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Noninvasive Ambulatory Hemodynamic Monitoring Based on Electrocardiogram and Impedance Cardiography ⋆

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Abstract

Two different noninvasive ambulatory hemodynamic monitoring devices (belt-type and chest-type) based on Electrocardiogram (ECG) and Impedance Cardiography (ICG) has been designed, fabricated and tested. Hardware designs of the two ambulatory hemodynamic monitoring devices based on Tetrapolar configuration and placement of the electrodes were introduced. Hemodynamic parameters such as Stroke Volume (SV), Cardiac Output (CO) and Cardiac Index (CI) can be estimated according to Kubicek Formula by extracting characteristic points and characteristic periods in the ICG Signal. CI is CO divided by body surface area. CI is comparable among different people because it is not influenced by the body height and weight. The body's physiological responses to postural change are primarily a reaction to the change of gravity, because change of gravity can cause changes of blood flow distribution in organs and tissues. Different body postures (upright or supine) can result in reducing or rising of CO. The detection accuracy has also been validated with a commercial ICG detection instrument from Mindray company, and the correlation coefficient is 0.83.

Keywords: Electrocardiogram; Impedance Cardiography; Noninvasive Ambulatory Hemodynamic Monitoring; Characteristic Points; Cardiac Output; Cardiac Index; Postural Change

1 Introduction

Impedance Cardiography (ICG), also known as Thoracic Electrical Bioimpedance (TEB), is a technology that converts changes in thoracic impedance to changes in volume over time. It is used to track blood volume changes occurring during the cardiac cycle noninvasively and continuously.

This technology, originally used by NASA in the 1960's, has benefited from the advent of the microprocessor and the better understanding of the cardiac cycle, thanks to technology such

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as echocardiography and magnetic resonance imaging. Today, noninvasive methods of measuring of cardiac output are coming into clinical use on a larger scale than ever before and are compared with other methods such as thermodilution and the direct and indirect Fick methods [1].

ICG has been widely used in the investigation of hemodynamic performance in a variety of clinical and laboratory settings. Cardiac Output (CO) estimated by ICG, one of the most important hemodynamic parameters, has been validated via comparison with thermodilution with participants ranging from infants to adults with cardiovascular disease, with correlations ranging from 0.82 to 0.92 [2].

Ambulatory ICG monitoring is a promising technique allowing the estimation of cardiac hemodynamic parameters during transient events. The analysis of hemodynamic parameters during the patient's normal activity would be difficult or even impossible to perform using other classical methods [3]. Ambulatory ICG monitoring is able to be performed in patients continuously and noninvasively, whether you are at home or do exercise outside. This technique is a useful tool to facilitate more convenient and safer treatment plans for cardiovascular patients.

Currently there are mainly two electrode configurations to perform bioimpedance measurements: Bipolar configuration and Tetrapolar configuration (Fig. 1). In the Bipolar Configuration two electrodes are used and both play the role of injecting the current and sensing the voltage. This configuration is problematic because the potential difference sensed between the two electrodes includes the nonlinear voltages generated by the current flowing through the polarization impedance at the electrode-skin interface.

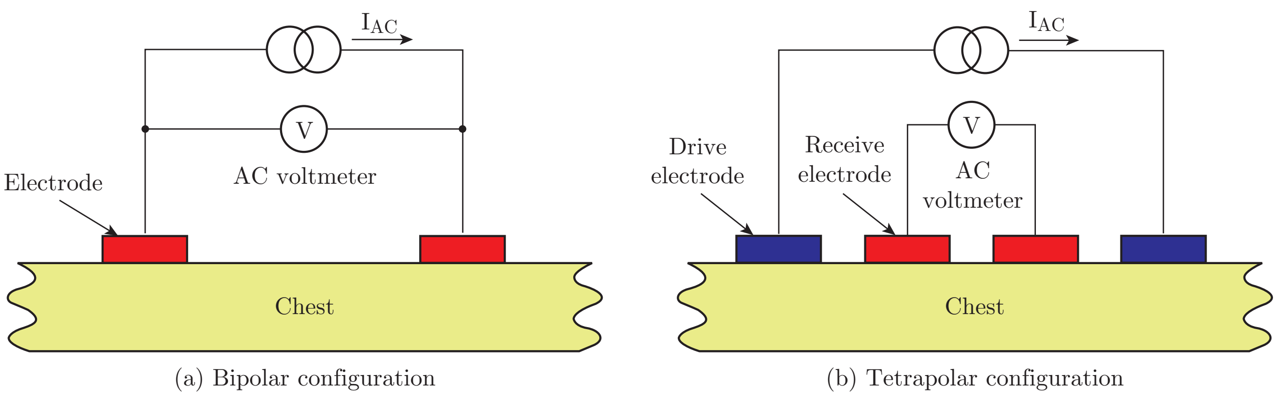

Fig. 1: Electrode configuration of ICG measurement

The second method involves the use of four electrodes (Tetrapolar), which means two couples of electrodes play different roles. Two drive electrodes apply the alternating current with high frequency and small amplitude; while the other two receive electrodes sense the potential. This method minimizes the load of the skin-electrode contact impedance, because under ideal circumstances the input current in the voltage sensing is zero, therefore the sensed voltage is equal to the tissue voltage and the electrodes voltage are zero [4].

The remainders of this paper are divided as follows: in Section 2 we introduced hardware design of two different ambulatory hemodynamic monitoring devices. And then we calculated hemodynamic parameters and performed comparison experiments in Section 3. In Section 4 we verified postural change can impact hemodynamic parameters. Finally, we got our conclusions in Section 5.