

BLOOD VISCOSITY MEASUREMENTS IN THE DETECTION OF EARLY CEREBROVASCULAR DISEASE

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Introduction

Antonova, Velcheva and Boeva [1] measured whole-blood viscosity in 38 c.v.d. patients. The viscometer was capable of shearing the blood at rates of between 0.0237 and 128 sec⁻¹. Over this range, the viscosity fell by about nine orders of magnitude. Nevertheless, it was found, that at *ALL rates of shear, the AVERAGE whole-blood viscosity was higher in the patients than in the controls.*

These results as published [1] showed deviations too wide for diagnostic purposes, but suggested that, with refinements, blood-viscosity measurements might be capable of revealing the small changes taking place in early stages of ischaemia.

The primary assumption, indeed, springs from the work of Einstein [2] who treated the viscosity of a particulate suspension in terms of the disturbance created in the dispersion fluid by the presence of the particles.

Whittington and Harkness [3] presented the "TOKYO EXPRESSION"

$$(1) \quad \eta/\eta_0 = \left\{ \frac{A}{(1 - \log \gamma / \log \gamma_c)^\beta} \right\}^\psi,$$

where ψ is the HCT %

η is the whole-blood viscosity (mPa.s)

η_0 is the plasma viscosity (mPa.s)

γ is the rate shear (sec⁻¹)

γ_c is the critical low shear rate (sec⁻¹) derivable from the manufacturer's data (see MATERIALS AND METHODS)

A is the "viscosity parameter"

β is the "shear-sensitivity exponent" which links the non-Newtonian relaxation effect into the eq.(1).

Features of the "Tokyo Expression"

(1) It is essential to begin with the relative viscosity η/η_0 , in view of EINSTEIN'S approach mentioned above.

(2) Removal of the non-Newtonian relaxation is obtained by setting $\beta = 0$, giving the simple exponential $\eta/\eta_0 = A^{\psi(2)}$ for suspensions of rigid particles.

(3) Thixotropic behaviour results when $\beta < 0$.

(4) When $\gamma = \gamma_c$, $\eta/\eta_0 \rightarrow$ infinity, the driving-torque becomes impossible large.

(5) $1 - \log \gamma / \log \gamma_c$ is an arbitrary presentation of the applied shear-strain.

(6) A and β are solved for two widely-spaced rates of shear in Eq.(1).

The value $\gamma_c = 1 \text{ sec}^{-1}$ precisely is forbidden by the form of rate-function, since here β temporarily disappears from the equation.

To place A and β in the same convenient numerical domain we write $Y = 10^3(A - 1)$ and $X = 10^3\beta$. The preponderance of the viscous over the relaxation effect we then express as $Y - X = h = 10^3\beta(A - \beta - 1)$.

The significance of the number h (representing the viscous predominance) is shown in Fig.(a), where extreme values for the Sofia controls average about $h = 20$. Working at King's College Hospital, London, under the aegis of Professor A. J. Bellingham, Dep. of Clinical Haematology, S. M. Hussain [4] found that h averaged about 45 in sickle-cell patients with full O_2 saturation. Hussain took the opportunity of observing (IN VITRO) the reaction of h of an artificial reduction in O_2 saturation. The physico-chemical effects of this deprivation led to large, but somewhat irregular increases in h , up to a value of about 70. One of us (R.B.W.) named h as the "blood rigidity number" as a results of these experiments. A short paper was read by Fisher, Whittington and Hussain (using slightly different definition of h) at the Royal Society of Medicine [3].

Materials and methods

The group of 11 patients included latent, transient and chronic disturbances of the cerebral circulation. The apparent viscosity of whole blood and hematocrit values were estimated in all patients and the results were compared to a control group of 18 healthy persons. Also hemoglobin and some plasma and serum protein and lipid constituents: total protein, fibrinogen, total cholesterol and triglycerides were examined.

Whole-blood viscosity was determined by means of a rotational viscometer Couette LS 30 Contraves at a steady flow. Blood was drawn from a cubital vein between 8 and 10 a.m. and heparinized (15 IU/ml blood). One

