FREQUENCY DEPENDENT MODEL BACKGROUND OF METHODS FOR ASSESSMENT OF HUMAN CEREBRAL AUTOREGULATION

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Introduction

Cerebral autoregulation (CA) keeps cerebral blood circulation constant, also while systemic blood pressure changes. Physicians need information about the state of cerebral autoregulation for optimizing patient treatment. Assessment of cerebral autoregulation status is difficult because of a lack of physiological knowledge and several effects which are hardly to quantify. Reproducibility of common techniques using special test manoeuvres or physiological (intrinsic) low frequency variations of blood pressure is insufficient. Standardized cuff deflation test [1] requires an external manipulation in arterial blood pressure. Healthy young volunteers show such a high intraindividual dispersion of autoregulatory index (ARI), that "intact autoregulation status" seems to be not reliable. Provocation tests like A. carotis compression, MÜLLER manoeuvre, VALSALVA manoeuvre, tilting, and also the use of spontaneous pressure oscillation are further possibilities for assessment of CA, using various kinds of signal processing methods and modelling. In clinical language, with the help of "static" and "dynamic" autoregulation assessment methods functions and parameters are calculated. From the engineering point of view we observe the stationary (dynamic) steady state or provocation test answers - transient dynamic signal variations with the aim of continuous monitoring of CA status. Looking for a Gold Standard for autoregulation assessment, we find various definitions of models and methods in time and frequency domain (cerebrovascular resistance, autoregulation index, rate of regulation, cross and moving correlation coefficient, coherence function, velocity pressure gain, impulse response and transfer functions) , i.e. [2]. Our aim is to describe and compare frequency dependent models and assumptions and to quantify parameters under certain measuring and processing conditions for reproducable CA assessment.

Material and Methods

14 patients with severe traumatic brain injury, 6 patients with higher grade subarachnoid hemorrhage and 11 healthy volunteers were studied. Cerebral artery blood flow velocity (CBFV; by transcranial Doppler sonography), arterial blood pressure (ABP) and intracranial pressure (ICP) are recorded invasively for the intensive care patients, CBFV and ABP (finger plethysmography) for the healthy volunteers. Cuff deflation test [3], pressure - flow cross-correlation [3] and WIGNER analysis in three frequency ranges [4] were analyzed and compared. Model parameters were identified.

Results

Information about the behaviour of flow and pressure signals, described in models in time and frequency domain, is contradictory. There are different definitions for frequency areas for slow and fast oscillations, lower, middle and higher frequency fields and the limits of TRAUBE-HERING-MEYER-waves for frequency dependent assessment of cerebral autoregulation in literature. Estimation / identification of model parameters for assessment of CA depends on signal properties (sampling frequency, length of data set for "continuous" assessment, filtering, model algorithms), patient conditions (medication, ventilation frequency), hardware equipment (sensor and channel charcteristic). Methods for CA assessment will be compared in order to evaluate stationarity, reproducibility and variability in time for patients and healthy volunteers.

Conclusions

A wide variety of signal processing methods in time and frequency domain including identification methods for model parameters is the basis for defining model parameter standards for CA assessment. Best methods should use non-invasive data acquisition for continuous CA assessment with complex models, and basic principles of signal acquisition and processing theory should be considered for reproducable application in clinical routine.

References

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