Vinod K. Pandey, Suppression of artifacts in impedance cardiography, Ph.D. Thesis, Biomedical Engineering Group, School of Biosciences and Bioengineering, IIT Bombay, 2009.

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***Abstract -*** Impedance cardiography is a noninvasive technique for monitoring stroke volume, based on sensing variation in the thoracic impedance, z(t), due to the blood flow. Time derivative of the thoracic impedance is known as the impedance cardiogram (ICG) and is used for estimating ventricular ejection time (Tlvet), the ICG peak ((-dz/dt)max), stroke volume, and some other cardiovascular indices. Respiration and motion artifacts cause base line drift in the sensed impedance waveform, particularly during or after exercise, and this drift results in errors in estimation of the parameters. Objective of the research reported in this thesis is to investigate techniques for removal of the artifacts from ICG for estimation of stroke volume and other cardiovascular indices, without smearing the beat-to-beat variations.

A baseline restoration circuit and signal processing technique for suppression of artifacts are developed and investigated. The baseline restoration circuit, based on amplitude tracking, is developed for partly removing the artifacts for effective utilization of the input dynamic range of the signal acquisition hardware. The signal processing techniques developed and investigated are based on adaptive filtering and wavelet based denoising. A signal related to respiration is sensed by a thermistor based airflow sensor and is used as the reference input for the respiratory artifact cancellation. For a better approximation of the respiratory artifact, cubic spline fitting is applied on the sensed impedance signal in synchronism with the respiratory phases. Adaptive filtering is not suitable for suppression of motion artifact because of practical difficulty in obtaining reference signal related to the various motions causing variation in the thoracic impedance. A wavelet based denoising technique, not requiring a reference signal, is investigated for removal of respiratory and motion artifacts. These artifact suppression techniques are evaluated on signals with simulated artifacts and signals acquired from several volunteers with normal health.

For validation of the techniques under a clinical setting, Doppler echocardiography is used as the reference. The values of stroke volume estimated from impedance cardiography were compared with those obtained from Doppler echocardiography, on beat-to-beat basis, for subjects with normal health and ward referral patients. Artifact suppression resulted in increased correlation, low scatter from linear regression, and a decrease in the mean bias and the standard deviation of the differences, showing that the artifact suppression techniques can be used with impedance cardiography instrument for continuous monitoring of stroke volume and other cardiovascular parameters.