TIME FREQUENCY ANALYSIS OF CANINE HEART SOUNDS

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Abstract — Six different time frequency distributions (TFDs) have been used to analyze the first and second heart sounds. These TFDs have been applied to both simulated heart sound data and to experimental phonocardiogram data (N = 6) recorded in the anesthetized dog. Using the distributions, no significant systematic rising frequency component was observed in either the first or second heart sounds. As revealed using the CWT, the energy of the lower frequency components are found to decrease more rapidly than the higher frequency components as the myocardium is progressively depressed by applying increasing concentrations of the gaseous anesthetic agents, halothane and isoflurane.

INTRODUCTION AND METHODS

Traditional methods have analyzed the phonocardiogram (PCG) signal visually in the time domain and used conventional Fourier techniques to examine spectral properties of the signals.

In a study of canine first heart sounds recorded from the epicardium [1] used the Binomial reduced interference distribution to observe a strong rising frequency component in early systole. Other researchers did not observe this component. Indeed, in a more recent study by [2], recordings from 27 sites across the human thorax showed that the first heart sound consisted only of quasi-stationary and impulse-like components.

In order to gain a greater understanding of the genesis of the first and second heart sounds; we investigated transthoracic canine heart sounds recorded from the apex region using six different time-frequency distributions; Spectrogram, Minimum Mean Cross Entropy (MMCE) combination of Spectrograms, Continuous Wavelet Transform (CWT), Wigner-Ville Distribution (WVD), Choi-William Distribution (CWD) and Zhao-Atlas-Marks Distribution (ZAM). These distributions were also tested on simulated heart sound data.

The aims were to compare and identify optimal time-frequency distributions (TFDs) for the characterization of the heart sounds and from this characterization assess the likelihood of a rising frequency component in the first and second heart sounds. A secondary aim was to assess the effects of the anesthetic agents, halothane and isoflurane on the heart sounds and to correlate these effects with their cardiodepressant action as determined by measurement of cardiac output. To investigate these effects, moment-based time-frequency measures including signal localization in time and frequency, Heisenberg-Gabor Principle and the Renyi-entropy are also presented.

RESULTS AND DISCUSSION

Simulated first and second heart sounds generated to test the above distributions, as well as experimental data, showed that ZAM and CWT are able to provide the best representation. The two major frequency components of the first heart sounds are resolved clearly. For time-frequency representation of the second heart sound, due to the important time information regarding the separation of closure of the aortic (A2) and pulmonary (P2) valves, ZAM was found to be superior. However, in visualizing TFDs as an energy density function, the CWT is the best because it is manifestly positive and provides good resolution. The Spectrogram is limited by insufficient resolution because its time and frequency resolutions cannot be simultaneously optimized. Attempts to use the MMCE combination of Spectrograms to improve the TFD gave little improvement and the use of the WVD is limited by extensive presence of cross-terms. The CWD suppresses some of the cross-terms in the representation of the heart sounds and its representation is able to provide better time and frequency localization with little smearing.

Using the six distributions, no significant systematic rising frequency component was observed in either the first or second heart sounds. Analysis of experimental heart sounds with the intervention of anesthetic agents revealed that the energy of the heart sounds decreased with the concentration of the anesthetic agents as would be expected due to their cardiodepressant effects. As revealed using the CWT, the energy of the lower frequency components are found to decrease more rapidly than the higher frequency components as the myocardium is progressively depressed. In addition, the time localization of the frequency components is progressively delayed as the myocardium is depressed with the application of the anesthetic agents.

REFERENCES