

Development of Position Changing System for Obstructive Sleep Apnea Patient using HRV

Soo- Young Ye, Dong-Hyun Kim

II. METHODS

Abstract—Obstructive sleep apnea in patients, between 70 and 80 percent, can be cured with just a posture correcting. The most important thing to do this is detection of obstructive sleep apnea. Detection of obstructive sleep apnea can be performed through heart rate variability analysis using power spectrum density analysis. After HRV analysis we needed to know the current position information for correcting the position. The pressure sensors of the array type were used to obtain position information. These sensors can obtain information from the experimenter about position. In addition, air cylinder corrected the position of the experimenter by lifting the bed. The experimenter can be changed position without breaking during sleep by the system. Polysomnograph recording were obtained from 10 patients. The results of HRV analysis were that NLF and LF/HF ratio increased, while NHF decreased during OSA. Position change had to be done the periods.

Keywords—Obstructive sleep apnea, Heart rate variability, Air cylinder, PSD, RR interval, ANS

I. INTRODUCTION

OBSTRUCTIVE sleep apnea (OSA) is caused by obstruction of the upper airway and is characterized by repetitive pauses in breathing during sleep, and is usually associated with a reduction in blood oxygen saturation and snoring. Symptoms may be present for years, even decades without identification, during which time the sufferer may become conditioned to the day time sleepiness, fatigue, headache, hypertension, cardiac infarction, stroke, etc [1],[2]. The evaluation of obstructive apnea syndrome (OASA) should be diagnosed through the biomedical signals from polysomnography. As there are many disadvantages of this examination, such as time, price, etc., many researches have more concentration on the diagnosis method using several biomedical signals. OSA was diagnosed from the respiratory signal by Peppard[3], snoring sound by Kushida[4], and oxygen saturation by Seiko[5]. Many studies suggest that the changes of the activation of autonomic nervous system were related to the repetitive reduction in blood oxygen saturation and arousal reaction[6]. In other words, OSA period could be detected using the heart rate variability (HRV)[7] that reflects the activation of autonomic nervous system. The block sections have to be investigated since the treatments of OSA depend on the frequency and the symptom.

In the study, the block sections were detected from the activation of autonomic nervous system by using the result of time and frequency domain analysis of HRV. The subjects were the patient with OSA. After OSA detection, position of the patient was changed by the air-compression.

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OSA signals were acquired from ECG signals of 10 patients in ASO center of Pusan National University Hospital. Block section of sleep apnea with 1 minutes period was set by clinician, which was based on the respiration signal and oxygen saturation. Normally, apnea-hypopnea index (AHI) is used as the ASO index, which means apnea and hypopnea frequency. That AHI index is over 20 means severe apnea, while that AHI index is over 15 means mild apnea.

A. HRV analysis

The flowchart of HRV analysis of OSA patients was presented in Fig. 1.

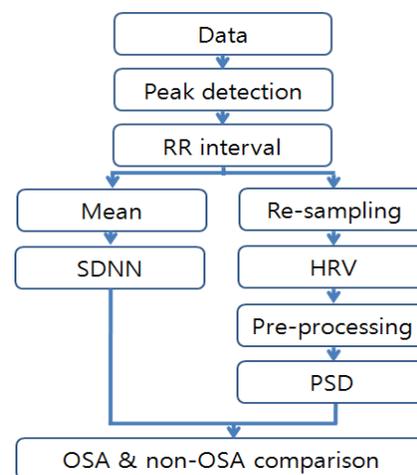


Fig. 1 Flowchart of the HRV signal analysis with OSA patients

R-R intervals were calculated after ECG peak detection. The average of R-R interval, SDNN(standard deviation normal to normal), and RMSSD(root mean square standard deviation) were estimated for time-domain analysis. Time-domain analysis reflects overall dynamic characteristics of R-R interval, but has no specific information on physiological mechanism and activation of autonomic nervous system. To make up for these weak point, the frequency components were analyzed after resampling of R-R interval. To evaluate the PSD (power spectrum density), the signals were preprocessed. At first, end matching was applied to eliminate the DC component of HRV, and mean subtraction & normalization were also applied. PSD was evaluated from the results of applying Fast Fourier transformation(FFT) to reconstructed HRV in frequency analysis[8]. Normally, HRV was analyzed in low frequency band (LF, 0.1-0.15 Hz) and high frequency (HF : 0.15-0.25 Hz). LF was influenced by the sympathetic and parasympathetic nerves, and closely related to pressure receptor and vasomotion. HF was influenced mainly by the parasympathetic nerves, and called respiratory zone as this has close relationship with respiration period and reflex system [9]. And total power was calculated to use to normalize.

B. Implementation of system

The supine posture of subject could be checked using the 40 sensors located nearby shoulders and heart.

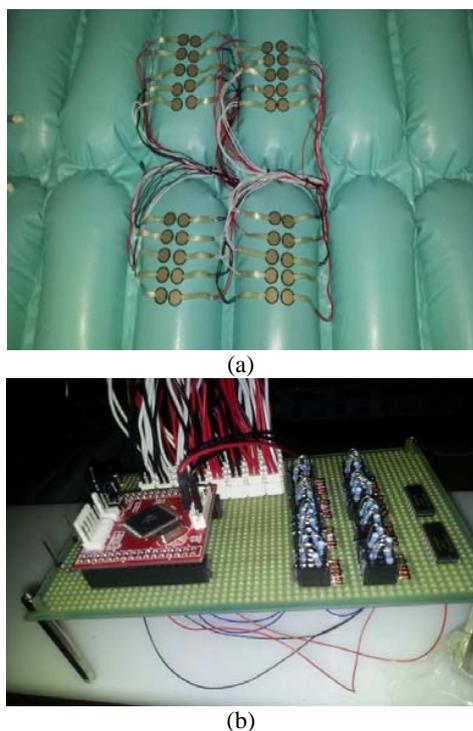


Fig. 2 Implementation of system

The biomedical signals were acquired from the sensor on the mattress with internal air pressure. ATmega 128 module was displayed in Fig.2, which converts pressure sensor and pressure signal from digital signal to analog signal. The measured pressure signals were displayed by Visual Basic 6.0 (Fig. 3). The input voltage was displayed with different colors and figures depending on the pressure, and the postures of subjects were checked by color. Data communication was used to RS-232.

