31st Annual International Conference of the IEEE EMBS
Minneapolis, Minnesota, USA, September 2-6, 2009

Pulse Rate Variability and Gastric Electric Power in Fasting and Postprandial Conditions

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***Abstract*—Photoplethysmography (PPG) is typically used to extract cardiac-related information like heart rate and cardiac output, though extra-cardiac information like respiratory rate can also be extracted from PPG. The aim of the current study is to advance this approach further and investigate existence of gastric-related activity in PPG. To this end, we consider pulse rate variability (PRV), which provides information analogous to heart rate variability (HRV). Finger PPG and electrogastrography (EGG) signals were recorded from 8 healthy volunteers in fasting and postprandial state for 30 minutes. Peak-to-peak interval (PPI) analysis shows that the power of high frequency (HF) component in fasting and postprandial state changes significantly. The power ratio (PR), which is the ratio between powers of low frequency band (LF, 0.04-0.15 Hz) to that of high frequency band (HF, 0.15-0.4 Hz) and the EGG power were calculated in fasting and postprandial state. PR was positively correlated with EGG power (r = 0.46; *P*< 0.05). PR indicates the balancing sympathovagal modulation and vagal nervous activity. The significance of this study is that PR from PRV analysis could be used as a tool for diagnosing gastric system instead of the present invasive/cumbersome methods.**

I. Introduction

PHOTOPLETHYSMOGRAPHY (PPG) is typically used to extract cardiac-related information like heart rate and cardiac output, though extra-cardiac information like respiratory rate can also be extracted from PPG. The aim of the current study is to advance this approach further and investigate existence of gastric-related activity in PPG. To this end, we consider pulse rate variability, which provides information analogous to heart rate variability (HRV). HRV refers to the beat-to-beat alterations in RR intervals in electrocardiography (ECG), which is becoming increasingly standardized. HRV has considerable potential to assess the role of autonomic nervous system (ANS) fluctuations (parasympathetic and sympathetic neural) in normal healthy individuals and in patients with various cardiovascular and non-cardiovascular disorders [1]. This non-invasive methodology has numerous clinical applications, specifically in physiology, in cardiology and in pharmacology. Many vital organs in the body are controlled by this neuronal control.

PPG is a simple, non-invasive, low-cost electro-optical technique used to detect blood volume pulse in the microvascular bed of tissue [2]-[4]. Since each peak in the PPG signal is related to a single heart beat, peak-to-peak intervals (PPI) measured on PPG signal can substitute ECG RR intervals [5]. PPG provides an advantage in a routine physical examination at a work site, because it is often easier to acquire than the ECG. Though PPG is affected by motion artifacts, compared to ECG it gives more valuable information about hemodynamics of blood circulation, arterial stiffness, and other valuable clinical parameters. PPG based technology can be found in a wide range of commercially available medical devices for measuring oxygen saturation, blood pressure and cardiac output, assessing autonomic function and also detecting peripheral vascular disease [6].

Electrogastrography (EGG) is a method to record electrical activity of the stomach which oscillates at a frequency of about 3 cycles/min (0.05 Hz) towards distal antrum. Though there have been a few reports on the relationship between the parameters of ECG, EGG and autonomic nervous function [7], the relation between PRV, EGG in the fasting and postprandial state has not been well assessed in relation to autonomic nervous function, which is thought to be an important modulator of gastric activity. The spectral analysis of the PPI and EGG was carried out and the existence of rhythmic oscillations was revealed.

The purpose of this study was to analyze the significance of power ratio (PR) in PRV analysis as like in HRV particularly vis a vis EGG activity. In HRV, PR represents the sympathovagal balance modulating the sinoatrial node. Here we analyze this PR and its clinical role in diagnosing vagal nerve function of the stomach in relation with EGG power. In Section I, we describe the ANS relation with HRV, clinical usage of PPG and its significance in PRV analysis and EGG relation with ANS. Section II describes the measurement setup used for PPG and EGG signal acquisition and signal processing techniques. Section III reports the benchmark parameters, data analysis and performance assessment. Section IV discusses the clinical significance and outcome of the findings and future work.

Manuscript received April 23, 2009.
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978-1-4244-3296-7/09/$25.00 ©2009 IEEE

II. Materials and Methods

A. Subjects

This study was performed in 8 healthy non-smoking and non-athletic male volunteers without symptoms and history of gastrointestinal, cardiovascular or other diseases. The volunteers participating in this study were recruited from the student population of our institute. The mean age was 22.0 ± 2.7 (SD) years (range 20-28 years) and the mean body mass index (BMI) was 22.3 ± 1.7 (SD) (range 19.7-25.3). Informed consent was obtained from all volunteers, and the study was approved by the Ethical Committee of Indian Institute of Technology Madras.

