FLOW THROUGH A BLOOD VESSEL WITH AXIALLY MOVING CONSTRICTION

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ABSTRACT

Massage therapy is a hands-on manipulation on the soft tissues of the body including blood vessels, muscles, connective tissue, tendons, ligaments and joints. It has a history of over 2000 years in China and has been widely accepted as an effective therapy which is comfortable and free of side effect. It is becoming an acceptable therapy for rehabilitation and disease prevention.

Considerable work for massage has been reported in the past twenty years [1,2]. Most of them were carried out on various aspects of clinical application. Research on its hemodynamic mechanism has been lacking. In this paper, a kind of massages called rolling manipulation is investigated. It is one of the most effective manipulations of Chinese massages. With this manipulation, the artery under the skin, where the operator applied the force, forms a constriction which moves with his hand. Its main benefits arise from a mechanical behavior: promoting blood circulation. In clinical studies, data has show that after the application of rolling manipulation, the blood flow rate of the recipient in the vessel under the target region increases by about 50%.

In this paper a model (Fig.1) of the flow through a blood vessel with axially moving constriction, has been developed to understand the mechanism by which the flow rate increases, from the perspective of hemodynamic principles. However, a complete explanation may be complicated and may involve some biochemical reactions and the functioning of nerve system. These non-hemodynamic factors should also be taken into consideration in seeking to understand the therapeutic effects of Chinese massage.

However, the motivation for the present work is not limited to application in massage because the present flow model can be extended to investigate a general flow field involving tubes with a moving constriction. There are a many studies [3-6] on such flows, an example being stenotic flow. However, only a few of study on stenotic flow considered it in motion. In most of these studies, assumptions have been made, like lubrication flow, mild constriction, low Reynolds number, or simple pressure-flow conditions at inlet. In this paper a model is developed which solve the full Navier-Stokes (N-S) equation by using an Arbitrary Lagrangian Euler Finite Element Method [7] (ALE-FEM) which can handle flow with moving boundary at moderate Reynolds number and large constriction amplitude.

Attention is given to the effect on the flow rate and wall shear stress created by the constriction characteristic parameters such as moving frequency and constriction coefficient. The numerical results show that the constriction moving frequency, or the frequency of rolling manipulation, has significant effect on the flow wave form (Fig.2) and wall shear stress (Fig.3). Higher frequency will lead to higher wall shear stress while the average flow rate remains relatively constant. The constriction coefficient, which controls the severity of the constriction, is another controlling parameter in rolling manipulation; it shows a significant effect on the flow rate (Fig.4) and wall shear stress (Fig.5). The magnitude of wall shear stress rises with the increase of constriction coefficient while the average flow rate decreases rapidly. Since wall shear stress is of special interest in the clinical applications, these numerical results may provide some data that may be taken into consideration when massage is used in therapy.

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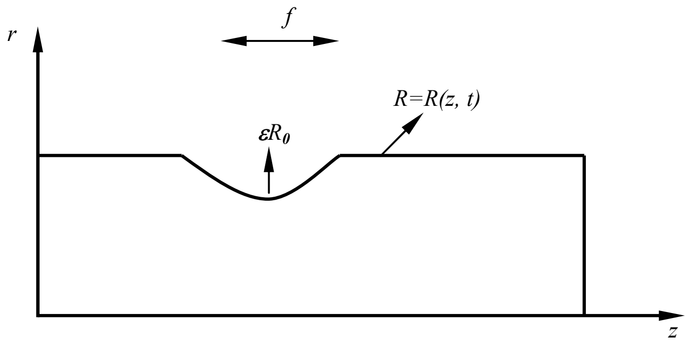

Fig.1. Model of blood vessel with moving constriction

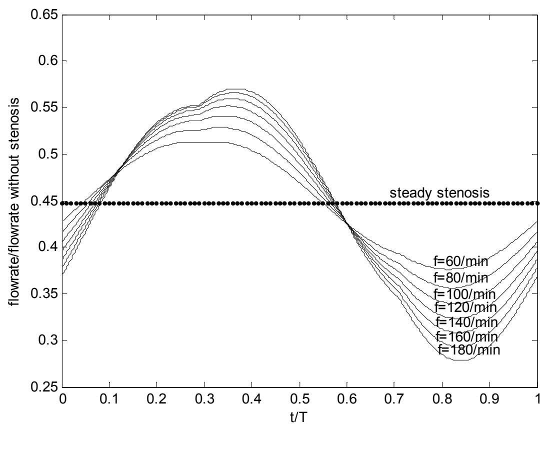

Fig.2 Flow rate in one cycle for various constriction moving frequency *f* and at $\varepsilon = 0.5$

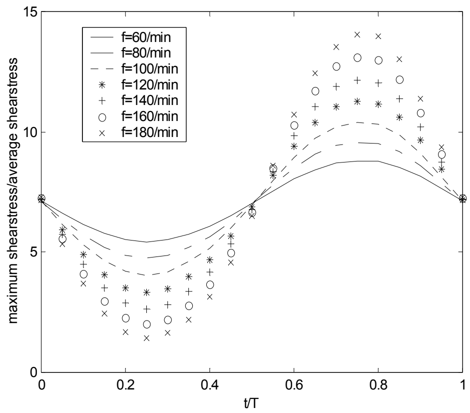

Fig.3 Maximum wall shear stress for various constriction moving frequency *f* and at $\varepsilon = 0.5$

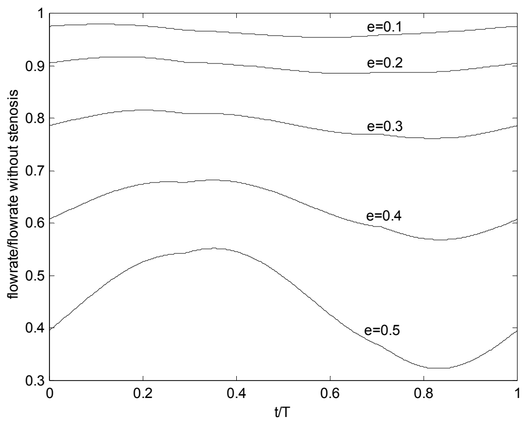

Fig.4 Flow rate in one cycle for various constriction coefficient ε and at *f*=120/min

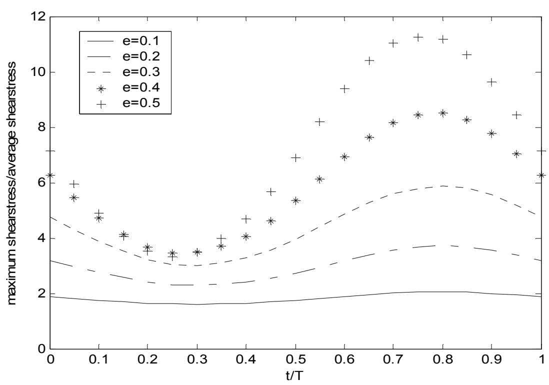

Fig. 5 Maximum wall shear stress for various constriction coefficient ε and at *f*=120/min