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# Adaptive Filtering and Characteristics Extraction for Impedance Cardiography

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**Abstract**

Impedance Cardiography (ICG) is a noninvasive technique for monitoring stroke volume, cardiac output and other hemodynamic parameters, which is based on sensing the change of thoracic electrical impedance caused by blood volume change in aorta during the cardiac cycle. Motion artifact and respiratory artifact can lead to baseline drift in ICG signal, particularly during or after exercise, which can cause errors when calculating hemodynamic parameters. This paper presents an LMS-based adaptive filtering algorithm to suppress the respiratory artifact of ICG signal without restricting patients' breath. Estimation of hemodynamic parameters requires error-free automatic extraction of the characteristic points. Wavelet transform is used for extracting characteristic points which include its peak point (Z), start point (B) and end point (X) of left ventricular ejection time.

*Keywords*: Impedance Cardiography; Adaptive Filtering; Wavelet Transform; Characteristic Points; Hemodynamic Indices; Respiratory Artifact

## 1 Introduction

Impedance Cardiography (ICG) is a simple, inexpensive and noninvasive method to monitor electrical impedance change of thorax which is caused by periodic change of blood volume in aorta. An appropriate thorax model can be used for estimating Stroke Volume (SV), Cardiac Output (CO) and other hemodynamic parameters [1]. A typical ICG waveform and its characteristic points is shown in Fig. 1. Points B, Z and X are the three main characteristic of ICG trace. Point B represents opening of the aortic valve, while point X denotes closing of the aortic valve. The point Z corresponds to peak of the ICG waveform, while the point X is the lowest point in the ICG waveform. The time interval between point B and point X is the Left Ventricle Ejection

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Time (LVET) [2]. SV is generally calculated using Kubicek's equation using two hemodynamic parameters: the LVET and the $dz/dt_{max}$ of ICG [1].

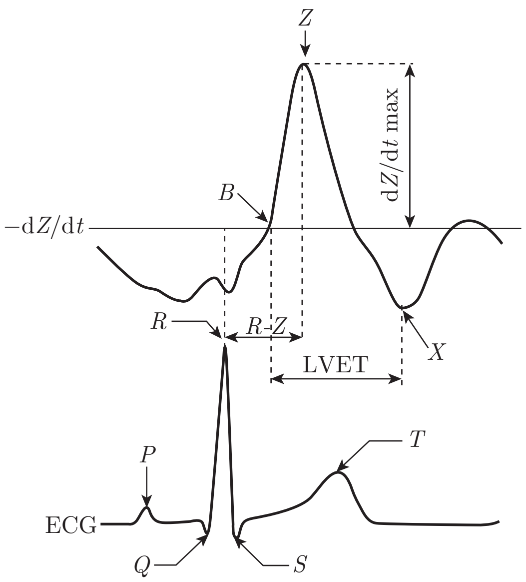


Fig. 1: A typical ICG waveform and an Electrocardiogram (ECG) waveform

The ICG signal is influenced mainly by motion artifact and respiratory artifact. Respiratory artifact is primarily caused by changes of thoracic volume during breathing, while motion artifact is generally caused by body movements and contraction of muscle. The frequency spectrum of respiratory and motion artifacts partly overlap with frequency spectrum of the ICG signal, so it is critical to remove all the artifacts. The electrical impedance change caused by blood volume change in aorta typically accounts for 2-4% of the base impedance (usually about 20ohm), while the electrical impedance change caused by the respiratory artifact and motion artifact may be 30% or even more [1]. Therefore the motion and respiratory artifacts may lead to a large baseline drift in the ICG signal, subsequently resulting in errors in characteristic points extraction and calculation of the hemodynamic parameters.

Some algorithms of removing the respiratory artifact in the ICG signal have been published. Pandey used an LMS-based adaptive filter to suppress respiratory artifact with an airflow sensor sensing breath [3]. Barros adopted an adaptive filter and a scaled linear Fourier combiner to express the ICG signal as a scaled Fourier series with a period equal to the R-R interval of ECG signal [4].

Unlike Heart Rate Variability (HRV), stroke volume variability and cardiac output variability has not been widely applied as a medical index for diagnosing cardiovascular diseases, because accurately estimating SV in a long period is very difficult [5]. This paper presents an LMS-based adaptive filtering algorithm to suppress the respiratory artifact of the ICG signal without restricting patients' breath and applies wavelet transform to extract characteristic points (B, Z and X).

The remaining portions of this paper are divided as follows: in Section 2 we analyzed signal processing technique for denoising ICG. And then we adopted wavelet transform to extract characteristic points of ICG in Section 3. In Section 4 we estimated hemodynamic parameters by classic formula. Finally, we obtained our conclusions in Section 5.