S. Mohan Mahalakshmi Naidu / Supervisor: Prof. P. C. Pandey, "Beat-to-beat estimation of stroke volume using impedance cardiography," *PhD Thesis*, Department of Electrical Engineering, IIT Bombay, 2017.

Abstract

Impedance cardiography is a low-cost noninvasive technique, based on monitoring of the thoracic impedance, for estimation of stroke volume (SV) and some other cardiovascular indices. Impedance cardiogram (ICG) is the negative of the first derivative of the impedance signal. Detection of its characteristic points B, C, and X is used for SV estimation. Our research objective is to develop a method for automatic beat-to-beat SV estimation to improve the acceptability of this technique for use in clinical practice. For this purpose, two investigations are carried out: (i) development of a technique for characteristic point detection and (ii) use of artificial neural network (ANN) for SV estimation using echocardiography as the reference technique. An ICG-echocardiography database is developed with recordings from subjects with normal health under rest and in the post-exercise condition and from subjects with cardiovascular disorders under rest.

A technique for automatic detection of B, C, and X points is proposed. It uses wavelet-based artifact suppression and multiple time-domain features in ICG along with R and T peaks of ECG as reference points to reduce errors due to morphological variations. Evaluation with reference to the visually marked points in ICG and with reference to the intervals measured from echocardiography showed its performance to be better than the established techniques. For estimation of the B-X interval, the mean and standard deviation of differences, as referred to the mean R-R interval, were 3.2% and 7.1%, respectively.

An ANN-based technique for SV estimation is proposed, with the input ICG parameters obtained by automatic detection of the characteristic points and the target values obtained by beat-to-beat SV measurements from time-aligned Doppler echocardiogram. A three-layer feed-forward ANN with error back-propagation algorithm is optimized by examining the effects of the number of neurons in the hidden layer, activation function, training algorithm, and set of input parameters. Performance of the optimized ANN was much better than that of equation-based estimations. Results showed that the ANN trained using the pooling of the under-rest and post-exercise recordings from subjects with normal health can be used for SV estimation for the recordings from subjects with cardiovascular disorders, it resulted in mean error of −0.1 mL, standard deviation of errors of 7.2 mL, and correlation coefficient of 0.93. Thus the proposed method may be helpful in improving the acceptability of impedance cardiography in clinical practice and as a research tool for study of SV variability.