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Construction of a Dynamic Model of Cerebral Blood Circulation for Future Integrated Control of Brain State

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Abstract : Currently, brain resuscitation becomes increasingly important due to revising various clinical guidelines pertinent to emergency care. In brain resuscitation, the control of brain temperature (BT), intracranial pressure (ICP), and cerebral blood flow (CBF) is required for stabilizing physiological state of brain, and is described as the essential treatment points in many guidelines of disorder and/or disease such as brain injury, stroke, and encephalopathy. Thus, an integrated control system of BT, ICP, and CBF will greatly contribute to alleviating the burden on medical staff and improving treatment effect in brain resuscitation. In order to develop such a control system, models related to BT, ICP, and CBF are required for control simulation, because trial and error experiments using patients are not ethically allowed. A static model of cerebral blood circulation from intracranial arteries and vertebral artery to jugular veins has already constructed and verified. However, it is impossible to represent the pooling of blood in blood vessels, which is one cause of cerebral hypertension in this model. And, it is also impossible to represent the pulsing motion of blood vessels caused by blood pressure change which can have an affect on the change of cerebral tissue pressure. Thus, a dynamic model of cerebral blood circulation is constructed in consideration of the elasticity of the blood vessel and the inertia of the blood vessel wall. The constructed dynamic model was numerically analyzed using the normal data, in which each arterial blood flow in cerebral blood circulation, the distribution of blood pressure in the Circle of Willis, and the change of blood pressure along blood flow were calculated for verifying against physiological knowledge. As the result, because each calculated numerical value falling within the generally known normal range, this model has no problem in representing at least the normal physiological state of the brain. It is the next task to verify the accuracy of the present model in the case of disease or disorder. Currently, the construction of a migration model of extracellular fluid and a model of heat transfer in cerebral tissue are in progress for making them parts of an integrated model of brain physiological state, which is necessary for developing an future integrated control system of BT, ICP and CBF. The present model is applicable to constructing the integrated model representing at least the normal condition of brain physiological state by uniting with such models.

Keywords : dynamic model, cerebral blood circulation, brain resuscitation, automatic control
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