

Reliable Home Blood Pressure Self-Measurement in the Unsupervised Setting with Focus on Morning Rise Time and Medication

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Abstract

The goal of the present study is to augment the existing home blood pressure measurement method used for monitoring hypertensive patients in the unsupervised setting. The study presents an adherence verifier solution, that will monitor when the patient rises from bed, and when morning medication is taken, and when morning blood pressure is measured. Obtained blood pressure measurements are logged, and via a web service transferred to the physics.

This is followed by a suggestion to an adherence aid solution, which will guide the patient not to take his medication before taking blood pressure measurement and remind the patient to take the morning blood pressure measurement within 30 minutes of getting out of bed.

Keywords-component, Home blood pressure measurement, Hypertension, Diabetic nephropathy, Hypertension medication, telehealth.;

I. INTRODUCTION

Hypertension increases the high risk of cardiovascular disease associated with type 1- and 2 diabetes, and is also a risk factor for the development of diabetic nephropathy[1]. High blood pressure is one of the main indicators to define a high-risk group for progression to diabetic nephropathy[2]. Diabetic nephropathy is a renal disease arising from diabetes. Diabetes is a condition with excessive amounts of glucose in the blood or high blood sugar. This condition may have a negative effect on the kidney membranes which could leak and lead to hypertension. The condition affects about 40 % of all patients with type 1- and type 2 diabetes [3].

Studies show that tight control of blood pressure reduces urinary albumin excretion, and thereby prevents microvascular complications[1]. To control the blood pressure within a normal range, regularly blood pressure measurements and correct medication are advised [4].

To ensure the best valid blood pressure measurements, blood pressure self-measurement (BPSM) is recommended. Studies have shown the need of home monitoring of blood pressure to ensure a more valid result compared to blood pressure measured clinical settings. It is proved that the blood pressure

when measured at the doctor can be incorrect and therefore less valid. Many patients experience the so-called “white coat effect” which entails an elevated blood pressure[5], therefore when measuring blood pressure at home these challenges which can influence the resulting data-quality can be eliminated.

When measuring BP at home the patient has to follow the recommendations defined by a range of national and international clinical associations including the Danish Society of Hypertension.[6, 7]. This paper focus especially on two of the recommendations. The first is the importance of measuring the BP at the same time every day [8]. A study shows that the BP measured in the morning, is one of the best indicators for progression in diabetic nephropathy [9]. To get the most valid BP measurements a challenge is to ensure that the BP is measured before the patient takes the hypertensive medication, because the hypertensive medicine can affect the blood pressure [10].

Studies indicate a high rate of failure of patient compliance by using the recommendations described [8]. The failures are due to contextual bias cause by patients who do not follow the recommendations. Even incorrectly performed measurements must be send to the doctor, since these data may have relevance. However, current state-of-the-art does not allow marking of these data as valid or invalid.

The aim of this paper is to make a verification solution[11] where technology can support the patient’s self-adherence. A system should ensure that the patient follows the guidelines, which this paper presents. Furthermore, in order to fulfill the targeted goal we present some adherence aid solutions that in the future could be implemented in continuation of this study.

II. METHODS AND MATERIALS

In the developing of this solution the ASEF framework where used[11]. A reduced adherence model (RAM) has been defined for BPSM of diabetes. This RAM describes a system of which the implementation includes the following features for detecting related contextual biases:

- Obtain the patient's BP within 30 minutes after waking up.
- Record whether the patient's self-medication was taken before obtaining his BP.
- Calm technology to provide the patient with adherence aid in order to perform correct BP measurements[12].
- Automating logging of BP measurements and providing the different stakeholders with the logged data via a web service or the like.
- Present the obtained BP measurements to the stakeholders with a clear indication, describing whether the obtained measurements are valid or not.
- A filter to prevent BPM, not obtained by the patient or during the patient's morning routine.

To sum up the main focus according to this prototype is on verifying the obtainment of BP measurement within 30 minutes after the patient getting awake, and before the patient takes his medication.

The main keyword for implementing the above described RAM is contextual awareness, which was achieved by involving sensors (The 1018_2 – PhidgetInterfaceKit 8/8/8 with two pressure mats (one for the bed and one for the floor). The sensors were used to detect whether the patient is awake and out of bed or still sleeping. Furthermore a distance sensor (1101_0 – IR Distance Adapter coupled with a 3520_0 – Sharp Distance Sensor 2D120X (4-30cm)) were involved to detect time of the patient's self medication. Finally the system uses a blood pressure measurement device (The digital blood pressure monitor UA-767PC from A&D Medical, Tokyo Japan).

Choosing the listed sensors also had the advantages that the setup was mobile and could be brought with the patient on holidays.

