Development of Position Changing System for Obstructive Sleep Apnea Patient using HRV
Soo-Young Ye, Dong-Hyun Kim

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.

II. METHODS

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 OSA 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.

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.

Soo-Young Ye is with Dept. of Radiological Science the Catholic University of Pusan, Korea (e-mail: syye@cup.ac.kr).
Dong-Hyun Kim is with Dept. of Radiological Science the Catholic University of Pusan, Korea (e-mail: dhkim@cup.ac.kr).
B. Implementation of system

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

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.

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).

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>
<thead>
<tr>
<th>Parameter</th>
<th>Non-OSA period</th>
<th>OSA period</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR inter.</td>
<td>896.20 ± 138.32</td>
<td>828.58 ± 127.76</td>
</tr>
<tr>
<td>SDNN</td>
<td>116.02 ± 12.48 *</td>
<td>72.63 ± 14.98 *</td>
</tr>
</tbody>
</table>
After posture change, snoring signal decreased and the saturation frequency of SpO₂ decreased.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(20120004409).

REFERENCES


Soo-young Ye was born in Pusan, Korea. She received the M.S. degree in electronic engineering from Pusan National University, in 1998. She received the Ph.D. degree in biomedical engineering in 2004 from the same institution. Her research interests include biomedical signal processing and measurement. She is currently a Professor at department of Radiological Science in Catholic University of Pusan.

Dong-Hyun Kim was born in Pusan, Korea. He received the M.S. degree in environmental engineering from Pusan National University, in 2002. He received the Ph.D. degree in biomedical engineering in 2009 from the same institution. His research interests include Radiological Science and medical images processing. He is currently a Professor at department of Radiological Science in Catholic University of Pusan.