HEMODYNAMIC SURROGATE MEASURES SYMPLIFYING NEURALLY MEDIATED SYNCOPE MANAGEMENT

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Abstract: Neurally mediated syncope (NMS) is characterized by the European Society of Cardiology (ESC) by critical low heart rate (HR) and/or low systolic blood pressure (SBP). We have shown that pulse arrival time (PAT) consistently increases before NMS complementing prodromi such as dizziness and sweating. This approach might be suitable to improve syncope diagnostics e.g. where continuous non-invasive blood pressure measurements are not available, might enhance workflows in syncope management units by shortening tilt table testing or help in syncope training. This paper discusses our findings by using PAT and HR based algorithms as hemodynamic surrogate measures compared to the SBP and HR based definition of NMS.

Keywords: Syncope, surrogate measure, pulse arrival time, physiological response, blood pressure regulation

Introduction

Neurally mediated syncope (NMS) is a critical hemodynamic state, with the inherent risk of serious injuries due to uncontrolled falls. The European Society of Cardiology (ESC) defines this state as characterized by critical low heart rate and/or low systolic blood pressure [1]. In order to detect impending NMS early on, continuous blood pressure measurements would be needed, as been shown by [3]. This approach, however, is technically not feasible in an ambulatory setting. In our previous publications we have found that pulse arrival time (PAT) is a useful marker of impending syncope during tilt table testing. Using sophisticated signal processing schemes detection performance of up to 90 % sensitivity and specificity could be achieved with detection times of up to one minute before syncope [5]. Since ECG and PPG can be easily and comfortably acquired synchronously, these measures might open a range of interesting applications in NMS diagnostic as well as NMS training procedures. This paper discusses a graphical representation of the existing guidelines and its relation to the new measure PAT in an intuitive visualization approach. Our discussion focuses on PATfoot only, however results using PATtop give similar results.

Experimental Methods

55 patients were enrolled in a clinical study to assess the feasibility of PAT as surrogate marker (Clinical-Trials.gov Identifier: NCT01262508) of which 44 could be used for data analysis. During scheduled tilt table tests based on a standardized protocol [10] HR and PATs were extracted from simultaneously acquired electrocardiogram (ECG) and the finger photoplethysmogram (PPG) measured with a Philips MP50. PAT is defined as time span between the ECG-R-peak and pulse onset (PATfoot) or pulse maximum (PATtop) in a peripheral photo-plethysmography (PPG) signal [4]. Continuous SBP was measured with a Taskforce Monitor [7]. Details on signal processing can be found in [4, 8].

Table 1: Patient Characteristics; GTN-Glycerin Trinitrate

<table>
<thead>
<tr>
<th>Tilt positive (#21)</th>
<th>Tilt Negative (#23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [y]</td>
<td>55±19</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>85±16</td>
</tr>
<tr>
<td>BMI [kg/m2]</td>
<td>26.9±4.6</td>
</tr>
<tr>
<td>Male/female</td>
<td>13/8</td>
</tr>
<tr>
<td>GTN (yes/no)</td>
<td>19/2</td>
</tr>
</tbody>
</table>

ESC Definition of Syncope Types

The European Society of Cardiology defines a tilt table test as positive if the patients experiences syncope in the presence of bradycardia, hypotension, or both [1].

Figure 1: Visualization of ESC Criteria of NMS by presence of bradycardia (HR < 40 bpm), and SBP less than 80 mmHg or both; shock index is shown as well. Here, bradycardia is defined as a heart rate of less than 40 bpm and hypotension as systolic blood pressure of less than 80 mmHg. This definition is visualized in Figure 1, including the boundary of the well-know shock index (HR/SBP > 0.7 [11]) as well as a critical maximum SBP of 200 mmHg. A typical response of a
tilt positive patient is included as well, where HR and SBP cross critical values.

**PAT and HR based algorithms as hemodynamic surrogate measures**

In our approach HR and PATfoot are continuously compared with reference values. These reference values are determined 1 min after the patient was brought into up-right position at the beginning of a tilt table test [4]. Using these measures tilt positive patients can be easily separated from tilt negative as shown in Figure 2, where a plot of the normalized PATfoot and HR is presented for both patients groups (red dot: tilt positive, blue: tilt negative). The plot depicts the normalized measures 15 s before the patient was tilted back to supine. Error-bars refer to the variance of PATfoot and HR during the reference period. The normalized PATfoot with a threshold around 1.1 accompanied with a low normalized heart rate result in a good discrimination of these groups.

![Figure 2: plot of normalized PATfoot and HR 15 s before the end of the passive standing interval; red dots: tilt positive patients, blue dots: tilt negative](image)

In [9] a consistent linear relation SBP=A*PATfoot+B was found, with a large inter-patient variability of A of [-0.3 … -1.8] mmHg/ms and B of [392…500] mmHg. Therefore, a SBP decrease of 40 mmHg will result in PATfoot differences of larger than 20 ms, which can reliably detected by appropriate signal processing schemes.

Since PATfoot and SBP show high linear correlation [8], these relations can be translated into a similar plot as shown for Figure 1 and is presented for an example case in Figure 3; here PATfoot has been used for SBP instead. Using this larger dataset we could confirm critical regions in PATfoot-HR as speculated in [9].

![Figure 3: PAT-HR plot during tilt table experiments with critical boundaries of PAT and HR](image)

**Conclusion**

PAT and HR based algorithms are promising hemodynamic surrogate measures during tilt table testing. Monitoring during impending syncope might simplify neurally mediated syncope management by being useful for improved syncope diagnosis and tilt training.

Current results have to be confirmed in realistic application scenarios complemented by already available wearable sensor technologies.

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**References**

[6] Philips MP 50: [www.philips.com](http://www.philips.com)