Mathematical Model of the Effect Of Ischemia–Reperfusion on Brain Capillary Collapse and Tissue Swelling

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ABSTRACT

Restoration of an adequate cerebral blood supply after an ischemic attack is a primary clinical goal. However, the blood–brain barrier may break down after a prolonged ischemia causing the fluid in the blood plasma to filtrate and accumulate into the cerebral tissue interstitial space. Accumulation of this filtration fluid causes the cerebral tissue to swell, a condition known as vasogenic oedema. Tissue swelling causes the cerebral microvessels to be compressed, which may further obstruct the blood flow into the tissue, thus leading to the no-reflow phenomenon or a secondary ischemic stroke. The actual mechanism of this however is still not fully understood. A new model is developed here to study the effect of reperfusion on the formation of vasogenic oedema and cerebral microvessel collapse. The formation of vasogenic oedema is modelled using the capillary filtration equation while vessel collapse is modelled using the tube law of microvessel. Tissue swelling is quantified in terms of displacement, which is modelled using poroelastic theory. The results show that there is an increase in tissue displacement and interstitial pressure after reperfusion. In addition, the results also show that vessel collapse can occur at high value of reperfusion pressure, low blood osmotic pressure, high cerebral capillary permeability and low cerebral capillary stiffness. This model provides insight on the formation of ischemia–reperfusion injury by tissue swelling and vessel collapse.

KEYWORKS: Blood–brain barrier; Ischemia–reperfusion; Cerebral blood flow; Vasogenic oedema

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