Ordinal Pattern Statistics for RR Intervals during Head-up Tilt Test in Patients with the History of Vasovagal Syncope

Beata Graff, Grzegorz Graff*, Agnieszka Kaczewska, Danuta Makowiec, Szymon Budrejko, Dariusz Kozłowski, Krzysztof Narkiewicz

Abstract—We apply ordinal pattern analysis to quantify differences in distribution of patterns of length 3 and 4 in basal state and during head-up tilt test (HUTT) in patients with the history of syncope and positive (HUTT(+)) or negative (HUTT(-)) responses to the test. We identify the patterns related to prevalence of sympathetic or parasympathetic cardiac modulation as well as describe the relations between the response to the test and distribution of the patterns.

1. INTRODUCTION

The pathophysiology of vasovagal syncope (VVS) is still not fully understood. In patients with fainting the head-up tilt test (HUTT) is widely used to provoke syncope, but it has many limitations according to sensitivity, specificity and reproducibility. There are numerous studies on heart rate variability (HRV) assessed during HUTT in patients with vasovagal fainting. However, they provide contrasting results when it comes to time- and frequency- domain parameters. For example, LF/HF was reported to increase with tilting in some studies while in others LF/HF decreased or did not changed. Moreover, standard HRV parameters reflect better sympathovagal balance than sympathetic and parasympathetic activity alone.

Recently, a phenomenon of heart rate asymmetry related to unequal contribution of heart rate accelerations and decelerations has been observed [1], [2]. Moreover, symbolic dynamics methods were reported to be able to mirror sympathetic and vagal modulation of heart rate during supine rest [3] and tilting [4], [5]. Therefore, the main aim of the study was to use ordinal pattern statistics for the analysis of heart rate in patients with the history suggesting vasovagal faints.

We compare features of heart rhythm in supine and tilted positions as well as patterns of heart rate in subgroups with positive (vasovagal faint as a result of HUTT) and negative (no syncope) reactions to the test.

II. METHODS

A. Ordinal patterns

Ordinal pattern analysis is a new and promising method of investigation of a complex time series based on concept of order [6], [7]. For a given time series \( \{x_t\}_{t=1}^N \) a sliding window of length \( L \), \( x_{n+1}^{n+L} := x_{n+1}, \ldots, x_{n+L}, \) \( 0 \leq n \leq N - L \) is considered. Elements of the window are ordered in ascending order (in case \( x_i = x_j \), we set \( x_i < x_j \) for \( i < j \)) and we get

\[ x_{n+\pi_1} < x_{n+\pi_2} < \cdots < x_{n+\pi_L}, \]

which defines the ordinal pattern of \( x_{n+1}^{n+L} \) as the permutation \( \pi = (\pi_1, \pi_2, \ldots, \pi_L) \) of \( \{1, 2, \ldots, L\} \). There are \( L! \) ordinal patterns of length \( L \).

In this research we examine the ordinal patterns of length \( L = 3 \) and \( L = 4 \) for consecutive RR intervals, studying differences in distribution of patterns in basal state and during head-up tilt test.

B. Standard HRV parameters

Linear parameters of heart rate variability including mean RR interval, SD of all normal-to-normal RR intervals (SDNN), root-mean-square of differences of adjacent normal-to-normal RR intervals (RMSSD), the percentage of interval differences of successive normal RR intervals greater than 50 ms (pNN50) as well as LF/HF (low frequency/high frequency ratio) were obtained with the use of Kubios HRV Pro Version software (University of Kuopio, Kuopio, Finland).

C. Subjects and measurements

30 patients with a negative HUTT result (HUTT(-) group) and 20 patients with a cardiodepressive reaction (HUTT(+) group) were included in the study. All patients have the history suggesting vasovagal syncope but did not have structural heart disease. Each patient remained supine for 20 minutes and then the table was tilted to 60 degrees. Either a passive test or concomitant active test with nitroglycerin (NTG) was then performed. Passive test lasted 30 minutes, active test lasted 20 minutes or until syncope occurred. In cases of contraindications to NTG, just a 45 minutes passive test was performed. Series of 500 RR intervals recorded in a supine position and during first minutes of tilting were analyzed.

III. RESULTS

1. In a supine position among all heart rate patterns both for \( L = 3 \) and \( L = 4 \), runs (123), (321), (1234) and (4321) were significantly more frequent than others in both HUTT(+) and HUTT(-) groups.

2. During tilt the percentage of acceleration patterns (321) for \( L = 3 \) and the percentage of both acceleration (4321) and deceleration (1234) patterns for \( L = 4 \) have increased in both HUTT(+) and HUTT(-) groups, which confirms the
previous observations that this kind of patterns represents increased sympathetic modulation.

During tilt the asymmetry between acceleration and deceleration runs was observed (bigger contribution of (321) than (123) patterns and bigger contribution of (4321) than (1234) patterns).

3. In HUTT(+) patients the asymmetry between the contribution of acceleration and deceleration runs is bigger than in HUTT(-) patients.

4. The percentage of patterns with just one change ((3421), (2134), (4312), (1243), (1423), (4132), (3241), (2341), (4123), (1432), (3214)) have decreased in the upright position, which may mirror the lower vagal activity. Similar reaction was previously reported in healthy subjects [5].

5. Distribution of patterns within the same experimental condition (supine or tilting) has not differed between HUTT(+) and HUTT(-) groups.

6. Mean RR interval was longer in HUTT(+) than in HUTT(-) group in the supine position but during tilting mean RR interval did not differ significantly between HUTT(+) and HUTT(-) groups. There were no significant differences in other standard HRV parameters between HUTT(+) and HUTT(-) groups analyzed in supine and tilted positions except for SDNN which was greater in HUTT (+) patients during tilting. The change of standard HRV parameters as a result of tilting in both tested groups is presented in TABLE

II.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HUTT(+)</th>
<th>HUTT(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean RR</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>SDNN</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>RMSSD</td>
<td>↓</td>
<td>ns</td>
</tr>
<tr>
<td>pNN50</td>
<td>↓</td>
<td>ns</td>
</tr>
<tr>
<td>LF/HF</td>
<td>ns</td>
<td>↑</td>
</tr>
</tbody>
</table>

Fig. 1. Distribution of ordinal patterns of length 4 for HUTT(-) group during supine and tilt.

Fig. 2. Distribution of ordinal patterns of length 4 for HUTT(+) group during supine and tilt.

IV. CONCLUSIONS

The results of the study confirm that the ordinal pattern statistics method is able to reflect autonomic modulation changes in patients with vasovagal syncope. It seems that the method is also able to show differences between heart rate response during first minutes of tilting in patients with positive and negative reactions to HUTT. Further studies are needed to confirm if the change in distribution of patterns is able to mirror sympathetic and vagal changes separately.

REFERENCES