MONITORING THE ACTIVATION OF THE SYMPATHETIC NERVOUS SYSTEM TO IMPROVE HEMODIALYSIS PROCESSES

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Abstract: We propose to monitor and analyze currently not considered activation parameters of the sympathetic nervous system during hemodialysis processes. This additional data as well as simultaneously captured patient’s condition values are merged with datasets of the utilized dialysis machines. The final goal is the stabilization of the patient’s condition and the improvement of hemodialysis processes due to new findings based on the analysis of these merged datasets. For this purpose an I/O Box was developed that captures vital signs as well as condition parameters of hemodialysis patients and transmits them to an research database for further classification and display options.

Keywords: monitor, dialysis, sympathetic nervous system

Introduction

A hemodialysis therapy is an intense physical and mental stress for affected patients. Further their number is increasing in Germany [1]. Clinical problems are related to relative intravascular hypovolemia and decrease of sympathetic activity and do result in muscular cramps. One of the main problems is the loss of consciousness through an unexpected drop of blood pressure and central sympathetic nerve activation. Such a common breakdown of the dialysis procedure could be avoided by a faster and more precise adjustment of the dialysis process parameters. Possible effects of profiled hemodialysis were proposed by [2]. We propose to monitor and analyze the activation of the sympathetic nervous system during hemodialysis processes to create patient profiles and to obtain reasonable data to provide a prediction of the probability of consciousness loss. Based on this data the dialysis process parameters may be adjusted to prevent the patient from unconsciousness and maybe speed up the individual hemodialysis process. For this purpose an I/O-Box was developed that captures vital signs as well as condition parameters of dialysis patients and transmits them to an research database. There the captured data are subsequently merged with common data of the utilized dialysis machine to find correlations. In case of an appropriate consistency of the captured data a classification analysis is projected to find correlations with the patient’s condition.

System design and implementation

In the following section the architecture of the I/O Box is presented. Beyond that the utilized biosensor system is described as well as the research server and the concept of the complete monitoring system (Fig. 1).

Monitoring concept

We intend to obtain data of the sympathetic activity of hemodialysis patients by noninvasive measurement principles. These data are extended by NTP-synchronized time stamps, the patient’s ID and binary patient’s condition data. After conversion to XML representation it is transmitted to an online research server. On the research server the I/O Box data (BD) and the dialysis machine data (MD) are merged and prepared to be displayed in an appropriate way. Further the data are hold for advanced analysis.

System implementation

I/O Box: The main function of the developed I/O Box is to provide access to data of sensors with industry standard hardware communication interfaces utilizing proprietary data protocols. Furthermore it adapts these propri-
etary protocols to the XML representation and has the ability to transmit the data via WLAN or LAN. In that function it represents a gateway for certain supported sensors. The sensor support is extensible by appropriate software driver modules. An enhanced functionality of the I/O Box is to provide additional generated data. The usage of this function depends on real time requirements of the final application and the CPU speed. In the determined field of application the generation of data like heart rate variability (HRV) or respiration frequency (RF) is a useful option. The hardware is based on the OMAP4460 PandaBoard ES REV B1. It provides all required standard interfaces like USB, WLAN/LAN, SD/MMC reader and a LCD expansion option. With the OMAP4460 that includes two 1.2Ghz ARM Cortex-A9 processor cores it provides the ability to run the utilized high level open source operating system (OS) Debian. Debian is a well-known OS based on the Linux kernel. The system time is synchronized using NTP.

**GUI:** The I/O Box is controlled via a GUI utilizing a 7” TFT-LCD touch panel (Fig. 2). The GUI is able to display selected sensor data and to capture the patient’s condition information. For this purpose it offers sensor selection buttons as well as condition buttons to capture the occurrence of muscle cramps or nausea or if the patient eats or drinks something.

**Patient ID card:** The captured data during a dialysis process are assigned to an encoded patient’s ID. This ID is stored on an individual patient’s smart card that is a common part of encoded data assignment systems in several dialysis facilities. The patient’s ID is obtained by a card reader connected to the I/O Box. On the basis of the patient’s ID it is possible to merge the MD and the BD.

**Sensors:** The currently used sensor system is the “Biomonitoringsystem” (BMS) of the FTZ Leipzig and was proposed to measure bio-signals [3]. It is utilized to capture the activation parameters of the sympathetic nervous system (PSNS) during hemodialysis processes. It consists of three sensor modules and a base station. The sensor modules transmits the captured data via Bluetooth to the base station. The base station receives this data and provides it via USB interface utilizing a proprietary data protocol. All sensor modules are powered by common 1,2V AA/AAA rechargeable batteries and offer a battery life of about 20h. The BMS fulfills the galvanic isolation requirements and provides 12-lead ECG, 2-channel (ch) EMG, 1-ch EDA, 2-ch (chest and abdominal) respiration (RES) and 2-ch temperature (TEM) data. An detailed overview of the available PSNS is shown in Tab. 1. In its current version the GUI has a sensor functionality as described in section “GUI”.

<table>
<thead>
<tr>
<th>PSNS</th>
<th>ch</th>
<th>sample rate</th>
<th>range</th>
<th>resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG</td>
<td>8</td>
<td>1000 sps</td>
<td>-4...4mV</td>
<td>2µV</td>
</tr>
<tr>
<td>RES</td>
<td>2</td>
<td>100 sps</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EMG</td>
<td>2</td>
<td>1000 sps</td>
<td>-4...4mV</td>
<td>2µV</td>
</tr>
<tr>
<td>EDA</td>
<td>1</td>
<td>100 sps</td>
<td>0...1MΩ</td>
<td>5Ω</td>
</tr>
<tr>
<td>TEM</td>
<td>2</td>
<td>1 sps</td>
<td>-20...100°C</td>
<td>0.0625 °C</td>
</tr>
</tbody>
</table>

Table 1: Detailed PSNS

**Research server:** The research server is used to merge the BD and the MD based on NTP synchronized time stamps and the patient’s ID. Further the merged data are stored for advanced analysis and prepared to be displayed in appropriate charts to allow a fast and detailed overview and to create individual patient profiles. The BD are received via RESTful webservice using the local patient network of the dialysis facility (DF). The server isn’t authorized to obtain the MD during the dialysis process. Thus the MD, available as XML document, are subsequently integrated.

**Figure 2:** I/O Box with touch panel/GUI, sensor system and smart card reader

**Conclusion**

The requirement of the I/O Box and the whole data acquisition system is to provide consistent data of the patients’ sympathetic activity. The system will be verified on the basis of clinical tests with 10 hemodialysis patients. Further the BD are merged with MD to find possible correlations. In case of a successful BD validation, advanced data analysis is projected. The system currently provides the described PSNS but the data is not verified yet. On the basis of significant parameters of the sympathetic activity an individually adapted hemodialysis could be applied to avoid patient’s unconsciousness and other problems like muscle cramps. Especially parameters like HRV, EMG and RF are expected to be significant.

**Bibliography**


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Unauthenticated