Multiple Factor Analysis of the Autonomous Nervous System during PTCA

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Abstract - This study describes the Autonomic Nervous System (ANS) response before, during and after a percutaneous transluminal coronary angioplasty (PTCA). The study population consisted of 37 patients undergoing PTCA from Staff-3 Database. Classical Heart rate variability (HRV) parameters: RR mean, SD, rMSSD, LF, HF, LF/HF and LF/(HF+LF) were extracted and a multiple factorial analysis (MFA) was carried out. Preliminary results show that sympathetic activity increases during and after PTCA, and global HRV decreases during PTCA and increases after PTCA. These findings suggest that MFA provides a powerful tool allowing assessment of ANS's response during PTCA.

I. INTRODUCTION

Heart Rate Variability (HRV) is used to study the autonomous nervous system’s (ANS) control behavior, since it modulates the cardiovascular system during percutaneous transluminal coronary angioplasty (PTCA) [1].

Some experimental studies indicate that coronary occlusions cause an excitatory response in the sympathetic drive through the activation of terminals in the ischemic myocardium [2].

Former HRV studies during coronary occlusion were carried out by Airaksinen et al [3, 4]. In a study with over seventy (70) patients exposed to 110 seconds average occlusion, was found that 29 (41%) did not show changes in heart rate (HR) or HRV, 24 (34%) had an increase in high frequency (HF) spectral band of the HRV or bradycardia or both, and 17 patients (24%) had a decrease in HF spectral band of the HRV or tachycardia or both [5].

Another study with an average of 112 seconds occlusion showed that 58 patients without beta-blockers had a significant increase in LF (p<0.01) and HF (p<0.001) spectral bands of the HRV. However, with beta-blockers exposure, HF spectral band did not change and LF spectral band had a significant increase (p=0.01) for the same 58 patients [6].

A study about the relationship between the HRV and the incidence of ventricular tachycardia during PTCA, showed that during an occlusion of 2 minutes, the HRV (RMSSD) increased and the HR decreased in patients without ventricular premature complexes (PVCs), whereas the opposite situation happened in patients with PVCs [7].

Joho et al analyzed the heart rate and left ventricular pressure variability during PTCA over 14 patients using wavelets. During occlusion, LF and LF/HF indexes increased on 7 patients (50%) until the beginning of ischemia measured through ST deviation, which happened around 80 seconds after inflation of the balloon, and then, indexes decreased at the final phase of inflation [8].

Clariá et al [9] studied two groups of patients with PTCA and occlusions until 240 seconds of the right coronary artery (RCA), left anterior descending (LAD) and left circumflex artery (LCX). Occlusions were at proximal and distal level. This study analyzed instantaneous frequency and group delay functions over the LF, MF and HF spectral bands, using time-frequency representations techniques. Results showed that the LF group delay respect to LCX occlusions is greater than in RCA, and the RR signal energy is more delayed than in LAD occlusions, and in LAD it is more delayed than in RCA occlusions. However, few studies on human beings exist about the HRV analysis during PTCA.

The purpose of this study is to provide a characterization of ANS changes as a response over three periods of a PTCA procedure using a multi-factorial analysis of the classical variables of HRV.

II. MATERIALS AND METHODS

A. Database

This study used the Staff-3 database, obtained at Charleston Area Medical Center. It is formed by ECG registers before, during and after PTCA, which constitute an appropriate model to study ischemia. Signals were acquired with equipment Siemens-Elena (Solna-Sweden) at 1 KHz, with 0.6µvolts resolution and stored on hard disk for posterior analysis. Standard leads I, II, III and precordials V1,V2,V3,V4,V5 and V6 were digitized. The whole database includes 108 patients, a first selection considered 43 patients like in [10], among those without previous myocardial infarction history according with the ECG QRS Scoring System of Selvester et al. [11]. A second selection was necessary due to poor stationary
behavior of the RR sequences. Finally a smaller study group of 37 patients were analyzed: 20 RCA, 10 LAD and 7 LCX occlusions (24 males, 13 females: 63 ± 11.42 years). Each patient has a 5 minutes pre-ptca ECG register in supine position at the catheterization lab, a ptca ECG register with an averaged obstruction time of 4' 10'' (1' 30'' min. and 7' 17'' max.) and an averaged post-ptca register 3' 19'' long (20'' min, 10' 45'' max.) (see Fig. 1).

B. Electrocardiographic Variables
The detection of the QRS complexes was conducted using the Gritzaldi’s algorithm described in [12]. From each RR sequence, the classical temporal parameters, i.e. the mean, the standard deviation (SD) and the square root of the mean squared difference of successive intervals (rMSSD), were then extracted.

