Application of Morlet Transform Wavelet in the Detection of Paradoxical Splitting of the Second Heart Sound

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Abstract

This study aims at utilising wavelet transforms, namely the Morlet wavelet, in early detection of a reverse in the appearance of A2 and P2 within the second heart sound.

With the collaboration of the Cardiology Department at Brighton and Sussex University Hospital in England, and using a newly build data acquisition system developed at the University of Sussex, a number of patients with LBBB (Left Bundle Branch Block), and others with fitted pacemakers, were studied. The data was then analysed with Morlet algorithm. From the displayed results it is relatively easy to detect the reverse in A2 and P2. This technique offers an effective, economic method of detecting the paradoxical splitting of S2, which is otherwise very difficult to detect with the human ear. The technique can works together with the ECG to increase the reliability of the diagnosis of LBBB cases.

1. Introduction

The first heart sound has a frequency of between 25-45 Hz, and lasting for 0.15 seconds, where the second heart sound has a frequency of about 50 Hz, and lasts for about 0.12 seconds [1]. Both comprise of two components M1, T1, and A2, P2 respectively. The analysis in this paper centres on the second heart sound (S2) in terms of characteristics and components.

The separation of the components in S2 is a normal phenomenon in healthy individuals during held inspiration. If this splitting persists or appears in other parts of the breathing cycle, it can indicate the presence of pathological heart conditions. However, when the separation of A2 and P2 is reversed (paradoxical splitting) it indicates the certain presence of a heart condition. One of these pathological conditions is LBBB. Which is usually seen in dilated cardiomyopathy, hypertrophic cardiomyopathy, hypertension, aortic valve disease, coronary artery disease, and a variety of other cardiac conditions.

The paper looks at patients with LBBB and pacemaker patients, as they come under the list of patients with possible paradoxical splitting of S2.

1.1. Paradoxical splitting of S2

Paradoxical splitting occurs when the closure of the aortic valve is delayed, so that the pulmonic closure occurs first followed by aortic closure. In this case the interval between pulmonic and aortic closures is heard during expiration and disappears during inspiration. One of these pathological conditions is LBBB. There are other diseases that cause paradoxical splitting, such as (i) Right Ventricular Ectopic and Paced Beats, where the delay in the left ventricular contraction resulting from ectopic or paced right ventricular beats causes the paradoxical split, (ii) Left Ventricular Outflow Tract Obstruction, which is caused by prolonged left ventricular ejection period that is usually secondary to congenital valvular aortic stenosis, (iii) Wolff-Parkinson-White Syndrome, where there is an additional or accessory conducting pathway which leads from the atria to the ventricles, and if these pathways favour an earlier conduction of the right ventricle, this causes P2 to move before A2.

2. Wavelet representation

Due to the importance of S2 as an indication of the presence of heart disease, Tilkian [3] wrote in his book about auscultation " It is important to persist in training the ear because once you can hear the splitting of S2, cardiac auscultation becomes clinically more useful, specially detecting expiratory splitting of S2, a helpful clue identifying cardiac disease". Thus, newer investigations and developments if new techniques to make it easier to listen, analyse, and interpret the components of the second heart sound is important.

The Continuous Wavelet Transform CWT, is frequently used [4-8] in the analysis of various heart sounds and murmurs. From these studies, it was confirmed that Morlet wavelet was the best suited for the analysis of heart sounds. From the natural shape of the mother Morlet wavelet, the Morlet waveform best resembles the shape of the PCG signal of the heart sound in terms of the fundamental frequency constituents.