ABSTRACT

Research on Heart Rate Variability (HRV) indicates that power in different frequency bands of HRV is instrumental in evaluating sympathetic and parasympathetic balance. The main goal of this study is to investigate whether variation of stress due to coronary angiography can be successfully assessed using HRV power spectrum analysis. Electrocardiography (ECG) signals of 8 patients (age 39 to 80 years, mean 57.9) who underwent coronary angiography operation at the Cardiology Center of Erciyes University (Kayseri, Turkey) were obtained. All patients were administered 5 mg of Diazepam Recordings were done at three stages: one hour before, during, and one hour after the angiography. The ratio LF/HF represents the ratio of the sympathetic to parasympathetic influence on the heart. Our hypothesis is that increased stress will lead to an increase in sympathetic nervous activity and hence an increase in this ratio. The results indicate that sympathetic nervous system (SNS) is suppressed during the coronary angiography operation. The possible reason of this could be the administration of Diazepam medicine. We must record ECG signals from a control group which were not administered Diazepam to quantitatively assess changes in the emotional state of subjects undergoing critical operations.

KEY WORDS

Biomedical Signal Processing, Heart Rate Variability, Coronary Angiography and Anxiety.

1. Introduction

In advanced societies sleep loss, fatigue, stress and anxiety problems are some of the common healthy problems. Particularly stress and anxiety contribute to the growth of heart and cerebrovascular disease, hypertension, peptic ulcer, inflammatory bowel diseases, musculoskeletal disorders, absenteeism from work, negative emotional reactions and reduced work efficiency [1]. Although emotional changes have a strong impression on the people, in contrast to sleep, stress, and anxiety do not have standardized tabulation or scoring system. The cause of this is the difficulty on the measurement of the emotional variations [2]. This situation has impacted the advancement of technology and technologists have largely ignored emotional factors while creating new experiences. To overcome this problem, to increase the interaction between people and computers, new technologies and theories are being developed. A new area called “affective computing” investigates the design of devices that can measure, interpret, and process human emotions [3].

The main goal of this study is to investigate whether variation of stress due to treatment techniques used in a hospital setting can be successfully assessed and/or quantified using physiological variables. And its results may come in support of the concept of affective computing. To this end, electrocardiography signals of 8 patients who underwent angiography operation at the Cardiology Center of Erciyes University (Kayseri, Turkey), were obtained. Using ECG signals of the patients, Heart Rate Variabilities (HRV) were measured. ECG is one of the best known biomedical signals in psychophysiological research and serves as the most accurate measure of cardiac function. As such, it is the basis for many studies including heart rate and nearly all investigations of HRV.

HRV is used to assess the relationship between cardiac events and autonomic nervous system (ANS) [4, 5]. ANS consists of sympathetic and parasympathetic nervous system. Sympathetic nervous system (SNS) is responsible for setting a homeostatic mechanism. In addition, when a person comes personally with a stressor, SNS produces a response known as the fight-or-flight [6]. Thus, physiological variables controlled by SNS are measured in the studies which want to evaluate stress quantitatively. Sympathetic and parasympathetic nervous systems control the heat rate. SNS tends to increase heart rate and its response is slow [7]. Parasympathetic nervous
system (PNS), on the other hand, tends to decrease heart rate and mediates faster [7]. Therefore, HRV is selected as a physiological marker for the measurement of stress and anxiety. Frequency domain analysis of HRV was performed and the power spectral density analysis for low frequency (LF: 0.04-0.15Hz) and high frequency (HF: 0.15-0.40Hz) band was computed. HF component is the best known spectrum component of the HRV, and it is controlled by PNS. LF component is another known component of HRV and it is controlled by SNS [7, 8]. In addition, Very Low Frequency (VLF) components are also available for 24-hour period records but the physiological explanation of the VLF is still a bit vague [9].

2. Materials and Methods

Electrocardiography (ECG) signals of 8 patients (age 39 to 80 years, mean 57.9) who underwent coronary angiography operation at the Cardiology Center of Erciyes University (Kayseri, Turkey) were obtained (Figure 1).

![Figure 1](image1.png)

Figure 1: A sample baseline noise eliminated ECG signal, which is recorded after the coronary angiography operation.

