3) Rheological Approach to Medical Problems

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Rheology has been defined as "the science of the deformation and flow of matter". In spite of the fact that any vital phenomena are more or less accompanied by deformation and/or flow of cells, tissues, body fluid or organs, applicability of rheology to medical science has not yet been recognized sufficiently by a large majority of clinicians and clinical investigators. The following topics, to which rheological approach has been made or will be made in future, were picked up from various fields of medical science and discussed briefly.

1. Rheology of subcellular phenomena (Microbiorheology).

In order to keep the activity of any cells unchanged, it is essential for the cells to exchange incessantly ions, non-electrolytes and some high molecular substances through the plasma membrane by passive and active transport mechanism including pinocytosis and emeiocytosis. These transport mechanisms are invariably accompanied with flow of the substances or with deformation of the membrane.

2. Hemorheology.

Hemorheology is one of the most well-studied branches in biorheology and includes the three main subjects, non-Newtonian flow properties of blood, blood coagulation and viscoelasticity of the heart and blood vessels. From the first subject, the following topics were chosen and a few comments were made on each of them: dependency of blood viscosity upon hematocrit and rate of shear, sigma effect, validity of Casson's equation to the blood and non-parabolic, phase-dependent velocity profil of blood flow within the aorta.

3. Rheology of muscle.

Stress-strain diagrams of a single muscle fiber revealed not only non-Hookean elasticity but also marked hysteresis and elastic after-effect which indicate the presence of viscous element in the muscle. The presence was also verified by the experimental fact that the time-course of tension development with stretching a muscle bundle differed significantly with different stretching speeds used. Some rheological models were demonstrated for the purpose of explaining viscoelastic behaviors of skeletal and smooth muscle, one characteristic feature of the latter being highly plastic. As muscle shows typical Gouch-Joule effect, contraction mechanism of actomyosin molecule should be considered from the viewpoint of entropy elasticity as well as from energy elasticity.

4. Rheology of mucus.

Biological mucous fluids, such as cervical canal mucus, sputum, synovia, digestive juice, vitreous fluid, semen, etc., are not purely viscous but viscoelastic in nature. Estroscope is a device which has been utilized for measuring changes in the flow elasticity of cervical canal mucus with sexual cycle. Distinctive features of these viscoelastic fluids are that they have spinability and manifest Weissenberg effect. Diagnostic application of the measurement of spinability and Weissenberg effect, which has not so far been made for medical purpose, seemed to yield several valuable results.

5. Rheology of cavity organs.

Pressure-volume curves of cavity organs, such as the urinary bladder, gastrointestinal tract and uterus, typically consisted of three parts; (a) an initial slight rise in pressure when the first volume increment is added, which is probably due to abdominal pressure; (b) a prolonged, nearly flat segment, the steepness of which is held to reflect detrusor tone; (c) a sharp rise of pressure at a maximum volume. The second segment indicates the existence of viscous element within the wall. The existence could also be demonstrated by recording temporal change in pressure after injection of a known volume of physiological saline into the cavity. Pressure declined gradually with time despite the intraluminal volume was kept constant. This fall in pressure is attributed to "delayed compliance" which is brought about by viscous component in the wall.

5. Rheology of sensory organs.

Generator potentials of mechanoreceptors are evoked by their mechanical deformation. Accommodation of the eye is achieved by the passive viscoelastic recoil of the lense brought about by the contraction of ciliary muscle which pulls the ciliary body, relaxing the zonula.

6. Miscellaneous.

Rheological procedures will be applicable for analysing the mechanism of vocalization and for studying the functions and properties of supporting organs, e. g. bone, cartilage, tendon, ligament and articular capsule, which are stressed at every moment. Respiratory dynamics has recently begun to study from the rheological point of view. Rheological consideration should never be neglected in developing and designing artificial organs. Rheological measurements might be able to replace palpation by which only experts can get instructive informations, and thus quantitative description of, for example, surface properties and consistency of a tumor might become possible. On the other hand, however, psychorheology will also be important in interpreting obtained findings by physical examination.

Analogy between dynamic viscoelasticity, servomechanism and alternating current circuit was discussed.