The patient's morning scenario seen from the context aware sensors is as the following figure indicates:

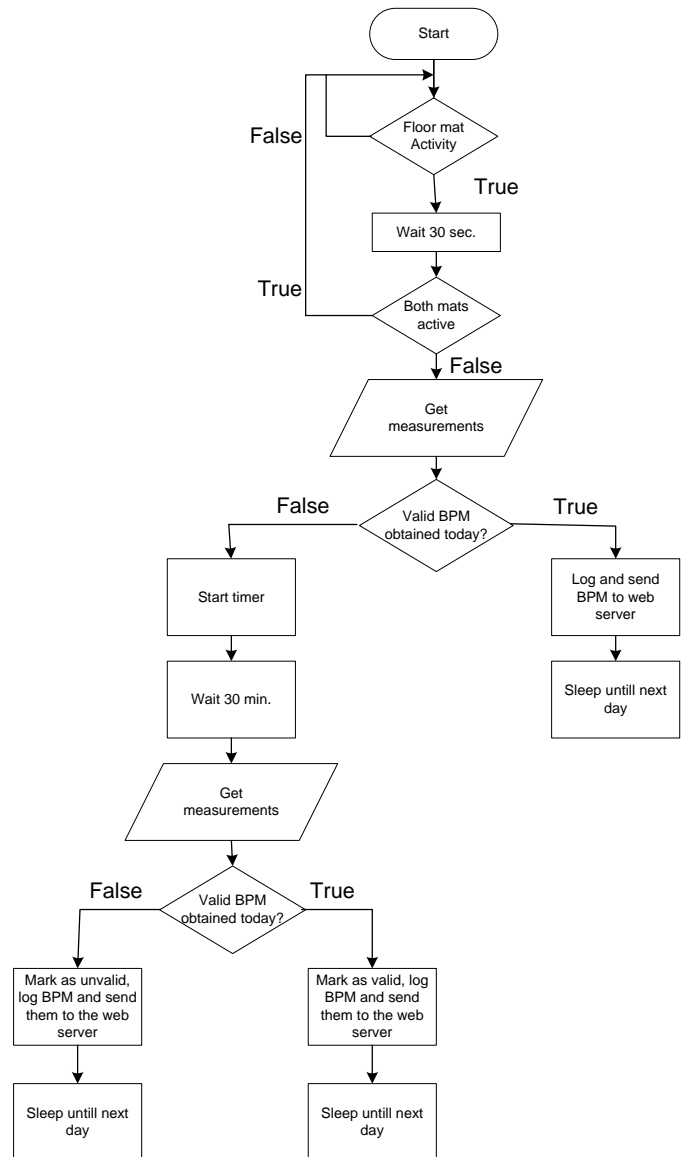


Figure 1: System overview, sequence of the program during the morning routine.

This is extended by an algorithm to decide whether the obtained BP measurement originates from the patient and from his morning routine or not.

The system compares the time when the BP measurements have been taken with the wake-up time of the patient and with the time where the medicine got taken, and concludes whether the BP measurements of the day were valid or invalid. This validation mark is logged together with the obtained BP measurements and the average BPM of the day.

After obtaining the daily BP measurements, the system will log the data together with the calculated average BP values of the day, a timestamp and a validity mark. Secondly, the system will send the described data to the different stakeholders, being the patient and the patient's doctor, via

uploading the measurement log file to a web server. It will on this web server also be possible to access older data, which enable the doctor to align the medication of the patient.

III. EVALUATION

The system is evaluated in the laboratory settings. The purpose of the evaluation is to verify that the system registers and logs the correct information about the patient’s behavior and obtained BP. The system is tested five times against three different scenarios. In all three scenarios the three BPM and the average BP will be logged.

The laboratory setup consists of a bed with a pressure mat placed underneath a mattress and another pressure mat which is placed in front of the bed. Furthermore there will be a small medication box with a sensor, to check if the medicine glass is being removed from the sensor. Finally the setup includes a digital BP monitor. As test persons we used volunteer students.

First the system is tested against the “success” scenario (scenario 1). The system is supposed to verify that the test person measures his BP within 30 minutes after he rose from the bed and before he takes his morning medication. Average BP of the day is calculated. The logged data will be marked as “VALID”.

Afterwards the system is tested against the “medicine before BP” scenario (scenario 2). The system is in the case supposed to verify, that the test person takes his medication before measuring his BP. Average BPM calculated. The logged data will be marked as “INVALID”.

Finally the system is tested against the “BP measured after 30 minutes” scenario (scenario 3). The system is supposed to verify that the test person measured his blood pressure after a time period of 30 minutes, from the time he rose from the bed. The logged data will be marked as “INVALID”.