Signal recording time is not less than 5 minutes and the ECG signals were A/D converted at 1000 Hz. The EMG signal acquisition is conducted by Biopac Sys., MP150 unit. The ECG100C amplifier was used to amplify and the module switch setting was set to 35 Hz LP filter, 0.05 Hz HP filter and 500 gain.

To decrease the amount of impedances between the electrode and skin’s surface, patients’ skins were abraded before electrode placement and then a small amount of electrode gel was applied to each electrode site. Recordings were done at three stages: one hour before, during, and one hour after the coronary angiography test. Especially during the angiography test, to facilitate the process the numbers of the electrodes were asked to be kept low. Therefore, the Lead I electrode placement was sufficient to acquire the ECG signals.

All 8 patients were administered 5 mg of Diazepam, which is a commonly used drug for treating anxiety, insomnia and muscle spasms, just before the angiography.

All patients who underwent angiography in the Erciyes University, Cardiology Center are administrated this medicine. This application is a normal practice in the Erciyes University and most hospitals in Turkey the diazepam or suchlike drugs are administered. In fact, it is also used before some kind of painful medical process to de escalate anxiety, and in some surgical operation to cause amnesia [10].

On ECG, the heart beats are identified as the time difference between the easily noticeable QRS complexes which results mainly from ventricular depolarization. Since R peaks in QRS complexes show the peak of ventricular depolarization, the beat instants are taken at these points and consequently, the beat-to-beat intervals are determined as the length in time from one R wave to the next one. Therefore, the term “inter beat interval” (IBI) refers to RR interval [4]. IBIs of the 8 patients are extracted using programs written in MATLAB software. Using this program, first the R peaks were found (Figure 2) and then time informations of these peaks were computed.

![Figure 2](image2.png)

Figure 2: R peaks identified ECG signal, which is recorded after the coronary angiography operation.

There are two most popular methods that have been used for the evaluating of the IBIs. One of them is Time Domain Methods and the other one is Frequency Domain Methods. Frequency domain HRV measures are based on the power spectral density (PSD) analysis of the interpolated IBIs [11, 12].

Interpolation is necessary to produce a uniformly sampled series out of the IBIs. The interpolation frequency was chosen as 4 Hz. After interpolation, Power spectral density (PSD) analysis was performed using Welch’s method with Hanning window. 256 samples and 50% overlapping were chosen thus 0.0156 Hz spectral resolution was achieved. Kubios HRV software was used for the analysis of the HRV.

We made the spectral estimate with Welch’s Method, which can be expressed as follows [13]:

\[
\tilde{P}_{\text{per}(n)} = \frac{1}{MUL} \sum_{i=1}^{L} \left| \sum_{n=1}^{N_{M}} x'_{n}(n)W(n)e^{-jn} \right|^2
\]  

where:

\[
x'_{n}(n) = x_{n}[n+(i-1)M], \quad 0 \leq n \leq M - 1, \quad 1 \leq i \leq L
\]
\[ U = \frac{1}{M} \sum_{m=0}^{M-1} W^2(n) \]  

(3)

Where \( x_m(n) \) is the signal of length \( N \) and is divided into \( L \) sections with length \( M \) overlapping each other, \( x_m(n) \) is the number \( i \) section of \( x_m(n) \); \( W(n) \) is the window function of length \( M \). Measurement of LF and HF power components are usually in the form of the absolute value of power (ms²). LF and HF may also be measured in normalized units. Because of the normalization tends to minimize the effect of the changes in total power on the values of LF and HF components, all the computations were done in normalized units.

3. Results and Conclusion

The LF/HF ratio gives an index of autonomic balance between sympathetic and parasympathetic activities. Thus, the total energy in the LF and HF band were calculated firstly. The obtained values are seen in Table 1.

Table 1.
Computed total energy in normalized unit values for LF and HF band.

