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Original Research Article

Detection of valvular heart diseases using impedance cardiography ICG

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ABSTRACT

Impedance cardiography (ICG) is a simple, non invasive and cost effective tool for estimating stroke volume, cardiac output and other hemodynamic parameters. It has been successfully Q3 used to diagnose several cardiovascular diseases, like the heart failure and myocardial infarction. In particular, valvular heart disease (VHD) is characterized by the affection of one or more heart valves: mitral, aortic, tricuspid or pulmonary valves and it is usually diagnosed using the Doppler echocardiography. However, this technique is rather expensive, requires qualified expertise, discontinuous, and often not necessary to make just a simple diagnosis. In this paper, a new computer aided diagnosis system is proposed to detect VHD using the ICG signals. Six types of ICG heartbeats are analyzed and classified: normal heartbeats (N), mitral insufficiency heartbeats (MI), aortic insufficiency heartbeats (AI), mitral stenosis heartbeats (MS), aortic stenosis heartbeats (AS), and pulmonary stenosis heartbeats (PS). The proposed methodology is validated on 120 ICG recordings. Firstly, ICG signal is denoised using the Daubechies wavelet family with order eight (db8). Then, these signals are segmented into several heartbeats and, later, subjected to the Linear Prediction method (LP) and Discrete Wavelet Transform approach (DWT) to extract temporal and time–frequency features, respectively. In order to reduce the number of features and select the most relevant ones among them, the Student *t*-test is applied. Therefore, a total of 16 features are selected (3 temporal features and 13 time–frequency features). For the classification step, the support vector machine (SVM) and k-Nearest Neighbors (KNN) classifiers are used. Different combinations between extracted features and classifiers are proposed. Hence, experimental results showed that the combination between temporal features, time–frequency features and SVM classifier achieved the highest classification performance in classifying the N, MI, MS, AI, AS and PS heartbeats with 98.94% of overall accuracy.

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1. Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide and according to the World Health Organization (WHO); it represents 31% of all global deaths. Particularly, valvular heart disease (VHD) is one of the most frequent CVD, which is characterized by the affection of heart valves, lung or other organs fluid retention. Mitral, aortic, tricuspid, and pulmonary valves involve two major types of problems: insufficiency and stenos, like the mitral insufficiency, the aortic stenos, etc. [1]. However, VHD may cause several serious complications such as pulmonary hypertension, stroke, and atrial fibrillation [2]. The early diagnosis and treatment can avoid these fatal complications. Generally, VHD is diagnosed and quantified using different tools, such as echocardiography, chest X-ray, and catheterization. The most commonly used technique is echocardiography, especially the Doppler echocardiography [3]. However, this technique is rather expensive, requires qualified expertise, discontinuous, and it is more dedicated to assess the severity and the morphology of the diagnosed lesions. Therefore, others techniques are needed for a simple diagnosis and for the analysis of a long time (ambulatory recordings). Impedance cardiography (ICG) is a simple, cost effective and continuously applicable tool which has been used for diagnosing some CVD. It has been used to detect heart failure [4,5], myocardial infarction [6], and mitral insufficiency [7]. ICG is generally used for assessing electrical impedance change of the thorax and for estimating several hemodynamic parameters such as stroke volume (SV) and cardiac output (CO) [8]. In order to validate its functionality, measurement by ICG has been strongly correlated with echocardiography [9,10], thermodilution [11,12] and Fick method [13]. The ICG waveform (dZ/dt) and its main characteristic points (B, C, and X) are shown in Fig. 1. These points are related to distinct physiological events in the cardiac cycle. In fact, the point B denotes the beginning of the ejection time and it appears simultaneously with the opening of the aortic valve. The point C is taken at the top of the ICG waveform and it is associated with the ventricular contraction. The point X is the lowest point after the peak C and it is associated with the closure of the aortic valve [14].

