INTRAVASCULAR ANATOMY OF BLOOD CELLS IN MAN — (MOVIE)

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The film is based on registrations made during vital microscopy of the microcirculation in man, utilizing a skin tube chamber technique and synchronized flash transillumination (Bränemark, 1971, Bränemark and Bagge, 1977). The chamber used consists of a titanium framework containing two glass elements about 100 μm apart (Figure 1). After instalation of the chamber into the skin tube a connective tissue of normal histological appearance grows into this thin space. While the connective tissue invades the space in the chamber the formation of the microvascular bed can be studied. At first there is an open circulation with the different blood cells slowly moving through a delicate network, probably consisting of fibrin (Bränemark, 1965). In about two weeks, newly formed vessels have invaded the chamber from the periphery to form a one-layer microvascular network (Figure 2) which allows high resolution observation of the blood cells including particles as small as chylomicra (Figure 3).

The film presents a number of cyto-rheological phenomena typical of the normal and disturbed microcirculation. Under normal experimental conditions the flow of red blood cells (RBC) is rapid and continuous in the arterioles, capillaries and venules and, unless the tissue is illuminated with a strobe light, the individual RBC can only be identified in capillaries where the RBC move in single file (Figure 4).

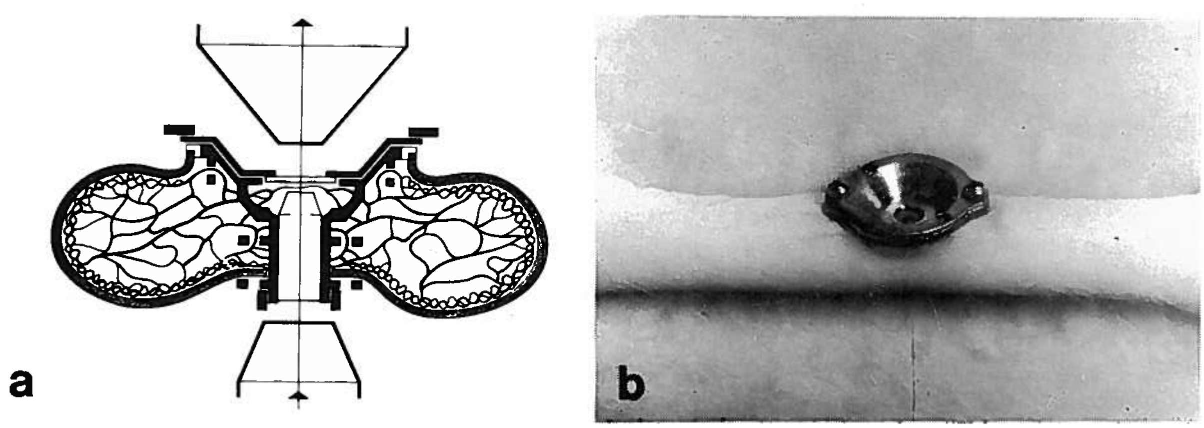

Fig. 1 — a) Schematic cross-section of the skin tube and the titanium chamber. b) The chamber in situ.

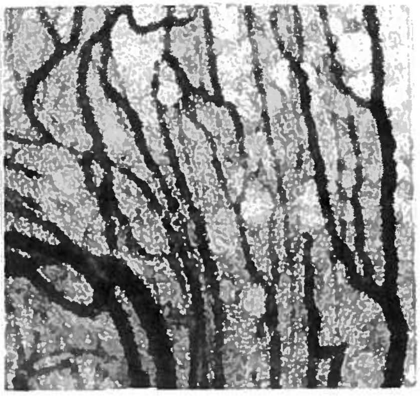

Fig. 2 — The micro-vascular bed of the chamber at low magnification.

However, three-dimensional observations in tapered glass tubes show that basic mode of deformation of the RBC is a folding or bending of the cell over the longitudinal axis of the tube (Bagge et al., 1980). In addition there is a pressure related forward distribution of the hemoglobin inside the RBC. In the film some sequences of RBC deformations are shown in slow motion, as RBC deformations are almost instantaneous due to the very high flexibility of the RBC.

When the flow rate is decreased, the RBC tend to form temporary aggregates — rouleaux (Figure 5). The rouleaux are primarily seen in the venules where the shearing forces become smallest. It is important to notice that these rouleaux break up easily and therefore do not seem to constitute any hindrance to the flow.

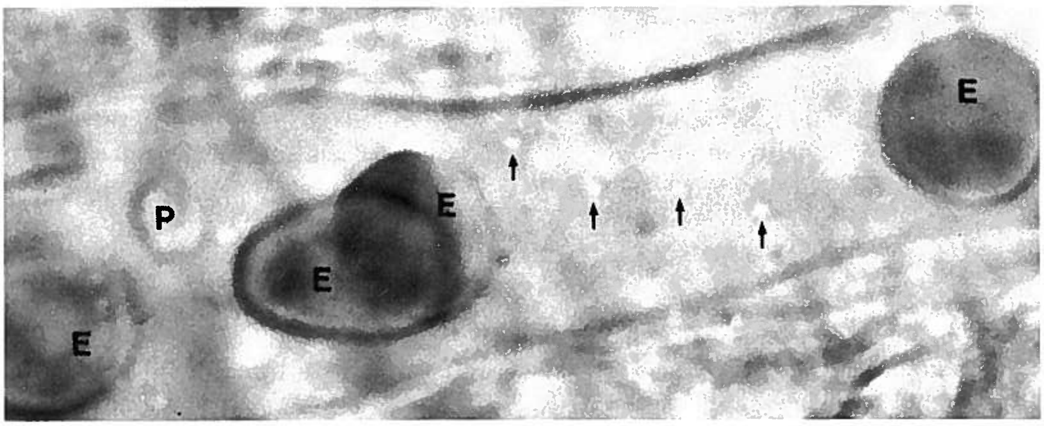

Fig. 3 — High magnification photograph of erythrocytes (E), a platelet (P) and chylomicra, some of which are depicted by arrows, in a small venule.

