LETTER TO THE EDITOR

Blood Flow, Slip, and Viscometry

Dear Sir:

In his paper of the above title, Nubar (1) may have supplied the unifying concept needed in hemorheology. He suggests that boundary slip may occur in blood flow and on this basis he develops a theory which explains many of the anomalous rheological properties of blood without having to postulate a flow-dependent viscosity.

Nubar does not, however, explicitly consider flow in tubes comparable in size with biological capillaries, yet here the only explanation which can be offered of the observed flow pattern is that boundary slip is taking place. In 1962 Prothero and Burton (2) noted the very low resistance to flow in such tubes and found that the mean apparent viscosity of whole blood in tubes of capillary size exceeded that of plasma by only 5%. Recently Rowlands and Skibo (3) have confirmed this very low resistance by pressure velocity measurements on red cells and red cell rouleaux in glass tubes of diameter $\simeq 6\ \mu$. Insertion of values from these experiments into Nubar's equation 10 together with middle values of his constants a'' and b'' gives a figure for apparent viscosity consistent with available observations (4, 2), though the nature of flow (bolus flow) in capillaries is different from what Nubar envisaged in his paper.

On the basis of his hypothesis Nubar gives a new explanation of the Fåhraeus-Lindqvist effect. Fåhraeus' original explanation (5), that of diminishing hematocrit with decreasing tube radius, has recently received support (6). This view, however, is linked with the concept of axial streaming of red cells and some of the quantitative support for this concept, derived from observations on the difference in transit times between red cells and plasma (7), has been questioned. Recent work (8) has suggested (9) that the observed difference in transit times is at least partially accounted for by differences in physical dispersion rates dependent on differences in diffusion coefficients of red cells and plasma proteins. If this proves to be the whole explanation, then Nubar's mechanism for the Fåhraeus-Lindqvist effect will be more acceptable.

Nevertheless, it is unlikely that slip can be the only anomaly in blood flow. Observations on the formation of rouleaux (10) suggest the presence of a surface energy when red cells come into contact. The degradation of this energy will contribute to the viscosity of blood and cause the viscosity to be flow rate–dependent.

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REFERENCES

1. NUBAR, Y. 1971. *Biophys. J.* **11**:252.
2. PROTHERO, J. W., and A. C. BURTON. 1962. *Biophys. J.* **2**:199.
3. ROWLANDS, S., and L. SKIBO. 1971 *a. Can. J. Physiol. Pharmacol.* **49**:373.
4. BRAASCH, D., and W. JENNETT. 1968. *Pfluegers Arch. Gesamte Physiol. Menschen Tiere.* **302**:245.
5. FÅHRAEUS, R. 1929. *Physiol. Rev.* **9**:241.

6. BARBEE, J. H., and G. R. COKELET. 1971. *Microvasc. Res.* **3**:6.
7. GROOM, A. C., W. B. MORRIS, and S. ROWLANDS. 1957. *J. Physiol. (London).* **136**:218.
8. BATE, H., S. ROWLANDS, J. A. SIRS, and H. W. THOMAS. 1969. *Brit. J. Appl. Phys.* Ser. 2. **2**:1447.
9. BATE, H., S. ROWLANDS, J. A. SIRS, and H. W. THOMAS. 1969. *J. Physiol. (London).* **202**:38P.
10. ROWLANDS, S., and L. SKIBO. 1971 *b. Biophys. Soc. Annu. Meet. Abstr.* **11**:168a.

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