Despite the simplicity of the impedance cardiography tool, its use is still very limited in the classification of CVD, especially VHD. In the literature, Ben Salah et al. [15] have proposed a CAD system based on the ICG signal analysis for the detection of cardiac diseases. In his study, temporal, spectral and cepstral features have been extracted from normal and abnormal ICG traces. Then, the classification has been performed by using linear discriminant method, and achieved 95.40% accuracy.

In this paper, a new computer aided diagnosis system is proposed to detect different types of VHD, based on the analysis of ICG signal. In order to achieve this goal, several steps are carried out. First, we denoised the ICG signals. Then, we segmented the ICG signals into several heartbeats in order to facilitate the feature extraction and the classification steps. Moreover, from each heartbeat, temporal and time–frequency features are extracted. Further, the Student *t*-test is applied to reduce the number of features and to select the most relevant ones. Later, the extracted features are classified using support vector machine (SVM) and k-Nearest Neighbors (KNN) classifiers.

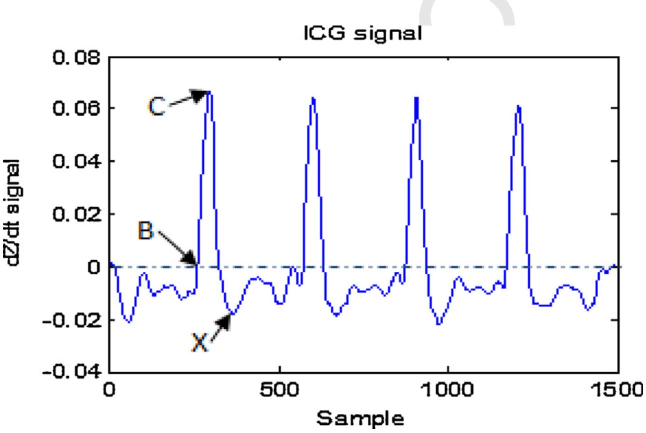

Fig. 1 – Characteristic points in the ICG signal.

2. Proposed methodology

The block diagram of the proposed methodology is shown in Fig. 2. First, in the preprocessing step, the ICG signals from the collected database are denoised. Then, these signals are segmented into several heartbeats. Thereafter, temporal and time–frequency features are extracted from each heartbeat. Later, the most relevant features are selected using the Student *t*-test. Finally, heartbeats are classified into different classes (normal heartbeats and different types of VHD heartbeats) based on the SVM and the KNN classifiers.

2.1. *Database collection*

In this study, 120 ICG recordings are selected corresponding to 73 subjects; 20 control subjects (10 females and 10 males) and 53 subjects with different types of VHD (25 females and 15 males). Five VHD are treated: 20 patients with mitral insufficiency (MI), 8 patients with mitral stenosis (MS), 8 patients with aortic insufficiency (AI), 10 patients with aortic stenosis (AS), and 7 patients with pulmonary stenosis (PS). The normal ICG signals are recorded from volunteers, whereas, the ICG signals with VHD are recorded from hospitalized patients who were identified by cardiologist. We selected for this study patients with isolated VHD; the patients who had additional diseases are excluded.

The ICG signals are recorded following the method proposed in [16]. In this method, a constant, high frequency and small current is applied, through two electrodes, placed in

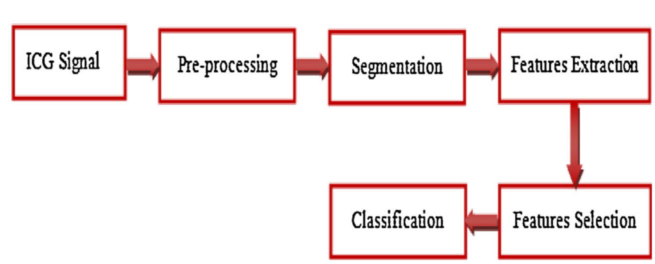

Fig. 2 – Block diagram of the proposed methodology.

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