7 Measurement of Whole-blood Viscosity

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7.1 Introduction

Very few “advances” in medicine are really new and the measurement of whole-blood viscosity is certainly not an exception. Clinical interest in abnormalities of blood viscosity was probably greater at the beginning of the century than now; in Albutt’s standard medical textbook, published in 1915, there was a whole chapter devoted to diseases due to abnormal blood viscosity (Albutt, 1915). There was, however, considerable confusion regarding the actual measurement of blood viscosity, with different laboratories using different equipment obtaining results which could in no way be compared. The cause of this confusion was explained by Hess’s discovery in 1915 that blood was non-Newtonian, and to define its rheological characteristics, viscosity measurements would have to be carried out at a range of constant definable shear rates (Hess, 1915). The clinical interest in haemorheology therefore ceased until such measurements became possible with the advent of rotational viscometers in the 1960s.
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Following a brief definition of the basic concepts, the general techniques of viscometry will be discussed and the currently available commercial viscometers will be compared.

The viscosity of a fluid is due to the internal friction between adjacent layers. In streamlined flow, where adjacent layers move parallel to each other, the velocity difference is a measure of the shearing within the flowing fluid and this velocity gradient is termed the shear rate. The velocity of flow and the shearing within the fluid is produced by a force which is called the shear stress. The velocity of the fluid is then defined as the ratio of the shear stress to the shear rate it produces.

Figure 7.1 illustrates these definitions: $A$ represents two layers of fluid flowing in relation to each other at velocities $v_1$ and $v_2$, pushed by a force $F$. The shear rate is the velocity gradient, $dv/dx$, where $v$ is the difference between $v_1$ and $v_2$ and $x$ is the distance between the layers of fluid being considered. The units of shear rate will be distance per time divided by distance, which equals the reciprocal of time, usually expressed as inverse seconds ($s^{-1}$). The shear stress is expressed as force per unit area, $F$ divided by $A$, and will be in Pascals (Pa). The viscosity of the fluid, being the shear stress over the shear rate it produces, will be expressed in Pascal seconds (Pa.s). The relative viscosity is the whole-blood viscosity divided by that of its plasma.

Newtonian fluids at a constant temperature have a single constant viscosity as the ratio of shear stress to shear rate is constant and a certain change in the shear stress applied to the fluid will produce an exactly proportional change in the resulting shear rate. This situation is shown diagrammatically by the continuous lines in Fig. 7.2. The slope of the straight line in Fig. 7.2a will represent the viscosity of the fluid. Blood, however, is non-Newtonian because as the shear