Phase-field Modeling and Numerical Simulation of Neurite Outgrowth

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ABSTRACT

Although nerve autograft and direct suture have performed as a treatment of peripheral nerve repair, there are several shortcomings such that, for example, dysesthesia and pain are retained for patients. Scaffold transplatation that bridge the site of injury and allow axonal regeneration has recently attracted great attention as a new treatment. However, because axonal regenerate speed is not enough in case of a large injury, we need a optimal design of the scaffold to promote the regeneration. To develop the optimum design technique, it is key to construct a numerical simulation method which can predict and control the neuronal elongation depending on extracellular environment. There are no models that enable to accurately express the complicated neuronal development and morphology, although some neuronal elongation simulations have been performed [1, 2].

A phase-field method is the most powerful tool to simulate material microstructure evolution and its complex morphology. The phase-field method has been also applied to the field of biology, whereas there are few phase-field models for the axonal extension of neuron. We previously tried to develop an axonal development model [3] by using a modified KWC (Kobayashi-Warren-Carter) phase-field model which is used in the solidification of materials [4, 5].

In this study, to develop more accurate neuronal development model, we improve our phase-field model [3] to consider the translations of tubulin, calcium, extracelluar substance and so on inside and outside nerve cell. And, using the developed model, some neuronal elongation simulations are carried out to confirm the fundamental performances of the model.

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