World Academy of Science, Engineering and Technology
International Journal of Biotechnology and Bioengineering
Vol:12, No:08, 2018

Construction of a Dynamic Migration Model of Extracellular Fluid in Brain for Future Integrated Control of Brain State

Authors : Tomohiko Utsuki, Kyoka Sato

Abstract : In emergency medicine, it is recognized that brain resuscitation is very important for the reduction of mortality rate and neurological sequelae. Especially, the control of brain temperature (BT), intracranial pressure (ICP), and cerebral blood flow (CBF) are most required for stabilizing brain's physiological state in the treatment for such as brain injury, stroke, and encephalopathy. However, the manual control of BT, ICP, and CBF frequently requires the decision and operation of medical staff, relevant to medication and the setting of therapeutic apparatus. Thus, the integration and the automation of the control of those is very effective for not only improving therapeutic effect but also reducing staff burden and medical cost. For realizing such integration and automation, a mathematical model of brain physiological state is necessary as the controlled object in simulations, because the performance test of a prototype of the control system using patients is not ethically allowed. A model of cerebral blood circulation has already been constructed, which is the most basic part of brain physiological state. Also, a migration model of extracellular fluid in brain has been constructed, however the condition that the total volume of intracranial cavity is almost changeless due to the hardness of cranial bone has not been considered in that model. Therefore, in this research, the dynamic migration model of extracellular fluid in brain was constructed on the consideration of the changelessness of intracranial cavity's total volume. This model is connectable to the cerebral blood circulation model. The constructed model consists of fourteen compartments, twelve of which corresponds to perfused area of bilateral anterior, middle and posterior cerebral arteries, the others corresponds to cerebral ventricles and subarachnoid space. This model enable to calculate the migration of tissue fluid from capillaries to gray matter and white matter, the flow of tissue fluid between compartments, the production and absorption of cerebrospinal fluid at choroid plexus and arachnoid granulation, and the production of metabolic water. Further, the volume, the colloid concentration, and the tissue pressure of/in each compartment are also calculable by solving 40-dimensional non-linear simultaneous differential equations. In this research, the obtained model was analyzed for its validation under the four condition of a normal adult, an adult with higher cerebral capillary pressure, an adult with lower cerebral capillary pressure, and an adult with lower colloid concentration in cerebral capillary. In the result, calculated fluid flow, tissue volume, colloid concentration, and tissue pressure were all converged to suitable value for the set condition within 60 minutes at a maximum. Also, because these results were not conflict with prior knowledge, it is certain that the model can enough represent physiological state of brain under such limited conditions at least. One of next challenges is to integrate this model and the already constructed cerebral blood circulation model. This modification enable to simulate CBF and ICP more precisely due to calculating the effect of blood pressure change to extracellular fluid migration and that of ICP change to CBF.

Keywords : dynamic model, cerebral extracellular migration, brain resuscitation, automatic control
Conference Title : ICBCBBE 2018 : International Conference on Bioinformatics, Computational Biology and Biomedical Engineering
Conference Location : Barcelona, Spain
Conference Dates : August 20-21, 2018