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*Article in* Studies in health technology and informatics · August 2015

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Bioimpedance based monitoring system for people with neurogenic dysfunction of the urinary bladder

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Abstract Patients with impaired bladder volume sensation have the necessity to monitor bladder level in order to avoid urinary tract infections and urinary reflux that can lead to renal failure. In this paper the the effectiveness of an embedded and wearable solution for bladder volume monitoring using the bioimpedance measurement is tested. Data are streamed real-time using Bluetooth wireless technology. The bioimpedance measurements on a healthy subject prove the effectiveness of the proposed solution. In the future the system will be evaluated in real world scenarios with patients affected by spinal paralysis and bladder neurogenic dysfunction.

Keywords bioimpedence, bladder, disability, neurogenic dysfunction, wearable device, bluetooth

1. Introduction

People with serial spinal injury often have neurogenic dysfunction of the urinary bladder [1] [2], that causes the necessity of daily catheterism. From user’s point of view the absence of an urinary conscious stimulus can cause refluxes, damaging patient’s health and his psychological status. For such necessities, most patients require professional nursing, increasing the work of the staff and the overall medical costs. Furthermore catheterism itself applied everyday for a long period can cause infection in the urinary tract [3]. A non-invasive bladder monitoring system is necessary to find a way to automatically monitor patient’s bladder and help them to void.

Classical ways to measure bladder level are the ultrasound [4], the electrical impedance tomography (EIT) [5] and the bioimpedance. However the ultrasound and EIT techniques are best suited for high-cost medical equipments rather than wearable devices, due to the complexity and power consumption constraints of embedded devices.

A commercial device for real-time bladder level monitoring is not yet present. In [6] and [7] the authors prove the effectiveness of impedance measurement on healthy dogs, preventively sedated. In a most recent article [8] is described a non invasive bladder

1The final publication is available at IOS Press via http://dx.doi.org/10.3233/978-1-61499-566-1-892
monitoring system using the bioimpedance measurement. However these prototypes are not optimized in terms of power consumption and have a quite large size.

In last years, on the other hand, wearable systems [9] are quickly moving from research to market, typically targeting widespread diseases like, for example, chronic heart failure (CHF). This kind of technology is reaching a good degree of maturity and could be successfully extended to cover other diseases and needs. This work aims at verifying whether the technology developed by STMicroelectronics for the BodyGateWay (BGW), an electronic patch for the remote monitoring of cardiac and respiratory functions, can be successfully used for the development of a wearable real-time bladder volume monitoring system.

The concept of the system is showed in Figure 1. The sensor consists of a disposable patch and of an electronic device (Figure 2) which is equipped with an analog front-end for the acquisition of electrocardiogram and bioimpedance and with a tri-axial accelerometer. It is able to process the signals on board for the extraction of relevant physiological parameters (heart rate, breathing rate, position, activity level, etc.), and to store the data in the on-board memory. It is also connected through Bluetooth to a personal device assistant (PDA), for example a smartphone, providing patient interface and, eventually, a connection with a remote server for data collecting.
Together with the bioimpedance sensor, which is optimized for low power consumption as described in [10], concepts like patch-like electrode, connectivity, simple patient interface and reduced size are highly interesting for the development of a bladder volume wearable sensor. Anyway, since the bioimpedance sensor is used in the BGW for breathing rate monitoring, a deeper investigation about its capability to detect with enough resolution the bladder volume changes was needed.

2. Methods

In Figure 3 the electrodes placement is shown. The electrical impedance measurement \( Z_0 \) was performed using standard ECG electrode with a 50 kHz, 100 µA excitation current. The sense electrodes were placed above the bladder to increase the sensitivity of the measurement and they were connected to the BodyGateWay through cables, in order to increase the flexibility in electrodes placement.

The test was made on a sitting healthy subject, with minimal or no movement at all, in order to increase measurement reproducibility. The test was started at \( t = 0 \) s with empty bladder. The subject was asked to drink water (1.5 L) and \( Z_0 \) was monitored during filling process, taking a measurement every about 30 minutes. During emptying process the subject was sitting and \( Z_0 \) was continuously recorded. Finally the subject was asked to come back on the same seat of the filling phase and \( Z_0 \) was re-measured in the position assumed during the filling process to check its consistence.

3. Results

In Figure 4 and 5 the bioimpedance measurements acquired by the BodyGateWay device are shown. The filling process measurements (Figure 4) show a clear trend in bioimpedance. In particular the \( Z_0 \) value decreases about 1 Ω, from 16 Ω of completely empty to 15 Ω of full bladder, proving the correlation between impedance and bladder volume level and the effectiveness of the device in detecting it. The tiny higher spikes in the bioimpedance measurements are due to the concatenation in the same graph of different measurements, while the smaller spikes are related to the user’s legs movements.
that modify electrodes position and $Z_0$ value. Anyway for an user with spinal injury such issue is not present because of his reduced mobility.

The Figure 5 shows the bioimpedance changes during emptying process. The base value changed from $15\,\Omega$ to $16.5\,\Omega$ due to the posture changes of the subject who moved from the seat of the filling phase to the toilet. The difference from the beginning to the end of the emptying process ($1.5\,\Omega$), anyway, is comparable to the changes in the filling process. A clear trend is detectable also in this test and the higher differential value between the filling phase and the emptying one ($1\,\Omega$ versus $1.5\,\Omega$) can be explained with the fact that the bladder is compressed by muscles during the emptying phase; therefore it reaches a lower volume than the one measured for $t = 0$s. Indeed, the $Z_0$ value after the subject had came back in the same seat of the filling phase, resulted about $16\,\Omega$, very similar to the value recorded at $t = 0$s. These tests prove the ability of the BodyGateWay to detect, with good accuracy, the changes in bladder volume through bioimpedance measurements.

4. Conclusion and future works

In this paper we presents a preliminary test based on an embedded and wearable device to detect the small changes in the bioimpedance during bladder filling process. In the future we plan to evaluate the system with people with disability in real-world scenarios. The aim of this measurement plan is to evaluate the accuracy of the system, the sensitivity of $Z_0$ to user’s movements (upper limbs movements, wheelchair etc . . . ) and the body fat level, also in different environmental situations.
We plan also to involve end user in our experimentation in order to obtain useful feedback for driving future tests.

References