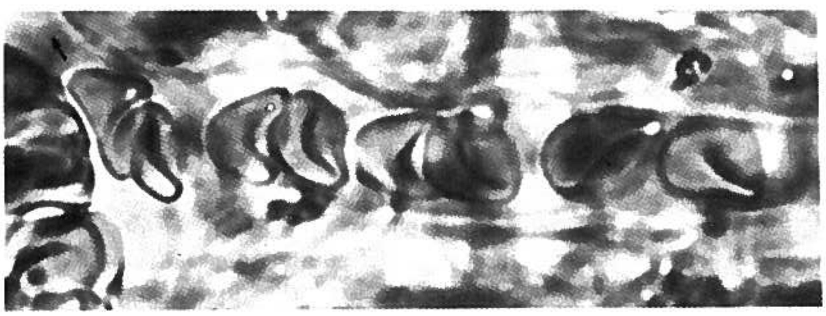

Fig. 4 — Red blood cells circulating through a capillary in single file, showing typical shape changes due to the deformation necessary for passage. The arrow indicates the direction of flow.

As the lumen of the capillaries is generally narrower than the diameter of the RBC, which is about 7.6 μm (Fung et al., 1981), the RBC have to deform in the capillary orifices and traverse the capillaries in single file. During this passage, the RBC have a parachute-like appearance. This shape has earlier been atributed to an axisymmetrical deformation of the red cells.

Leukocytes do not usually adapt as easily as the RBC to the small dimensions of the capillaries. The diameter of the leukocytes, which are spherical when undeformed, is about the same as that of the RBC (Schmid- Schönbein et al., 1980). Still the leukocytes frequently become temporarily arrested in narrow capillaries (Bagges and Braide, 1982) causing intermit-

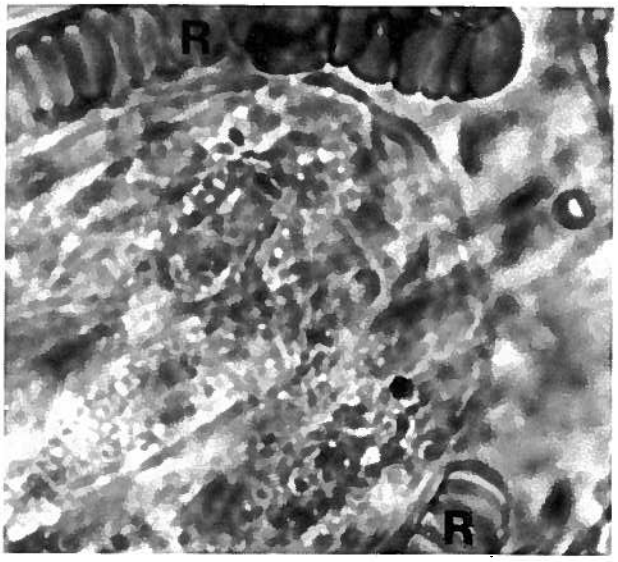

Fig. 5 — Two rouleaux (R) formed under low flow velocity conditions.

tent capillary flow (Figure 6). In low flow states plugging leukocytes may become permanently trapped in capillaries causing a significant rise of the vascular resistance (Bragge et al., 1981).

In the venules about half the number of leukocytes become marginated, typically rolling slowly along the vascular walls. This marginal pool of leukocytes is in instantaneous communication with the circulating pool.

In the studies presented in the movie, experimental tissue damage was induced with ultraviolet radiation or by clamping of the skin tube to cause ischemia for various periods. Ischemia alone caused surprisingly small lasting disturbances of the microcirculation (Romanus et al., 1978). After two hours of circulatory stand-still there were signs of edema in the tissue and some RBC in diapedesis (Bränemark and Ekholm, 1968). After 6 hours of ischemia edema was pronounced as well as RBC aggregation and extravasation. Further, wall adhering leukocytes were frequent. Despite these changes in the blood and the tissue the vascular bed was usually rapidly cleared when the clamps were removed, and as many as 80% of the microvessels regained an apparently normal circulation. After the combined action of UV-radiation and ischemia some micro-thrombi, consisting of activated platelets, RBC and fibrin, were also observed. These micro-thrombi were, however, removed when the flow was re-established.

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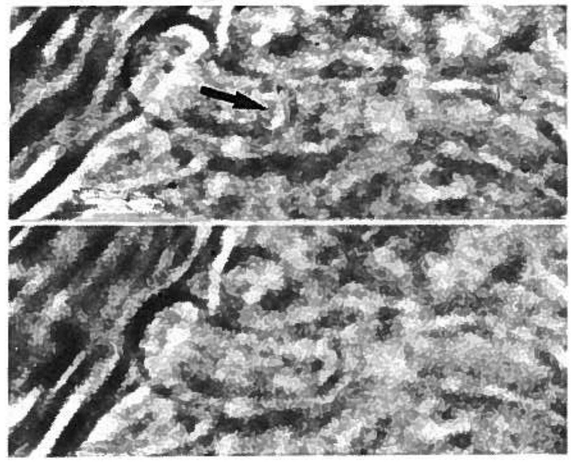

Fig. 6 — Photographs showing a leukocyte deforming in the orifice of a narrow capillary. The arrow indicates the direction of flow in the capillary.

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