Age-based sensitivity analysis on cardiac hemodynamics using lumped-parameter modelling

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ABSTRACT
Age is a major risk for heart failure, which is associated with the reduction in ventricular compliance, increase in arterial stiffening, and increase in systemic vascular resistance. In this study, a lumped-parameter model is used to investigate the effect of aging on the possibility of heart failure occurrence. Model parameters including the systemic and pulmonary arterial compliance and resistance, and the left ventricular elastance are calculated for different ages using a ratio-based method. These parameters are then used in the lumped-parameter model. Our findings show that as age increases, there is a leftward and a rightward shift in the left ventricle and right ventricle pressure-volume loops, respectively. For the left ventricle, there is a decrease in stroke volume and an increase in ventricular pressure as the age increases. This correlates with the occurrence of arterial hypertension in the older population. Meanwhile, the right ventricular pressure is maintained as the population gets older, despite the increase in the stroke volume. This is possibly due to the shift in intraventricular septum that causes an enlargement of the right ventricle as the age increases. This study provides understanding on the effect of age on the occurrence of heart failure.This study demonstrates the relationship of aging with cardiac hemodynamics, which provides the potential risk of heart failure occurrence. Although there are many risk factors that can cause heart failure, aging has been strongly associated with its occurrence. Understanding how age affects heart failure can help to differentiate them from other effects such as dietary, gender, and early cardiovascular diseases including arrhythmia and myocardial infarction.

KEYWORDS
Blood pressure; Cardiology; Diseases; Heart; Lumped parameter networks; Sensitivity analysis

REFERENCES

1] Haldeman, G.A., J.B. Croft, et al., *Hospitalization of patients with heart failure: National Hospital Discharge Survey, 1985 to 1995.* Am Heart J, 1999. **137**(2): p. 352-60 doi: 10.1053/hj.1999.v137.95495.

[2] Strait, J.B. and E.G. Lakatta, *Aging-associated cardiovascular changes and their relationship to heart failure.* Heart Fail Clin, 2012. **8**(1): p. 143-64 doi: 10.1016/j.hfc.2011.08.011.

[3] Li, H., M.H. Hastings, et al., *Targeting Age-Related Pathways in Heart Failure.* 2020. **126**(4): p. 533-551 doi: doi:10.1161/CIRCRESAHA.119.315889.

[4] Arbab-Zadeh, A., E. Dijk, et al., *Effect of aging and physical activity on left ventricular compliance.* Circulation, 2004. **110**(13): p. 1799-805 doi: 10.1161/01.CIR.0000142863.71285.74.

[5] Fujimoto, N., J.L. Hastings, et al., *Effect of ageing on left ventricular compliance and distensibility in healthy sedentary humans.* J Physiol, 2012. **590**(8): p. 1871-80 doi: 10.1113/jphysiol.2011.218271.