Prior to power spectrum density estimation, the RR sequence, which is intrinsically a non-evenly spaced data, was linearly interpolated in order to obtain a series of uniformly sampled data [1]. The retained sampling rate was set to 2 Hz. Using a sliding window of 25 seconds duration, a time varying auto-regressive modeling of the interpolated RR sequence was performed for estimating its power spectrum. The LF and HF bands were defined respectively by [0.04-0.15 Hz] and [0.15-0.4 Hz] as proposed in [1].

For each stage of the protocol, RR intervals were obtained, and seven (7) classical HRV parameters were determined: RR mean, SD, rMSSD, LF, HF, LF/HF and LF/(HF+LF).

C. Multiple Factor Analysis
Multiple Factor Analysis (MFA) deals with data in which a set of individuals is described by several sets of variables. The MFA can be represented in three spaces: subject’s space, variable’s space and the spaces of groups of variables [13,14].

We denote $X$ the whole matrix, $I$ the set of individuals, $K$ set of the variables (all together), $J$ the set of sub-groups such that $K = \bigcup_j K_j$ and $X_j$ is the sub-matrix associated with group $j$ (see Fig. 2). More precisely, the symbols $I$, $J$, $K$ denote the set and their ordinal at once.

The principle of the MFA is based on the Principal Components Analysis (PCA) of the whole table. This analysis makes possible to balance the role of the groups of variables and provides a representation of the individuals and variables which are interpreted according to usual rules of PCA.

In a summarized form, the MFA on a series of groups of quantitative nature consists in performing:

1. A PCA on the partial table $X_j$ with the objective to balance the influence between the groups;
2. A PCA of all the juxtaposed groups where each one of them has been previously weighed by the inverse of the root of the first eigenvalue coming from the partials PCA, such that:

$$X = \begin{bmatrix} \frac{1}{\lambda_1} & X_1 & \frac{1}{\sqrt{\lambda_1}} & X_{12} & \frac{1}{\sqrt[3]{\lambda_1}} & \ldots & \frac{1}{\sqrt{J}} & X_J \end{bmatrix}$$

Later, the coordinates of the variables of each group are calculated with respect to the factors and a global representation is obtained.

In our study the data arise in the following form: $I$=37 patients, $J$ = 3 stages (pre-ptca, ptca, post-ptca) $K$= 7 variables, as explained through the section II, in literals $A$ and $B$. 
III. RESULTS

A. Eigenvalues

Table I presents inertia decomposition of the first five MFA principal components. Table II presents coordinates and contributions for each group. Since most part of inertia is explained by the three first eigenvalues, we will limit to the examination of these three axes.

<table>
<thead>
<tr>
<th>N</th>
<th>(\lambda)</th>
<th>%</th>
<th>% Cum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>42.18</td>
</tr>
<tr>
<td>2</td>
<td>0.8688</td>
<td>16.28</td>
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<td>3</td>
<td>0.6212</td>
<td>11.64</td>
<td>70.1</td>
</tr>
<tr>
<td>4</td>
<td>0.4149</td>
<td>7.77</td>
<td>77.87</td>
</tr>
<tr>
<td>5</td>
<td>0.3375</td>
<td>6.32</td>
<td>84.2</td>
</tr>
</tbody>
</table>

Table II presents coordinates and contributions for each group. Since most part of inertia is explained by the three first eigenvalues, we will limit to the examination of these three axes.

A precise study of the coordinates of the variables shown in table II, leads to the following reports:

First axis: The most dependent variables are RR, SD, rMSSD, LF and HF, and all are positively correlated. This axis is interpreted like an axis of total HRV.

Second axis: The construction of the second axis depends mainly on the LF/(LF+HF) and LF/HF indexes, which are negatively correlated. Axis 2 is interpreted like an axis of sympathetic tonus response or ANS’s balance.

Third axis: The most dependent variables are SD, rMSSD, LF and HF from pre-ptca and post-PTCA periods. This axis is interpreted like sympathetic activity at rest.
IV. DISCUSSION AND CONCLUSIONS

The first factor (HRV Global response) in Fig. 3 corresponds to a direction of significant inertia of all groups of variables. The weakness coordinates, correspond to group 3 (During PTCA) and shows that heart rate variability decreases at PTCA and then tends to return to the normal conditions (post-PTCA). But only a partial recovery of HRV was observed. In the same way, the second factor shows that sympathetic response is increased during PTCA from rest condition; however during post-PTCA, sympathetic response continues to increase. This result could suggest that the ischemic condition is still present during post-PTCA period.

In Figure 4 we observed that there is a movement along axis three, from rest (pre-PTCA) to recovery (post-PTCA). This trend confirm tendency in HRV variability (factor 1).

These findings are in the same line as those shown in [6] and [8]. However further and deeper analysis is needed to highlights particular responses of ANS of each type of occlusion (RCA, LAD or LCX). Ours preliminary results show, therefore, that methods based on MFA are appropriates for the analysis of ANS response during PTCA.

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REFERENCES


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