from Dissertation Abstracts 29 (10) 3719B (1969)

ELECTRICAL IMPEDANCE MEASUREMENT TECHNIQUES AND TISSUE IMPEDANCE AT ULTRA LOW FREQUENCIES

(Order No. 69-5631)

Paul Leroy Hill, Jr., Ph.D.
University of Pennsylvania, 1968

Supervisor: Herman P. Schwan

Three problems were investigated: 1) Selection of the optimal technique for measuring the dielectric constant of highly conducting aqueous samples down to 1.5 Hz. 2) Determination of the frequency dependence of the maximum current density above which skeletal muscle tissue no longer behaves as a passive linear electrical impedance. 3) Measurement of the dielectric constant and conductivity of skeletal muscle tissue down to 1.5 Hz.

An analysis was made of the effects of electrode polarization upon the accuracy obtained by others during measurements of the dielectric constant of biological tissues. The conclusion reached was that a null-reading impedance measuring system with separate potential sensing electrodes, i.e., a four-electrode bridge, was needed to obtain the necessary resolution. Examples of the two types of four-electrode bridges (active and passive) were built and analyzed in detail. It was found that active bridges have the advantage over passive bridges, that active bridges are direct reading and hence a substitution technique can be used which eliminates some of the sources of measurement error.

Active bridges can be based on the principles of either voltage comparison or current comparison. When using the voltage comparison techniques, the gain of the first stage amplifiers can be larger than the unity gain of the differential amplifier which is used with the current comparison technique. It was found that increasing the gain of the first stage amplifiers--the ones which amplify the voltage across the sample and across the standard impedance--from a gain of one to a gain of thirty improved the resolution of the Half-Bridge by a factor of thirty. An active bridge using voltage comparison (the Half-Bridge) was built and all relevant factors affecting its performance were studied experimentally and theoretically.

A series of measurements was made in a separate bridge to determine the maximum current density (J_ℓ) at which muscle tissue behaved as a linear impedance element. It was concluded that, for frequencies below 4 kHz, skeletal muscle tissue behaves linearly for current densities below a nearly constant stimulation threshold of about 6 ma/cm^2. Current densities higher than 100 ma/cm^2 cause sufficient heating of muscle tissue at any frequency to change the measured resistance. For frequencies above 4 kHz, J_ℓ rises rapidly to this 100 ma/cm^2 value.

Measurement of the dielectric constant (ϵ) and conductivity (σ) of bullfrog sartorius muscle in the Half-Bridge over the frequency range of 1.5 Hz to 15 kHz show that ϵ and σ each approach a constant value at 1.5 Hz.

An experiment is suggested to help determine the correct physical mechanism for the frequency dependence of ϵ and σ between 1 and 1500 Hz. M $3.70; X $13.05. 288 pages.

CONTROL OF PERIPHERAL VASCULAR RESISTANCE: EXPERIMENTAL AND THEORETICAL STUDIES.

(Order No. 69-5632)

Lee Lawrence Huntsman, Ph.D.
University of Pennsylvania, 1968

Supervisor: A. Noordergraaf

An investigation was made of those controls of peripheral vascular resistance which act to effect changes of that resistance within one minute or less. Two controlling mechanisms are responsible for these changes, one acting through the nerves which innervate the vascular smooth muscle, the other autoregulation in the tissue itself.

The objectives of this investigation have been: 1) to gain new evidence about the nature and distribution of nervous influence on peripheral resistance, 2) to acquire quantitative data concerning the behavior of autoregulation in skeletal muscle, 3) to investigate the interaction of nervous and autoregulatory controls, and 4) to consider the mechanism of autoregulation from a theoretical viewpoint. The approach to these objectives has included two phases: measurements of regional peripheral resistance behavior in dogs, and formulation of a model of a metabolic autoregulatory mechanism.

The experiments were conducted in dogs with intact, reactive circulatory systems. Through the use of chloralose anesthesia and an epidural injection, data were obtained both with and without active nervous control. Arterial occlusions were applied to perturb the circulatory conditions and allow measurements of the dynamics of resistance control. The reactive hyperemia which followed release of an iliac artery occlusion was used to study autoregulation in skeletal muscle.

The conclusions resulting directly from the experiments may be summarized as follows:

1) In the tissues which receive their blood supply from the lower abdominal aorta, there is a hierarchy of nervous influence on peripheral resistance. Typical nervous discharge patterns: a) profoundly affect the resistance of skeletal muscle, b) affect the vascular resistance of the muscles and organs of the pelvic region less, but still significantly, and c) affect the resistance of the kidneys little or not at all.

2) The tonic (static) discharge of the nerves innervating the vascular smooth muscle is of little importance in determining the shape of the steady-state pressure-flow relationship. Rather, it acts to shift the relationship toward higher pressures.

3) In reactive hyperemia, autoregulatory mechanisms dominate blood flow control, overpowering both static and dynamic nervous influences. If both autoregulatory and nervous controls influence the same vascular smooth muscle, this dominance means that autoregulation probably acts to alter the basic ability of the smooth muscle to contract.

4) Quantitative data on reactive hyperemia implicate a likely metabolically linked autoregulatory mechanism and argue against a myogenic mechanism.

Results of several other investigations as well as those of this one indicate that autoregulation in skeletal muscle is at least somewhat related to the metabolic conditions in that tissue. Therefore, a possible mechanism for metabolic autoregulation which takes oxygen to be the autoregulatory agent has been postulated, formulated as a model, and examined theoretically.

Based on the model's behavior, and its comparison with reality, a number of conclusions have been reached:

1) The model of a metabolically linked, oxygen mediated autoregulatory mechanism displays: a) both steady-state and transient autoregulatory behavior, b) responses which are very similar in magnitude and time course to those observed in the dog for a variety of perturbations, c) the ability to change peripheral resistance rapidly.

The items following each abstract are: the price of a microfilm copy; the price of a copy enlarged by the xerographic process to approximately 6 x 8½ inches; the number of pages in the manuscript. Please order copies by order number and author's name.