The microvasculature forms an interconnecting network of vessels that supplies nutrients to the tissues in a timely manner and removes waste products. It serves as a conduit for blood and provides peripheral vascular resistance (necessary to maintain adequate blood pressure). The arterioles react to the accumulation of waste products from the tissues, dilating and constricting, resulting in rhythmic patterns of blood flow known as vasomotion.

The intricate geometric structure, biochemical negative feedback, flexible adaptation to changing demands, and distribution of multiple units demonstrating synchronization characterize the microvasculature as a complex system. Alteration of structure induces dynamic changes, which may become altered by disease. We studied the inherent rhythm in blood flow in the microvasculature using spectral analysis.

Blood flow was measured in the skin of the forehead using the Periflux PF3 Laser Doppler flow meter (Perimed, Sweden) in male and female subjects between the ages of 20 and 60. The data was collected at 8 Hz. Spectral analysis was performed by means of fast Fourier transforms using Matlab v. 6.5.

The raw data (blood flow vs. time) demonstrated rare sinusoidal behavior. Spectral analysis (power spectra) revealed multiple frequencies. Distinct peaks occurred between 0 and 0.2 Hz, with no peaks above 0.4 Hz. All studies showed a fundamental frequency of 0.000977 Hz (a period of 17 minutes). Each subject demonstrated numerous frequencies between the fundamental frequency and 0.16 Hz. Division of the higher frequencies by the fundamental frequency resulted in unique series of integers, such as {1,3,6,12,15,18,22,…101};{1,6,11,13,18,23,26,28,…101};{1,5,9,15,18,21,23,28,30,…101}; {1,4,8,13,16,18,22,28,31,…101}.

The original data set could be reconstructed by the summation of a series of sine waves, indicating a highly ordered deterministic system. Spectra from subjects with diabetes or hypertension demonstrate a decreased number of frequencies below 0.1 Hz and an increased power of those between 0.11 and 0.17 Hz.

Combining architectural structure, nonlinear response, time-delay and the dissipative use of energy with the presence of a complex periodic system (the frequencies are commensurate with the fundamental frequency) demonstrated by the spectra analysis defines the microvasculature as a nonlinear, dissipative system with limit cycles providing the source for the periodic behavior. Only a few elements in the series of frequencies represent a harmonic series. The non-harmonic components offer a means to study highly complex systems.

Analysis of the vasomotion spectra reveals that each person produces distinct sharp frequencies. Disease causes distinctive alteration in pattern with a decrease in the number of dominant frequencies and a preponderance of frequencies between 0.11 and 0.17 Hz.

Such a change in pattern may be the result of a simplification of the relationships among the component variables of the system. Spectral analysis of blood flow in the microvasculature offers a unique tool in understanding the complex behavior of blood delivery at the tissue level and may be useful in assessing the impact of disease prior to end-organ tissue damage.