Numerical Reproduction of Hemodynamic Change Induced by Acupuncture to ST-36

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Abstract—Acupuncture therapy is one of the treatments in Traditional Chinese Medicine. Recently, some reports showed effectiveness of the acupuncture but the distrust of acupuncture therapy has not been fully dispelled yet due to lack of information on mechanism of the therapy.

Watanabe et al. observed contribution of acupuncture applied to Zusanli (ST-36) to the hemodynamic parameters, i.e., blood pressure (BP), cardiac index (CI), systemic vascular resistance index (SVRI) and blood flow volume in superior mesenteric artery (SMA), focusing on hemodynamic change induced by the acupuncture. They showed that the blood flow volume in SMA increased significantly after the acupuncture, while the others changed little from their initial values. They argued that the increase in the blood flow volume was caused by the vasodilation of SMA, which was induced by the stimulation to ST-36 via excitation of the parasympathetic system and inhibition of the sympathetic system.

In this study, a lumped-parameter approximation model of blood flow in the systemic arteries modifying our previous model was developed to validate their argument from a viewpoint of fluid science. This model was extremely simple, consisting of the aorta, carotid arteries, arteries of the four limbs and SMA, and their peripheral vascular resistances. Here, the individual artery was simplified to a tapered tube and the resistances were modelled by a linear resistance. In addition, to the upstream end of the model, which correlates with the left ventricle, two types of boundary condition were applied; mean left ventricular pressure which correlates with BP and mean cardiac output which corresponds to CI.

We examined to reproduce the experimentally obtained hemodynamic change, in terms of the ratio of the aforementioned hemodynamic parameters from their initial values before the acupuncture, by regulating the peripheral vascular resistances and the upstream boundary condition. First, only the peripheral vascular resistance of SMA was changed considering our former study in which changes in blood flow volume in the left arm and SVRI induced by stimulation to LR-3 were quantitatively reproduced by regulating the peripheral vascular resistance of the left arm. It was found that, different from the former study, this was not enough to reproduce the experimental result. Then, we also changed the resistances of the other arteries together with the value given at upstream boundary. Here, the resistances of the other arteries were changed simultaneously with a same amount. Consequently, we successfully reproduced the hemodynamic change to find that regulation of the upstream boundary condition to the value experimentally obtained after the stimulation is necessary for the reproduction, though statistically significant changes in BP and CI were not observed in the experiment.

It is generally known that sympathetic and parasympathetic tones take part in regulation of whole the systemic circulation including the cardiac function. The present result indicates that stimulation to ST-36 could induce vasodilation of peripheral circulation of SMA and vasoconstriction of that of other arteries. In addition, it implies that experimentally obtained small changes in BP and CI induced by the acupuncture may be involved in the therapeutic response.

Keywords—Acupuncture, Hemodynamics, Systemic vascular resistance, Modeling, Lumped-parameter approximation

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