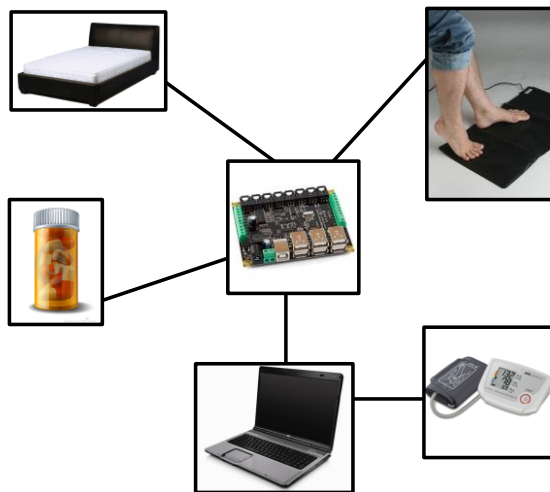


Figure 2: The test set up

IV. RESULTS

The evaluation of the system showed that the system tested against scenario one, was able to verify that the BPM was valid according to the recommendations [5, 6]. When tested against scenario two and three, the evaluation showed that the system was able to verify that the BP measurement was invalid according to the recommendations [5, 6].

Furthermore, in all three scenarios, the system was able to calculate the average BP of the day, and log the obtained BPM and calculate and save the mean BP. The mean BP was correctly calculated as the mean of the two most similar BP measurements.

In the table beneath is showed how many times the three scenarios are tested relative to the outcomes of the test. The outcomes are measured against if the system acted as expected or not.

Evaluation data		
	Number of tests	Expected/ non expected
Scenario 1	5	5/0
Scenario 2	5	5/0
Scenario 3	5	5/0

Table 1: Evaluation Data

V. DISCUSSION AND CONCLUSION

The present paper gives a solution how to verify that the patient follows two of the recommendations given for BPHM: 1) Measure the BP within 30 minutes after rise time from bed. 2) Measure the BP before taking the hypertensive morning medication. Other studies deal with how to aid patients in following some of the other recommendation. Ex. in a study by Wagner et al. they have developed a method to ensure the recommendations about resting time and correct positioning regarding to BPHM are met[8].

The state- of the art in this paper is that the Care@Home system verifies that the patient takes his blood pressure before taking his hypertensive morning medication. This is important regarding measuring a valid morning blood pressure [13]. Valid morning blood pressure measurements can be used to improve the prognoses for patients with diabetic nephropathy [9].

Existing BP devices do not automatically ensure that the recommendations are followed[8]. This can result in invalid data, and worse case wrong treatment.

The fact that the verification solution, proposed in this present paper only is tested in laboratory settings does that there might be bias which are not included in this paper. The system does not guarantee that the patients follow the recommendations, therefore a possible extension to the verification system would be an aid solution, which aim is to support the patients self –adherence.

When developing an aid solution, it is not even guaranteed that the patient follows the recommendation [14]. However an aid solution can contribute to, that the patients has the best conditions when performing the BP measurements.

The aid solution which could support the verification solution could contain several additions;

- Remind the patient if he forgets to obtain his blood pressure within the 30 minutes after wake-up time.
- A light emitting diode (LED) placed on the medication box which indicates whether or not the patients have obtained his blood pressure. The LED light will be red if the blood pressure is not obtained and green if the blood pressure is obtained.

The chosen solution for implementing a calm medication technology is a green LED (lightens up if it's okay to take the medicine) and a red LED (lightens up if it's not okay for the patient to take his medicine). The system decides whether it is okay or not for the patient to take his medicine based on the time of the BP measurement obtainment or missing of the same. 30 min. after the awaking of the patient the system will remind the patient to do the BPM and to take his medicine, by lighten up a green LED.

When performing BPHM there is a risk for wrong-user data, when another user beside from the intended patient uses the BP device. The measured data will automatically become a part of the dataset for the patients [8].

A solution to this problem could be an application for a smartphone, with a login function which should be used to ensure that the measured blood pressure belongs to the right patient. Only measurements measured in relation with the person logged in will be sent to the doctor.

Furthermore an aid solution would improve the patients self – adherence. A study by Gellis et al. shows that telehealth monitoring helps to improve the patients understanding of their medical condition [14]. A smartphone aid solution would make it possible for the patient to follow the progress of his blood pressure and thereby be more aware of his current health situation.

The development of a smartphone application should be done according to the target group. It would not be advantageously to make an application for elder people who are not confident using a smartphone. Therefore this suggested aid solution aim for people with confidence in using a smartphone.

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