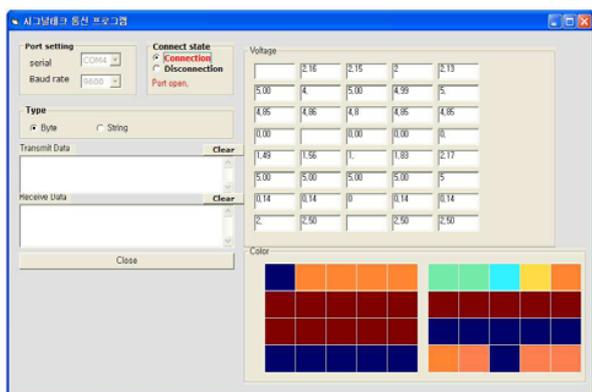


Fig. 3 Software program

The air to air cylinder was controlled by solenoid and relay valves. The aeration to lower part of cylinder makes the board lift, and the aeration to upper part of cylinder make the posture of patients change. The bed was implemented, which can makes patients postures changed using cylinder. The posture of supine subjects could be changed according to the inflation of mattress (Fig. 4).



Fig. 4 Position change using air cylinder

Air cylinder was connected by compressor which is non-noise device. This system was used in the mid-night during sleep so the noise was very important element. This system was enough to used in silent environment.

III. RESULTS

Table I shows the time-domain and frequency-domain analysis result (average ± standard deviation) of OSA patients. The paired-t test was used to compare OSA and Non-OSA period (p<0.05).

RR intervals were longer in non-OSA than OSA but there was no statistical significance. SDNN was longer in non-OSA than OSA and there was statistical significance. And also there was no statistical significance in the RMSSD, LF and HF parameters. But there was statistical significance in the LF/ HF ratio, NLF and NHF. That is, LF/HF ratio and NLF value were significantly increased in OSA period

TABLE I
RESULTS OF HRV ANALYSIS

Parameter	Non-OSA period	OSA period
RR inter.	896.20 ± 138.32	828.58 ± 127.76
SDNN	116.02 ± 12.48 *	72.63 ± 14.98 *

RMSSD	53.80 ± 36.86	53.28 ± 28.36
LF	1561.30 ± 1128.30	2188.67 ± 1799.80
HF	1430.57 ± 1068.47	1006.13 ± 910.28
LF/HF	1.18 ± 0.56 *	2.58 ± 1.10 *
NLF	0.52 ± 0.10 *	0.70 ± 0.08 *
NHF	0.49 ± 0.10 *	0.30 ± 0.08 *

* : P < 0.05 mean±SD

Statistical analysis program, SPSS(statistical package for the social sciences) 9.0 was used for data analysis. As shown in Fig. 6, SDNN decreased during OSA. There was no statistical significance in R-R interval, RMSSD and pNN50.

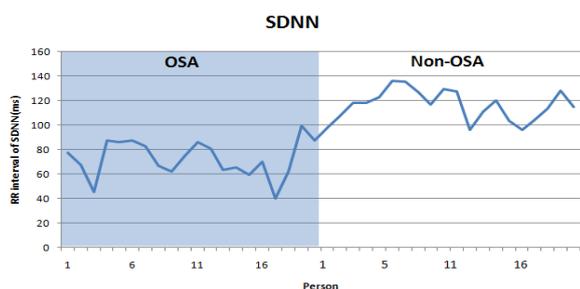


Fig. 5 The results of SDNN with OSA patients in time analysis

LF, HF and LF/HF ratio were calculated as the frequency analysis parameter, and Normalized Low frequency (NLF) and Normalized High frequency (NHF) were calculated using total power of NLF and NHF. NLF and LF/HF ratio increased, while NHF decreased during OSA. The posture of patients was changed using air pump during the period of NLF and LF/HF increase and NHF decrease, which could evaluated the HRV analysis of 5-minutes.

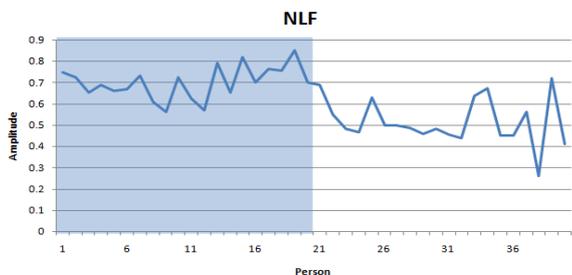


Fig. 6 The results of NLF with OSA patients in frequency analysis

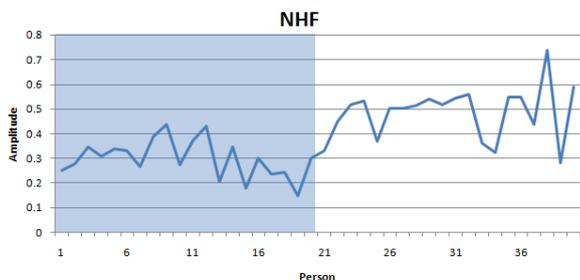


Fig. 7 The results of NHF with OSA frequency analysis

After posture change, snoring signal decreased and the saturation frequency of SpO₂ decreased.

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