B. Data Acquisition

We acquired the PPG signal from the finger tip using a reflection type infrared sensor. EGG signals are measured by Ag-Agcl electrodes placed over the abdominal surface. First electrode placed over the antrum of the stomach, the second 5 cm laterally left on a transverse line from the first electrode (bipolar signal for electrogastrography (EGG) was obtained by this pair), and the third, as a reference, 5 cm laterally right on a transverse line from the first electrode [8]. Data acquisition unit MP 35 (Biopac Systems, Inc, USA) is used here.

After resting for 15 minutes in a supine position for stabilization including a little practice of undisturbed respiration, PPG and EGG data were recorded as follows. First, the fasting data were collected after 5 hours fasting for 30 minutes in the supine position. Then the subjects were asked to sit up, eat meal (comprised of limited rice, fruit slices and one cup of water) and then again assume supine position. Postprandial data were collected for more than 30 minutes. During these procedures, the subjects breathed spontaneously at more than 10 cycles/min (or at 12 cycles/min = 0.2 Hz) and to the extent possible, remained quiet and still. The room temperature was regulated at 25°C. Both PPG and EGG signals were recorded at 100 Hz sampling rate.

C. Peak-to-peak Interval calculation Algorithm

Normal PPG signal and the method of peak-to-peak interval calculation are shown in Fig.1. Movement artifacts are removed by visual inspection and the slow baseline drift is removed by linear detrending. Noise removal is done by digital filtering using second order FIR band band-pass filter

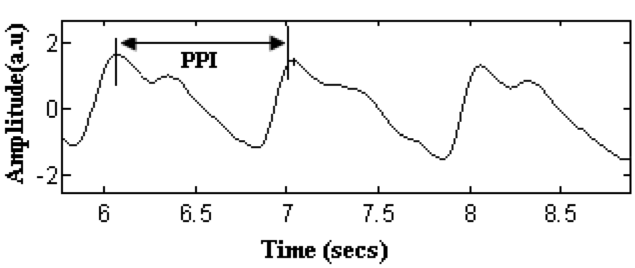

Fig. 1. Peak-to-Peak interval (PPI) in a typical PPG signal

extending from 0.01–40Hz prior to peak detection. The architecture for peak detection algorithm is shown in Fig. 2 which has two stages of signal processing. The preprocessing stage relies on signal derivatives and digital filters, emphasizes the desired components in order to maximize the signal-to-noise ratio (SNR). Detection stage decides if an incoming peak is a true component based on a user specified threshold and measures the time interval between two consecutive peaks (PPI) and rejects the secondary dicrotic peaks [9,10]. All these signal processing stages are implemented using MATLAB (The MathWorks co. MATLAB® version 7.2).

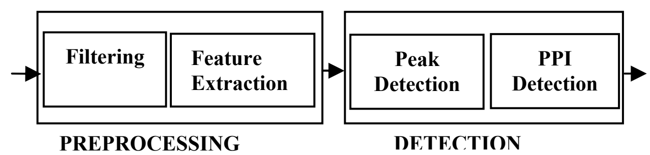

Fig. 2. Common architecture of peak detection algorithms. A preprocessing stage emphasizes the desired components and a detection stage performs the actual component detection.

D. Pulse Rate Variability (PRV)

Samples of peak-to-peak intervals in fasting and postprandial states for a healthy volunteer for the same periods are plotted (Fig. 3 a and b). PPI duration changes significantly from fasting to postprandial state. These PPI are fed in to heart rate variability (HRV) analysis software released by Biosignal Analysis and Medical Imaging Group (BSAMIG), University of Kuopio, Kuopio, Finland to obtain the physiological information.

