CHAPTER 5

LIMITATIONS, SUGGESTED CONCEPTS FOR FURTHER RESEARCH AND CONCLUSION

Limitations and suggested concepts for further research

Methodology proposed in this study is simplified for complicated behavior of aortic wall and to obtained mechanical properties of the aortic wall which has influent by its constituent as well. A number of limitations exist within the model and these are discussed by following.

In experiment it involves with five healthy mice which are monitored to estimate wall movement of aortic vessel and a different mouse which is measured for pressure profile. To come over this situation, the luminal pressure and aortic wall diameter variations are matched using the corresponding ECG by align the maximum and minimum peaks of the luminal pressure and diameter variations. That lead to suggestions for further research, methodology to provide aortic pressure should be improved. Luminal pressure and wall movement should be measured at the same position and the same subject. Increasing number of sample could improve accuracy of this developed modeling. Moreover, pressure profile obtained from catheter is not appreciate and inconvenient to used in view of clinical application. Non-invasive method for measure pressure such as pulse wave velocity is interested to use. For mechanical modeling, ultimate values of endothelium and internal elastic lamina are needed for further study.

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Although there are many studies attempted to determine the distance for each layers of arterial wall, exact distance between two layers still quite difficult to estimate. Holzapfel *et al.* (2004) had studied artery by separating layers of arterial wall. They found that heterogeneity of constituents made up the artery was continuous across the arterial wall but could be divided into multi-layer by its different proportional constituents of each layers. This implied that, the arterial wall can be experimentally separated into multi-layer. Moreover, in experiment of von Maltzahn *et al.* (1984), separated layer had a few constituent of adjust layer attached on the surface but it could be considered as individual layer as long as circumferential and longitudinal connections of that constituent of adjust layer had been destroyed. Present developed model can be suitable used based on this fact by defining that the multi-layers of the arterial are sequential, i.e., the outer radius of the inner layer can be employed as the inside radius of the adjust layer. This definition had been also used in several previous studies (Fung 1990, 1993, 1994; Humphrey, 2002; Holzapfel, 2001). However, if area between two layers has any abnormal substances such as plaque in case of atherosclerosis, present develop model is inappropriate to be used. In this point, it still need further study.

Because present model has been developed to study rupture of arterial wall which only primary tear or dissection between arterial layers was studied. The secondary tear across arterial layers is, therefore, not included in this study. Shear stress from secondary tear should be definitely included in further model for rupture risk prediction.

For more accurate to interpret for rupture risk prediction, mechanical properties of stress and strain should be more inside understand. Stiffness and

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toughness of arterial wall are interested to include. The effect of luminal pressure or the stress on transportation of the arterial should be in account.

Moreover, this mechanical model is appropriate only for considering in straight path in longitudinal distance of artery. Wave propagates characteristic of blood pulse in lumen and effect of torsion that provides shearing stress and strain to arterial wall are not included in this study. The developed model should be able to prediction initiated and propagated rupture area of artery at bending path, i.e. at aortic arc and able to account wave propagation and torsion for more realistic artery. This model can be contributed to develop of nonlinear finite element model which can consider more complexities of the arterial wall geometry and boundary conditions.

Conclusion

Constitutive equations for three dimensional multilayer stress and strain relationship model of aortic vessel by considering histology and using nonlinear constitutive equations suitably for each aortic layer can be successfully constructed. Moreover, stresses and strains distributions in aortic vascular wall can be consequently predicted. The major advantages of this new mechanical modeling can be summarized as following.

Stresses and strains distributions in coordinate of three dimensions and in five layers of aortic wall based on *in vivo* ultrasound imaging along cardiac cycle can be predicted with higher frame rate of 8 MHz. The ultrasound scanning is *in vivo* non-invasive method which gives a clear picture of soft tissues and can provide important data of aortic wall movement. No pain and surgery are experienced by this *in vivo* non-invasive method which is advantage in view of clinical application.

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The new mechanical modeling considers histology of arterial layers by using two suitable forms of constitutive equations to describe their mechanics behavior which can relate stress and strain in three dimensions and can consider non-linearity relation between the stress and strain. The endothelium and internal elastic laminar are treated as isotropic mediums and intima, media and adventitia are treated as anisotropic mediums if the collagen fibers are active.

Constitutive equations used in mechanical model involve with small number of parameters required to estimation, i.e. there are only one parameter involved in each layers of endothelium and internal elastic lamina (IEL) and only three parameters involved in each layers of intima media and adventitia which are advantage in view of computing time.

The new mechanical modeling can evaluate initiated and propagated rupture area of the arterial wall coupled with blood flow in the lumen and can present results in simple views as rupture area and rupture risk mapping which also advantage in view of clinical application.

The novelties of this research are that this is the new mechanical modelling can be developed to predict three dimensional stress and strain distribution using strain energy function related stresses and strains based on *in vivo* non-invasive experiment data. And, this new mechanical modelling involves with two different constitutive equations to descript behaviours of aortic wall. Moreover, this proposed methodology to illustrate results of arterial rupture based on *in vivo* non-invasive method and using three dimensional stress and strain relationship is firstly introduced.

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