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Research Article

CAN PHONOCARDIOGRAPHY EVALUATE THE LEFT VENTRICULAR EJECTION FRACTION?

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ABSTRACT
Digital form of heart sound is rarely used for complex cardiac diagnosis. In this work, the phonocardiographic (PCG) data of varied left ventricular ejection fraction (LVEF) (n=5) are processed and compared with the normal PCG data with the help of artificial neural network (ANN). It is identified that the ANN differentiated the PCG power spectrum of altered LVEF with respect to the normal PCG power spectrum with the accuracy of >70%. The observation suggests that digital form of PCG along with smart computational classifier can be used successfully for the diagnosis of complex cardiac changes such as changes in LVEF.

Key Words: *Artificial Neural Network, Left Ventricular Ejection Fraction, Phonocardiography*

INTRODUCTION
Applications of heart sounds or phonocardiogram (PCG) as an alternative diagnostic tool has been tried and discussed since long time (Abelmann *et al.*, 1953)**.** Past literature suggest that researchers in this domain have achieved remarkable success in automated recognition of different heart sounds (Singh and Anand, 2007 and Ergen *et al.*, 2012) and achieved encouraging results in diagnosis of cardiac valvular diseases (Ari *et al.*, 2008). However, the progress in this area is almost restricted on the diagnosis associated with cardiac auscultations only. The analyses of the changes in PCG frequency spectrum with the ejection fraction of the cardiac chambers have not been tried yet.

MATERIALS AND METHODS
With all ethical considerations and consent from the subjects, our research team had acquired PCG data from young male subjects along with the echocardiogram from specialized cardiac hospital, B.M. Birla Heart research Centre, Kolkata, India. Two channel Biopac Instrument and supported Acknowledge software (Biopac Inc., USA) was used for the data recording (sampling frequency 2000 cycles/second) and processing purposes. With the help of echocardiography data, we were able to classify the subjects with changed left ventricular ejection fraction (LVEF). The echocardiography also confirmed hypokinetic left ventricles in these subjects that resulted in decrease in LVEF. The variations of PCG frequency spectrum for the varied LVEF subjects (n=5) were evaluated and compared with the average PCG frequency spectrum data acquired from a normal subjects. After pre-processing, the final data analysis was done for the 0 to 200Hz of power spectrum. From each subjects, twenty noise free PCG epochs for complete cardiac cycles were randomly picked to calculate the average power spectrum. The PCG spectra show two distinct peaks (between 20-50Hz and 50-80Hz).

RESULTS AND DISCUSSION
The comparative PCG spectrum analyses for these subjects were showing distinct variations on both the spectral peaks of the power spectrum and more importantly the second peaks (50-80Hz) were found synchronized even with the minor changes in LVEF (Figure-1). Further, the backpropagation artificial neural network (ANN) with single hidden layer was also tried to automatically evaluate the LVEF. The

optimized network [2:10:1 (input: hidden: output nodes)] was found classifying the PCG spectral features with the accuracy of >70% after the training. Distinct visual differences between PCG data of impaired LVEF and PCG data of the valvular abnormalities are apparent.

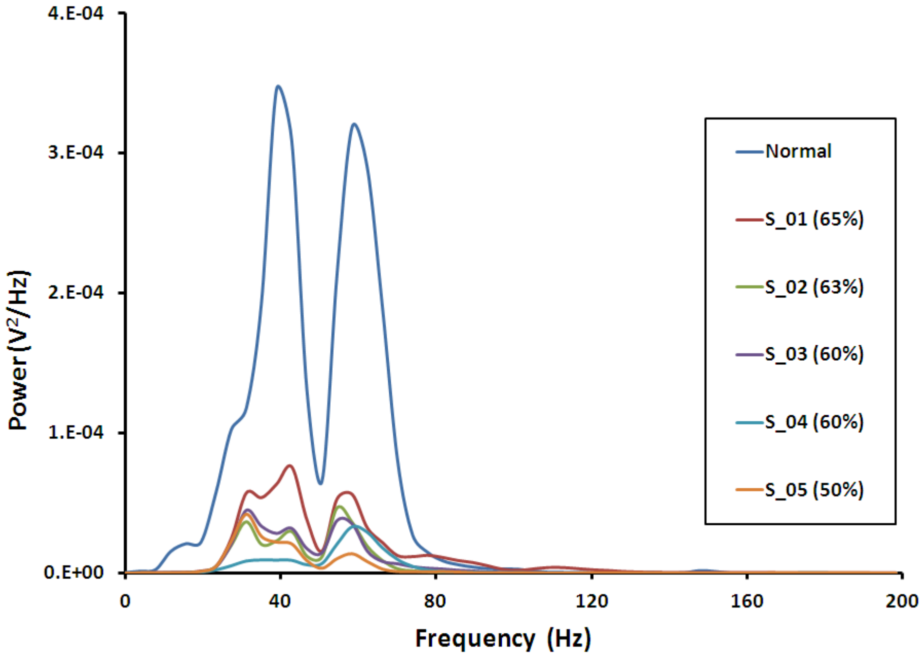

Figure 1: Figure represents comparative analysis of average power spectrum data (20 random epochs of complete cardiac cycle for each subject) for varied cases of left ventricular ejection fraction. Here 'S' (S_01 to S_05) represents the subjects of changed LVEF.

Valvular abnormalities cause distinct changes in raw PCG signals in 1st and 2nd heart sounds respectively for mitral and aortic valve abnormalities. However, the PCG data of impaired LVEF looks similar to the normal PCG signals. Thus, to analyze and identify the hypokinetic left ventricle through PCG signals, the applications of digital signal processing tools is essential. We tried with different form and combination of data, and identified that before final calculation of PCG power spectra, (i) data must be noise free and (ii) number of cardiac cycles selected as epochs for the spectral calculations needs to be optimized for the calculation as with increased number of epochs, chances to lose the information were higher. The distinct variations in PCG power spectra with varying LVEF suggest definite correlations between heart sound and LVEF and thus, the achieved results have certainly opened a new dimension for the application of PCG data in cardiac diagnosis.

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