A Method for Quantitative Estimation of the Extent of Tissue Ischemia

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When a tissue enters a state in which its blood supply does not meet its metabolic needs, it is said to be 'ischemic.' Nutrients and oxygen reach the cells in the tissue through the circulatory system. Coupled with this transport is the removal of waste products such as carbon dioxide. In the state of ischemia, the cells turn to anaerobic respiration, which causes a build up of lactic acid. If left in this state, the cell will eventually die. All tissues are susceptible.

A tissue can become ischemic progressively over the course of several years as in the conditions of Ischemic Myocardiopathy or Ischemic Colitis. The former can be the result of years of high blood pressure, high fat diets, high cholesterol levels, and/ or smoking. The latter is another ischemic condition, this one being linked with a history of congestive heart failure, strokes, diabetes, and/ or abdominal radiation exposure.

If a limb suffers a trauma, such as a crush injury or a large fracture, the blood supply to its tissues may become severely diminished. This is also an instance of ischemia, termed an 'Ischemic Contracture.'

Currently, there is no means of determining the extent of ischemia quantitatively. Physicians would take into account a patient's claim of discomfort in a certain area as well as pH measurements to determine if a tissue was ischemic. But these are not necessarily reliable and certainly not objective.

This study investigated the possibility of determining an algorithm that would be an indicator of not only the presence of ischemia, but also the extent of it. Ideally, such a system that determined the presence and extent of ischemia would be: harmless to the tissue and the patient, accurate, reliable, have a rapid response, stable, simple to use, and quantitative. The investigators kept these criteria in mind throughout the course of the study.

A healthy tissue can be characterized by its resistance to electrical stimuli. Impedance Spectroscopy in a tissue is the measurement of its subthreshold electrical response at multiple frequencies. A tissue can have up to three 'Dispersion Regions,' which are frequency regions in which the tissue exhibits fast impedance changes. This study focuses on the dispersions in the '_' region, which is 1 kHz to 1 MHz, of muscular tissue.

Below is an example of a typical dispersion in the _ region.
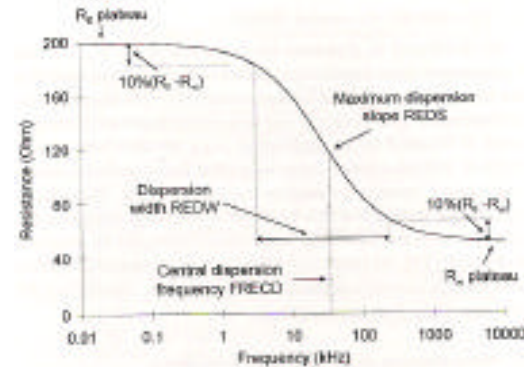
From such a graph, there are several model parameters that can be extracted. The investigators listed nineteen model and characteristic parameters that they believe have an influence on, or are a result of, ischemia.

These measurements were then examined by an Artificial Neural Network, or ANN. ANNs are nonlinear statistical analysis tools helpful in determining the relationship between input and output variables, when the intermediate process is unknown, but plenty of examples are available. This analytical tool can determine the appropriate weights of the input variables.

The study used the leg muscles of White New Zealand rabbits under anesthesia. From one complex impedance spectrum, the ANN in 13 ms was able to estimate tissue pH levels with a 94.5% correlation with an RMS of 0.148 pH units, a mean error of -0.0335 pH units and a _ of 0.15 pH units.

Overall, the algorithm determined by the ANN seems to be a promising method for the diagnosis and monitoring of tissue ischemia, but in rabbits. A similar study should now be done on human tissue.

References:
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