<table>
<thead>
<tr>
<th>Patient</th>
<th>One hour before angiography</th>
<th>During angiography</th>
<th>One hour after angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LF: 35.6</td>
<td>LF: 11</td>
<td>LF: 90.9</td>
</tr>
<tr>
<td>Patient 1</td>
<td>HF: 64.4</td>
<td>HF: 89</td>
<td>HF: 87</td>
</tr>
<tr>
<td>Patient 2</td>
<td>LF: 38.7</td>
<td>LF: 5.1</td>
<td>LF: 54</td>
</tr>
<tr>
<td>Patient 3</td>
<td>LF: 83.183</td>
<td>LF: 54</td>
<td>LF: 72.1</td>
</tr>
<tr>
<td>Patient 4</td>
<td>HF: 61.3</td>
<td>HF: 94.9</td>
<td>HF: 46</td>
</tr>
<tr>
<td>Patient 5</td>
<td>LF: 16.6</td>
<td>LF: 45.9</td>
<td>HF: 27.9</td>
</tr>
<tr>
<td>Patient 6</td>
<td>LF: 66.2</td>
<td>LF: 23.3</td>
<td>LF: 96</td>
</tr>
<tr>
<td>Patient 7</td>
<td>HF: 33.8</td>
<td>HF: 76.8</td>
<td>HF: 39.5</td>
</tr>
<tr>
<td>Patient 8</td>
<td>LF: 40.5</td>
<td>LF: 32.4</td>
<td>LF: 84.06</td>
</tr>
<tr>
<td>Patient 9</td>
<td>HF: 59.5</td>
<td>HF: 67.7</td>
<td>HF: 15.9</td>
</tr>
<tr>
<td>Patient 10</td>
<td>LF: 34.3</td>
<td>LF: 22.4</td>
<td>LF: 92.9</td>
</tr>
<tr>
<td>Patient 11</td>
<td>HF: 65.7</td>
<td>HF: 77.6</td>
<td>HF: 70.9</td>
</tr>
<tr>
<td>Patient 12</td>
<td>LF: 61.2</td>
<td>LF: 44.4</td>
<td>LF: 88.9</td>
</tr>
<tr>
<td>Patient 13</td>
<td>HF: 38.8</td>
<td>HF: 55.6</td>
<td>HF: 11.1</td>
</tr>
<tr>
<td>Patient 14</td>
<td>LF: 84.6</td>
<td>LF: 64</td>
<td>LF: 64.3</td>
</tr>
<tr>
<td>Patient 15</td>
<td>HF: 15.2</td>
<td>HF: 36</td>
<td>HF: 35.8</td>
</tr>
</tbody>
</table>

The ratio LF/HF was used as the characteristic feature for all patients. This feature represents the ratio of the sympathetic to parasympathetic influence on the heart. Our hypothesis is that increased stress will lead to an increase in sympathetic nervous activity and hence an increase in this ratio. SNS tends to increase heart rate and its reaction is slow. Therefore, LF component is associated with SNS. If the LF/HF ratio receives a high value, SNS will be predominance and PNS will be suppressed. On the other hand, a low value of the LF/HF ratio indicates PNS predominance.

When we look at the results, there are distinctive differences between recording stages as seen in Figure 3. LF/HF ratio attains its smallest value during the angiography test for all patients.

The results indicate that sympathetic nervous system (SNS) is suppressed during the coronary angiography operation. The possible reason of this could be the administration of Diazepam medicine. Diazepam may cause depression of SNS, which results in reduced irritability, induction of sleep and decreased muscle tone. When the effect of the Diazepam is over, the SNS is reactivated again. Therefore, LF/HF ratio increases after the coronary angiography. Like heart rate, skin resistance and blood volume are affected by SNS. These physiological variables must be taken into account to assess coronary angiography related anxiety and to quantitatively assess changes in the emotional state of subjects undergoing critical operations, we must therefore record ECG signals from a control group which were not administered Diazepam.

It is very difficult to analyze the human emotions. Presently, some research groups are studying the emotion and human body response through different approaches. We analyzed the relationship between emotion and the autonomic nervous system by HRV. Our preliminary results indicate that the variations in the LF/HF ratio across different subjects are remarkably consistent. This promising result is motivating us to consider and include other possible physiological variables and/or signals in our recording scheme to quantitatively assess changes in the emotional state of subjects undergoing critical operations.
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References


