Differentiating Vascular Pathophysiological States

by Objective Analysis of Flow Dynamics

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Background and Purpose: There is an unmet need to classify cerebrovascular conditions physiologically and to assess cerebrovascular system performance. We hypothesized that by simultaneously considering the dynamic parameters of flow velocity, acceleration, and pulsatility index (impedance) in individual Doppler spectrum waveforms, we could develop an objective method to elucidate the pathophysiology of vascular conditions and classify cerebrovascular disorders. This method, Dynamic Vascular Analysis (DVA), is described.

Methods: First, a theoretical model was developed to determine how any vascular segment and the ensemble of intracranial vascular segments could be defined according to its dynamic physiological characteristics. Next, the DVA method was applied to 847 anonymous serial complete clinical TCD studies of patients without regard for their diagnosis to ascertain actual reference ranges and the normality of the distribution curves for each dimension of the three-parameter nomogram. We applied DVA to two clinical cases to see if we could track the changes in vascular performance of two known progressive diseases. Data points measured for each segment included end diastolic velocity (EDV), time at EDV, peak systolic velocity (PSV), and time at PSV.

Results: The theoretical analysis identified 295,245 possible vascular states for the ensemble of vascular segments in the cerebral circulation. When applied to clinical TCD data, DVA revealed continuous, normally distributed data for the velocity, pulsatility index, and logarithm of the acceleration. Thus, a 3-dimensional nomogram was established for the physiological differentiation of cerebrovascular disease states. Two clinical cases demonstrated how DVA monitored changes in vascular flow states.

Conclusions: DVA is proposed as a method for monitoring the physiological state of each cerebral artery segment individually and in ensemble. DVA evaluates the relationship among acceleration (force or pressure), velocity and pulsatility index and provides an objective means to evaluate intracranial vascular segments using the paradigm of the well-described pressure-perfusion autoregulation relationship. DVA may be used to study cerebrovascular pathophysiology and to classify, evaluate and monitor cerebrovascular disorders or systemic disorders with cerebrovascular effects.