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Myocardial Contractility Assessment using Fiber Optic Sensors

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Abstract: A novel approach is proposed to measure ballistocardiogram (BCG) using optical fiber sensor and estimating Pre-ejection period (PEP) of the heart with electrocardiogram (ECG) signals. © 2019 The Author(s)

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1. Introduction

On a global scale, the number of older people is continuing to grow at an unprecedented rate. Currently, 11% of the worldwide population is over 65 years of age. By 2050, this number will more than double, reaching 22% (about 2 billion). Cardiovascular disease is a common disease in the elderly, and the incidence of this disease in the United States is rapidly increasing [1], thus family monitoring of older people is very essential in the aging society. Diseases such as myocardial infarction and heart failure are associated with pre-ejection period (PEP) [2]. PEP, one of the three basic systolic time intervals, is defined as the time interval from the ECG Q-wave to the impedance cardiogram (ICG) B-wave [3, 4]. It reflects myocardial contractility which is correlation to the heart rate [5]. However, as it requires complex ICG measuring device and multiple electrodes, it is typically much less convenient for home monitoring [6].

A non-invasive method BCG, originally discovered at the end of the 19th century [7] and developed to detect vital signs from people without confining them or causing any discomfort, seems to have more opportunities to become a widespread clinical tool for home or hospital monitoring [8]. It represents motions of the human body arising from ejecting blood into the vessels with each heartbeat (HB). The I-J-K wave of BCG corresponds to the ECG Q-R-S wave [9]. Studies and experiments have shown that the time interval between the ECG R-wave and the BCG J-wave (called the RJ interval) can be used to replace the PEP variation and as an assessment of myocardial contractility [10].

Some studies on BCG measurements require the participants to keep standing on a modified home bathroom scale with complex circuits [11]. This is not a practical approach for the elderly and disabled. Complex circuits inevitably bring noise, and the processed signal will have phase distortion or other errors, resulting in errors in the analysis results. The BCG signals obtained from a bathroom scale require filtration [12], while no filtering is required if it's obtained from a fiber optic sensor. To this end, a new method for measuring BCG using fiber optic sensor is proposed, which is based on the principle of Mach-Zehnder interferometer (MZI), shown in fig.1. It will be a widely accepted method of home use with high sensitivity, ease to use, low cost and immunity to electromagnetic interference.

2. Methods

Fig. 1 shows the setup of smart monitoring system and the two signals acquired simultaneously from one subject at rest. The BCG was recorded using fiber optic sensor system which contained a laser source (Amonics, 1550nm distributed feedback (DFB) Laser Source), a fiber optic interferometer and a photodetector (PD). The fiber optic sensor is Embedded in a mat. The ECG was recorded using AD 8232 heart monitor. These two signals were sampled at 2 kHz using a 16 bit data acquisition card (usb6210, National Instruments, Austin, TX) and then processed on a computer.

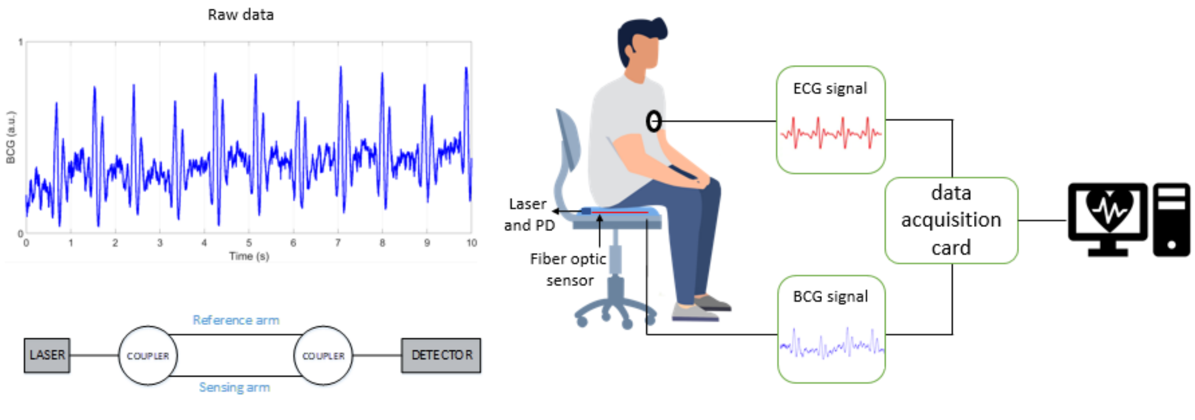

Fig. 1. BCG signal example, structure of MZI and block diagram of system setup.

