vessel lie in chains, one after the other. However, considerable deviations of erythrocytes from this arrangement also can be observed, and some single cells are present between the flows. Thus the separate flows are statistical in nature. In other words, erythrocytes are distributed virtually throughout the cross-section of the vessel, but at each moment of time their density is higher in the region of the "axis" of the flows. Another detail is that outlines of erythrocytes in peripheral flows are quite distinct, whereas in the central flows they are elongated and indistinct in form. This means that erythrocytes at the periphery move at a much lower velocity than in the central flows. Differences in velocity can in practice be determined, and perhaps even the absolute linear velocity of the erythrocytes approximately. However, this is a task for future research, for it depends on improvement of the filming technique.

The experiments thus showed that the dynamic structure of the blood flow in the smallest pial veins of the brain is one of separate flows of erythrocytes separated from one another by layers of plasma. It can be tentatively suggested that the corresponding structure also is found in the large veins, in the form of a number of these separate flows.

LITERATURE CITED

1. K. P. Ivanov, M. K. Kalinina, and Yu. I. Levkovich, Microvasc. Res., 22, 143 (1981).