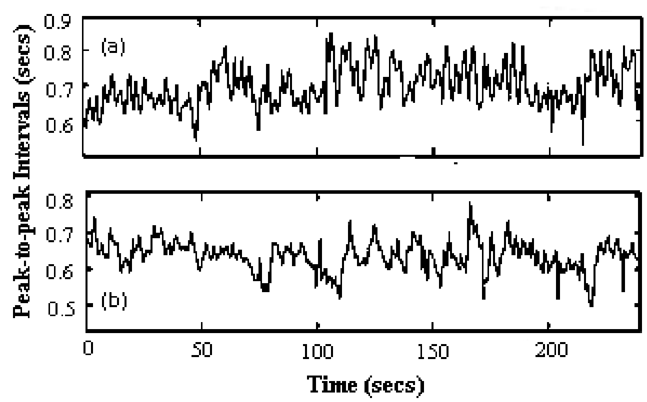

Fig. 3. Peak-to-Peak intervals (PPI) extracted from PPG signal in (a) Fasting state and (b) Postprandial state

In PRV spectrum the high frequency (HF) is generally thought to be a parameter of cardiac parasympathetic vagal nervous activity, whereas the power of the low frequency (LF) component reflects modulation by both sympathetic and parasympathetic activities to the SA node, and the ratio of LF to HF component power (LF/HF) which is denoted as PR represents the sympathovagal balance modulating the sinoatrial node [11].

E. Statistical Analysis

Mean and standard errors (SE) were calculated and the Student's t-test for paired data was used with *P* values below 0.05 were considered to be significant.

III. RESULTS

In the frequency-domain analysis power spectral density (PSD) of the PPI series is calculated. Here the PSD is estimated by nonparametric [e.g. fast Fourier transform (FFT) based]. The PSD is analyzed by calculating powers and peak frequencies for different frequency bands. The commonly used frequency bands are very low frequency (VLF, 0-0.04 Hz), low frequency (LF, 0.04-0.15 Hz), and high frequency (HF, 0.15-0.4 Hz). The most common frequency-domain parameters include the powers of VLF, LF, and HF bands in absolute and relative values, the normalized power of LF and HF bands, and the LF to HF ratio. Also the peak frequencies are determined for each frequency band. For the FFT based spectrum powers are calculated by integrating the spectrum over the frequency bands. The powers of HF, LF in both fasting and postprandial states are shown in Fig (5).

A) Bench mark parameter

In this study we used the *power ratio* (PR) of LF to HF as LF/HF. The bench mark parameter power ratio (PR) which is calculated as,

$$\text{Power Ratio (PR)} = \frac{\text{PSD value of LF band}}{\text{PSD value of HF band}} \quad (1)$$

B) Data Analysis

The power of LF and HF are more are less equal in fasting state. But in postprandial state HF power decreased and is very much less compared to LF power (Fig. 4a and 4b). This is consistent for all the eight subjects. Hence the postprandial PR was significantly higher than fasting PR ($P < 0.05$). Fig.7 shows that the postprandial EGG power was significantly higher in the fasting state ($P < 0.05$), confirming earlier experimental results [13].

C) Correlation between PR and EGG power

As PR increased, EGG power also increased and the two were positively correlated each other (n = 8, r = 0.46, $P < 0.05$).

IV. DISCUSSION

The present study revealed a significant decrease in HF power between fasting and postprandial state in healthy humans. This correlates well with the literature [13] that EGG power increases in the postprandial state. Only in five of the subjects postprandial PR increases 2 to 3 times of fasting PR. In the remaining subjects LF power decreases and compensates the decrease in HF. Literatures suggest that LF power, when expressed in normalized units, as both a quantitative marker for sympathetic modulations, and sympatovagal activity [10]. HF power is generally thought to be a parameter of cardiac parasympathetic vagal nervous activity [12], so there is a possibility that the change of EGG power in postprandial state is positively correlated with the change of vagal nervous activity.