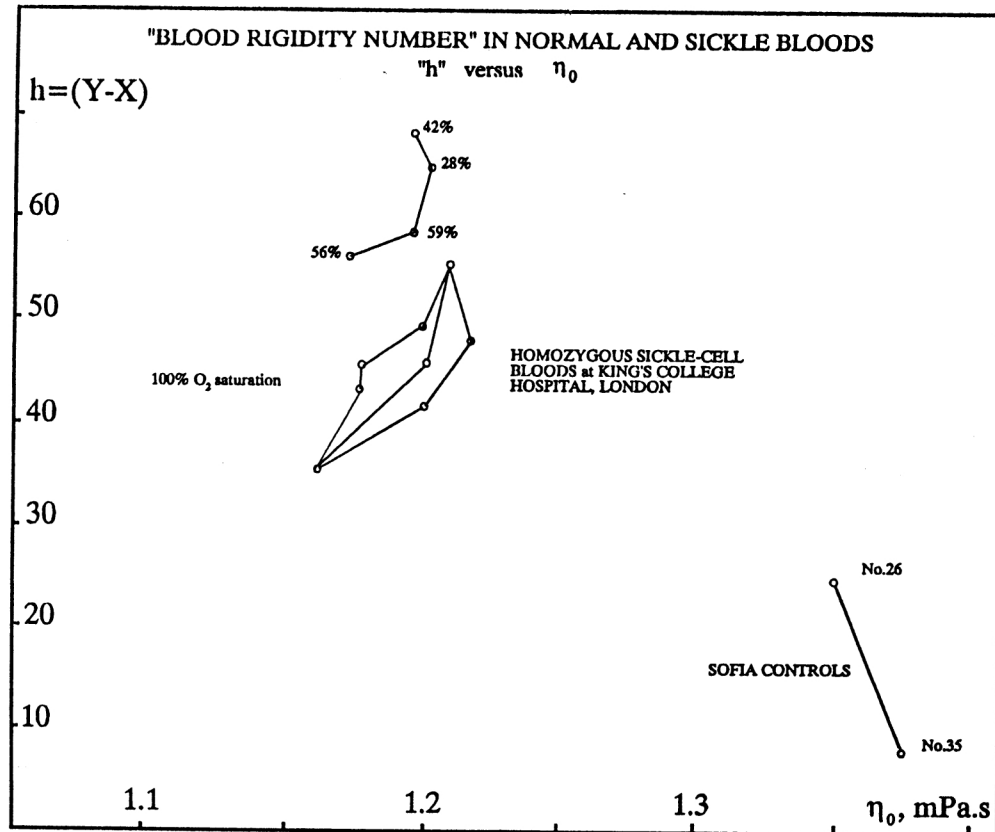


Fig. 1 "Blood rigidity number" in normal and sickle bloods

ml samples were estimated up to 3 hours after blood withdrawal at 37°C and at shear rates ranging from 0.0237 to 128.5 sec⁻¹. Estimations of hematocrit were done from the same sample with microhematocrit centrifuge TH 12 with centrifugation for 5 minutes at 10 000 min⁻¹. Plasma viscosity is determined by gravity force glassy capillary viscometers of Ubbelohde type [6]. The measured sample is 0.65 ml. The time, required for the plasma level to drop between the markers is estimated [7]. Cholesterol was examined by means of enzymatic colour reaction with tests of Boehringer.

Critical Rate of Shear

Each speed at the rotational viscometer LS 30 Contraves is designated by a "speed number" N , which increases in such a way that the shear rate is given by:

$$(2) \quad \gamma = \gamma_c \cdot 10^{N/7.5}$$

where γ_c is a lower limiting shear rate characteristic of the instrument and has the average value $0.012849 \text{ sec}^{-1}$ [8] for the standard dimensions of the suspended "bob".

Results

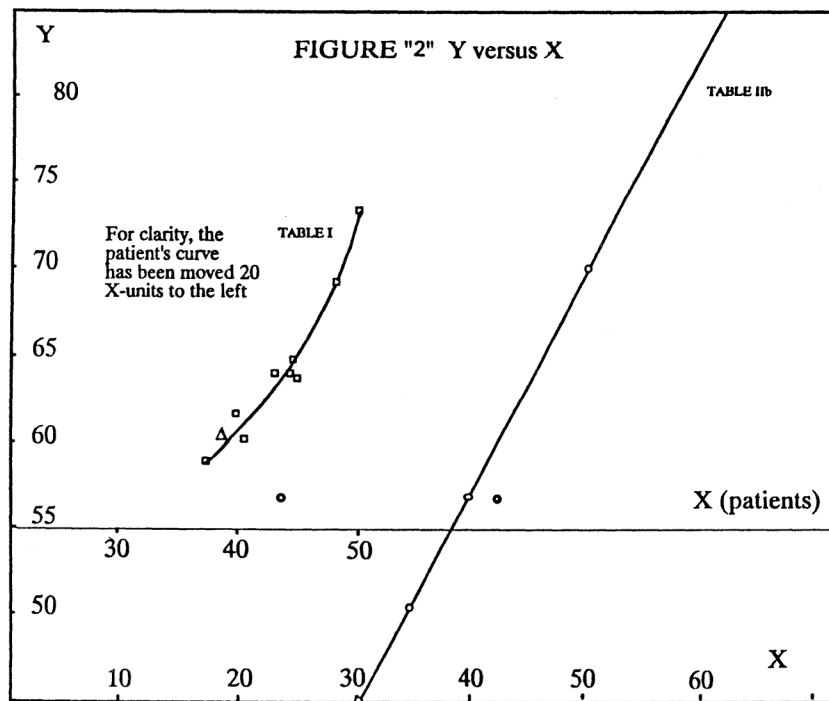


Fig. 2 The patient curve ($\square$) and control line ($\circ$) in the X, Y plane. The patient's points are shifted 20 X -units to the left

As shown in the Figure, the patients' curve has been shifted 20 X -units to the left, so that the two curves, patients' curve and control line can be examined more easily. They touch where the slope of the patients' curve equals 1.25. The patients' curve is for 11 cases one of which, No 5, may require confirmation of the diagnosis. A basic difference between the curves is that in the patients' curve, the second derivative, Y'' , is always positive: whereas in the control curve, Y'' is always zero.

