Uttam Rajaram Bagal (Supervisor: Prof. P. C. Pandey), “Detection of characteristic points of impedance cardiogram and stroke volume estimation,” PhD thesis, Department of Electrical Engineering, IIT Bombay, 2020.

ABSTRACT

Impedance cardiography is a noninvasive technique for sensing the thoracic impedance variation due to the blood volume variation during the cardiac cycle and using the sensed impedance to estimate the stroke volume (SV) and some other cardiovascular indices. The negative of the first derivative of the impedance signal is the impedance cardiogram (ICG), and its landmarks associated with significant events in the cardiac cycle are known as the characteristic points. The research objective is to develop a technique for automatic beat-to-beat SV estimation using the ICG parameters and the subject-dependent parameters without using thoracic impedance models. Investigations are carried out for improving (i) the detection of the ICG characteristic points for obtaining the ICG parameters and (ii) beat-to-beat SV estimation using an artificial neural network (ANN). The investigations use Doppler echocardiography as the reference technique, with a database comprising simultaneously recorded ICG and Doppler echocardiogram signals from 18 subjects with normal health and 22 subjects with cardiovascular disorders.

A technique is proposed for automatic detection of the ICG characteristic points based on time-domain features and without estimation of the baseline and manual selection of the processing parameters. It uses wavelet-based suppression of respiratory artifacts in the ICG signal, ECG R-peaks as reference for cardiac cycle segmentation, and multiple time-domain features. Evaluation results showed the proposed technique to perform better than the earlier techniques and to be suitable for waveforms with significant heart rate and morphological variations. The bias and precision related errors in measuring the left ventricular ejection time (LVET) were 2.1% and 3.4% of the mean R-R interval, respectively.

An ANN-based technique is investigated for beat-to-beat SV estimation, using a feed-forward network with back-propagation algorithm and the Levenberg-Marquardt method for synaptic weight adjustment, hidden layer(s) having ten neurons with hyperbolic tangent activation function, input set comprising the ICG parameters, and the subject-dependent parameters, and target SV values from time-aligned Doppler echocardiogram. The best performance was obtained for the network with one hidden layer and the input parameter set comprising three beat-to-beat parameters (LVET, ICG peak, R–R interval) and five subject-dependent parameters (age, height, weight, inter-electrode distance, basal impedance). The results also indicated SV estimation feasibility without measuring the inter-electrode distance and the basal impedance by training the network using a larger dataset. The technique resulted in the correlation coefficients of 0.946 and 0.761 for the pooled dataset partitioning and the subject-wise dataset partitioning, respectively. The correlation coefficient increased with an increase in the number of subjects in the training set, indicating that tracking subject-to-subject SV variation may need training the network on a dataset with a larger number of subjects.