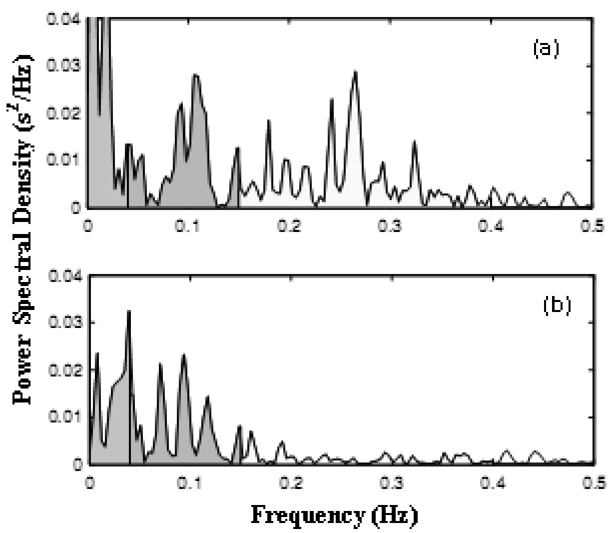

Fig. 4. PSD of PPI (a) Fasting state and (b) Postprandial state

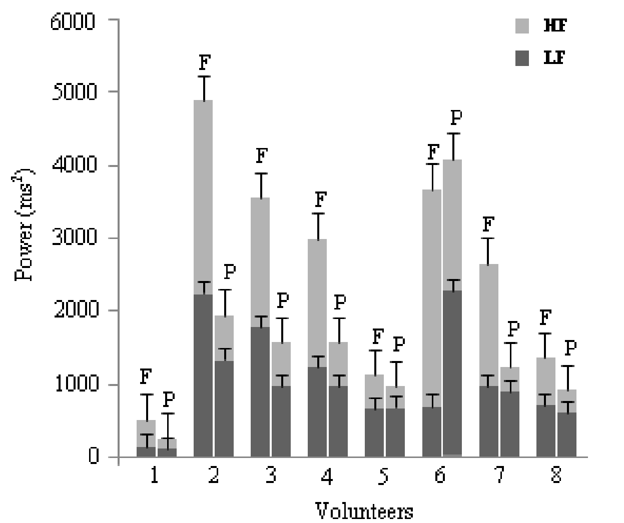

Fig. 5. Power of LF and HF in fasting and postprandial state (F – Fasting, P – Postprandial, LF – Low Frequency, HF – High Frequency)

Vagal nerve activity is considered to be associated with phasic motility, because the discharge frequency of vagal efferent fibers increases during the gastric motor activity in the fasted dog [15]. Consequently, the PR (LF/HF) could mirror sympatho/vagal balance or reflect sympathetic modulations.

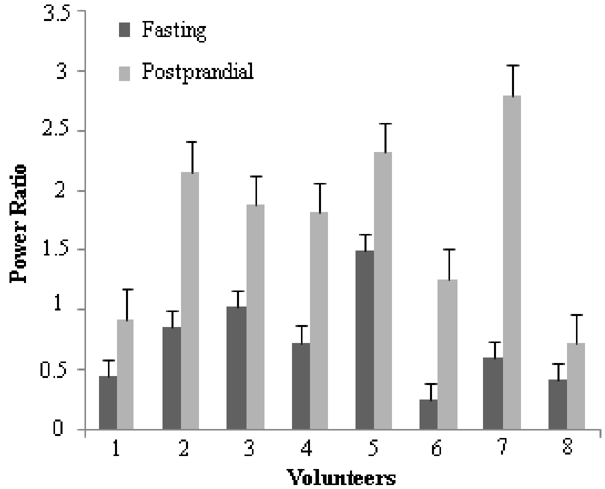

Fig. 6. Comparison of PR in fasting and postprandial state

PR (LF/HF) is generally thought to be a parameter of balancing sympathovagal modulation to SA node, so there is a possibility that the change of EGG power in postprandial state is positively correlated with the change of vagal nervous activity. This possibility is supported by the fact that postprandial EGG power increase is not seen after vagotomy[15]

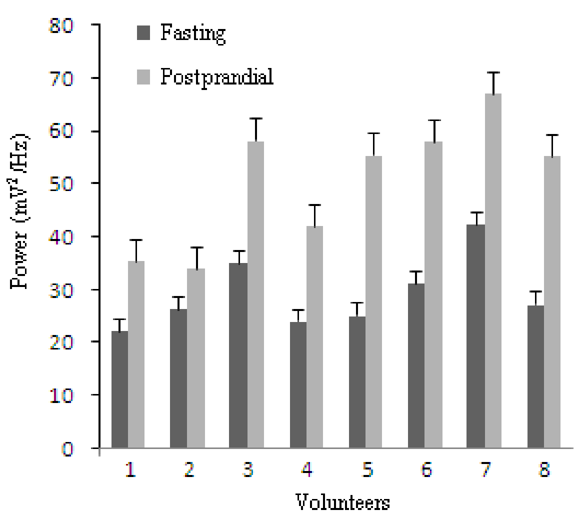

Fig. 7. Comparison of EGG Power in fasting and postprandial state

V. Conclusion

In conclusion, PR, which is a good index of cardiac parasympathetic activity, significantly increased from the fasting state to postprandial state, implying that PRV frequency domain analysis can be used to estimate the vagal nervous activity and the sympathovagal balance. Further research is necessary to analyze the HF component in more number of subjects specifically in postprandial state. In future this PR from PRV analysis could be used as a tool for diagnosing the patients in critical care unit. This noninvasive method can also be extended to patients with gastric disorders. Future research is also likely to see developments in diagnosing gastric disorders using PRV method instead of the present invasive/cumbersome methods like endoscopy and EGG methods.

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