A useful equation for a constant positive Y for patients is:

$$(3) \quad Y = 1/2aX^2 + bX + c$$

$$(Y' = aX + b; \quad Y'' = a) \quad a = 0.0175; \quad b = -6.59; \quad c = 183.$$

and for the control line is:

$$(4) \quad 4Y = 5X + 30$$

No.	1	2	3	4	5	6	7	8	9	10	11
$Y_{exp.}$	59.9	62.69	58.18	63.63	57.51	68.93	61.31	64.54	59.56	63.81	72.78
$Y_{form.}$	59.96	64.46	58.96	63.69	60.10	67.97	60.01	67.97	60.01	61.41	68.60
$X_{exp.}$	41.10	45.62	36.95	45.04	41.33	47.83	40.47	44.15	41.58	42.99	48.18
error	+0.06	+1.77	+0.78	+0.06	+2.59	-0.96	-1.30	-1.93	+0.43	-2.40	-4.18

Table 1. Absolute values of the formula error in $Y - \Delta Y$

The curve is very steep as we approach patient 11: therefore the error in Y becomes very large. The error in X is only about -2 .

In seeking the diagnostic test we assume that the provisional patients' curve divides the X, Y plane into two major regions:

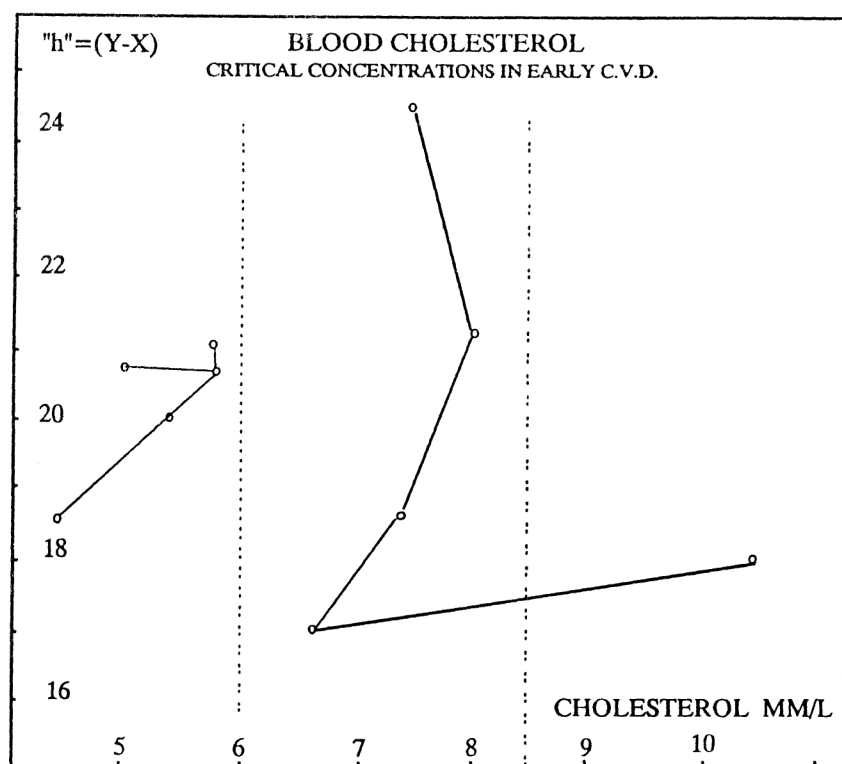


Fig. 3 "Blood rigidity number" as a function of Blood Cholesterol

(a) PATHOLOGICAL to the left of and above the curve. Curve less than experiment, error negative; and

(b) NORMAL to the right of and below the control curve.

Since there is inevitable "scatter", the area between curve and line is of doubtful meaning. However, patient 5 whose error in $\Delta Y+$ is more than FOUR times average $\Delta Y+$ must be regarded either as a FAILURE of the viscometric method, or a misdiagnosis in the first places.

Patients with negative errors (experiment greater than curve) must be regarded as pathological; and large errors, such as -4.18 (No.11) are of secondary or no importance.

The figure throws a different light upon the significance of the "Blood Rigidity Number, h ". It appears that there is a critical concentration range (about 6 to 8 mmol/l) in which h increases rapidly from about 17 to about 24.5. This is merely an interesting little deduction from our preliminary work on 10 patients.

The information which we have available suggests that there are other biochemical contributions of blood-cholesterol to the purely PHYSICAL picture which we are building up with our viscometers.

Discussion and conclusion

The results from our 11 patients suggest that viscometric test for early cvd is possible. The sensitivity of the method is in distinguishing very slightly disturbed bloods from the normal ones, must be improved. It is possible that this may be achieved by a re-deployment of the viscous and relaxational parameters.

Evidently, many more results are needed before the Patients' Curve (or its successors) can be anything more than *provisional*. Consequently it is hoped that the present research will be an on-going one; with viscometry and biochemistry proceedings together.

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