The subject is a healthy male with no history of previous heart disease and the signals are acquired in sitting position with normal breath. Because compared with the supine position, the time interval of sitting position is larger [14]. Another advantage of this position is that breathing does not affect HB signal, and we don't have to filter the signal Myocardial contractility was modulated by changing hemodynamic using the Valsalva maneuver. It is expected that after the release of Valsalva, the RJ interval will decrease and then recover within approximately dozens of seconds [13].

After affixing the ECG electrodes to the subject, he was asked to sit on the fiber optic sensor for 1 minutes for rest. Then the data started to record, and he was instructed to perform a Valsalva maneuver for about 20 seconds. After release, the subject remained still for 60 seconds to acquire the recovery period data.

3. Results and discussion

As mentioned above, the signals acquired by the fiber optic sensor do not require signal processing. We can calculate the RJ interval directly from the raw data. The BCG and ECG signals and the change of RJ interval are shown in Fig. 2. The RJ interval decrease rapidly after release, and then slowly recovers. This trend shown in Fig. 2 correspond to the result in [10].

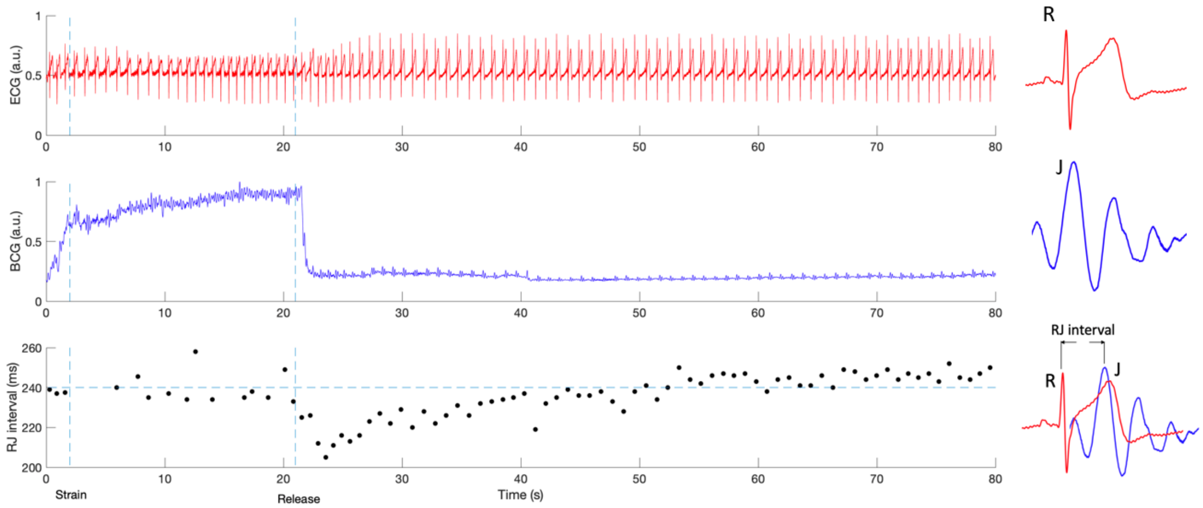

Fig. 2. The top two panels show BCG and ECG traces from one subject. The bottom panel show time series of the RJ interval.

4. Conclusion

In conclusion, a non-invasive HB monitoring fiber optic sensor system based on MZI is proposed and the BCG detection was realized through experiments. The time interval (RJ interval) can be used as a new parameter to assess the health of heart. In the future, the fiber optic sensor proposed in this study can be used as a low-cost home monitoring system to measure changes in relative myocardial contractility.

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