Investigating the Interaction between Ballistocardiogram and Respiratory Phases

Moein Enayati, *Student Member, IEEE*, Bo Yu Su, *Student Member, IEEE*, Laurel Despins, Marjorie Skubic, *Senior Member, IEEE*, James M Keller, *Life Fellow, IEEE*, and Mihail Popescu, *Senior Member, IEEE*

***Abstract*— Interactions between cardiovascular parameters and the respiratory phases have been studied previously using Electrocardiography. In this paper, we explore variations of waveform features extracted from Ballistocardiograms (BCG) at different phases during the respiratory cycle. We use a dataset collected from 58 volunteers, with a bed sensor positioned under the mattress. Results show considerable differences in BCG features between inhalation and exhalation peaks.**

I. Introduction

Previous studies have shown interactions between system hemodynamics and respiration [1]. Authors of [2] reported 2% increase in heart rate during inspiration as well as other effects of phasic respiration such as 17% inspiratory decrease of left ventricular systolic volume (LVSV). A study on PPG signals also showed a reduction in the peak amplitude during inspiration [3]. Significant changes in morphology of the BCG signal were noted by Starr [4], which repeated in corresponding respiratory cycles. In this paper, we study several morphological features of the BCG waveform, to investigate their possible variations with respect to the respiration cycles, for better characterization of the BCG waveform, and non-invasive health monitoring and tracking.

II. Methodology and Data

A group of 58 volunteers (ages 18-50) were asked to lie in the supine posture on a bed. Ten minutes of continuous BCG signals were collected using four hydraulic sensors located under the mattress. The respiratory waveform was collected from the chest band. The ECG R-peaks were used for reference to segment heartbeats in the BCG signal. The best transducer was selected based on the highest DC-bias, to extract the BCG beats. The BCG J-peaks were then mapped onto the respiratory signal to be assigned a label based on respiratory phase. J-Peaks with at least a 90% amplitude of the closet respiratory peak were labeled as Inhale Peaks (IP), and J-peaks with less than 10% of the amplitude of the closest respiratory valley were labeled as Exhale Peaks (EP). We used a moving range function (*movMax to movMin*) to estimate the upper and lower thresholds at each time. The rest of the heartbeats were labeled as Inhale Active (IA) or Exhale Active (EA), and were excluded from this study (Fig. 1).

Common morphological features (amplitude and time location of BCG I, J and K peaks, and their differences, Amp_IJ and Amp_JK) were extracted from the BCG beats. Then to evaluate the variation of the features between the two respiratory phases, we computed the average difference of each feature during IP and EP, from their global average. The average percentage of variation was computed for each feature, over all subjects. Thus, a positive value over IP shows the percentage of increase in that feature during IP, compared to its average value over all four respiratory phases.

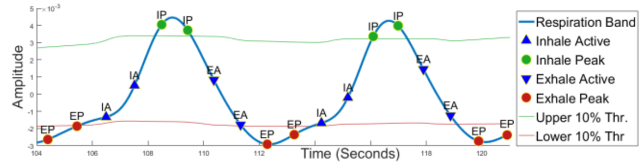

Figure 1. Heartbeats labeled with respect to the four respiratory phases. Upper and lower thresholds were computed using the moving range function.

III. Results

Our results in Fig. 2 show a 2.5% increase in heartrate during inhale, which is in accordance to [2], and, as a result, a decrease in the time delay of I and J. We also show a decrease of 6%-8% in amplitude of I, J and K waves during exhale. For the amplitude of IJ subtracted from JK, we captured a 16.8% increase during exhale and decrease of 30.7% during inhale.

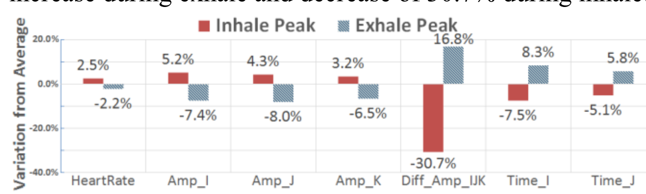

Figure 2. Variation of the features from their average values.

To conclude, we showed how different morphological BCG features vary over inspiration and expiration. These features have been used widely in the literature, but their respiratory-related variations are ignored most of the time. Our goal is to use the features to track cardiac health noninvasively. The results show that it may be necessary to consider where the heart beat occurs in the respiratory cycle.

References

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Moein Enayati, Bo Yu Su, Marjorie Skubic, and James M Keller are with the Dept. of ECE, Mihail Popescu is with the Dept. of HMI, Laurel Despins is with the SSON, all at U. of Missouri, Columbia, MO, USA. (e-mails: mektb, bsdg6, SkubicM, KellerJ, PopescuM, DespinsL @missouri.edu)