Penetration of the ICT Technology to the Health Care Primary Sector - Ljubljana PILOT

Tonka Poplas Susič* and Uroš Stanič**
* Health Centre Ljubljana, Ljubljana, Slovenia, antonija.poplas-susic@zd-lj.si
** Kosezi d.o.o., and Biomedical Research Institute –BRIS, Ljubljana, Slovenia, uros.j.stanic@gmail.com

Abstract – ICT technology on primary care sector can significantly improve the level of health care and consequently reduce its costs. Some initial results are shown in this paper obtained from the pilot study in the region of Ljubljana, Community Health Centre (CHC). ECG body sensors have been made available to several volunteers with potential disturbances in the heart rhythm in order to reach evidence based diagnosis and further treatment. Initial results from the screened volunteers show that arrhythmias can be excluded or confirmed and specified by this sensor without need to refer patients immediately to the secondary care level. This could have an important impact on the length of waiting queues and on the time needed for the competition of diagnostic process, which implies time and money savings. The ECG body sensor did not disturb patients and can be applied also to the disabled people at home. It enables patients centered medical care with early diagnoses, which will substantially influence the future health treatment.

I. Introduction

According to the OECD data, Slovenia has among EU countries the lowest number of subjects that could not afford health care services because of financial or other reasons [1]. Slovenia is in the group of 17 EU countries that assure the health care services to all its citizens and even to immigrants. The comprehensive analysis of WHO also revealed that Slovenia has a good coverage and available primary health care sector [2]. These facts motivated a large national consortium with over hundred stockholders from industry and academia to submit the e-Health and m-Health (EMZ) national project proposal on the cohesion funds call as a part of the SPS national system [3]. The ambitious project goals until 2020 are to reach 30% of the national population by ICT supported services with ultimate effects reflected in 10% of lower costs for health care [4] that could result in 2% of the GDP growth and could generate 5000 new work places. The EMZ realization has already started with several project pilots based on the multifunctional ECG body sensor of vital functions [5].

The Slovene approach within the EMZ project is somewhat similar to the Danish one, but compared to Denmark lacks system approach [6]. Namely, the JRC study is based on data collection depicting Danish conditions and serves as a benchmark for similar studies in the rest of the EU-27 countries. For example, one of positive characteristics of Danish health care system is that the percentage of people having a long-standing illness or health problem (in 65-74% of population) is lower in Denmark (37.9%) compared to the EU-27 average (54.4%) (source Eurostat 2009). The difference of 15% reveals the higher quality of life of elderly population but also represents considerable saving of money. One third of Danish population suffers from one or more chronic diseases. As 80% of the Danish healthcare system resources incurred by chronically ill patients (19.5 bn. EUR) the saving of 15% is around 3 bn. EUR. They concentrated their attention to the following eight diseases: diabetes, cancer, cardiovascular diseases, osteoporosis, muscle and skeleton diseases, asthma and allergies, COPD, and mental illnesses. For each of these populations the calculation was made, number of patients and the costs of treatment. Based on this data, they established Public Welfare Technology Foundation that (PWT) that funds two types of projects; Local demonstration (pilot) and national implementation projects. Similar to Danish approach, it is expected that the beneficial results of the Ljubljana PILOT will be implemented nationally as well.

It was shown that by using three differential leads (DLs) it is possible to synthesize high quality 12-lead ECG [7], [8]. Further, based on the ECG sensor measurements it is possible to analyze the timing of ECG signals and, based on this, to diagnose some arrhythmias [9]. The practical validation of these hypotheses is among the main goals of the presented pilot.

The design of pilot system is tailored to the specific needs of the Community Health Centre Ljubljana, which consists of seven units, offering continuous care to the citizens located in their region and to all daily migrants and visitors of Ljubljana, on the area of preventive [10] and curative [11] medical care. CHC is a development oriented institution in primary health care with more than 1400 employees (129 general practitioners) and with more than 440.000 registered patients. The medical personnel are committed to deliver immediate care, when the patients visit them. They wish to ensure a high-quality and time-wise optimal access to health care services for all of their users in all segments of acting. The patients come from Ljubljana and its periphery with rural areas and are treated within the medical doctrine and defined ethics aspects.

It is known, that primary care level solves more than 80% of patients health problems and just some patients are referred for treatment to the secondary/tertiary care level

[12]. Fast evolving technology can improve procedures and measures taken by family physicians.

The proposed pilot system which is for the first time implemented in primary care e.g. CHC could trigger a broad penetration of the ICT in medicine in the primary care level on the national level that could improve and complete the integrated health care with evidence based decisions. Also disable patients that cannot visit their physician could be supervised and treated by ICT. The pilot introduced in Ljubljana is providing responses of medical personnel to the system user interfaces and also the system acceptability level assessed with regard to patients, families and caregivers. The participating patients, occasional experiencing difficulties with heart rhythm, will be provided with a comprehensive care in terms of screening with preventive and curative treatments, and diagnostic. Initial results of the study including the acquired measurements and system efficiency are presented and discussed in the paper.

The rest of the paper is organized as follows. In Section II. the methodology used in the pilot measurements, the participants data and the ICT equipment is described. Section III. presents some illustrative measured results and some of the first feedbacks from patients and medical professionals. In Section IV., the first results from the pilot measurements are shown and some potential benefits and limitations are discussed. The paper concludes with the description of future broadening of the pilot to the rest of Slovenia.

II. Methods

A. Methodology

Differential leads (DL) [7] are bipolar leads that measure the potential between two closely placed body-surface electrodes. The DL measurements can be obtained by a body sensor that is fixed on the chest in the vicinity of heart. In Fig. 1., a set of possible positions for ECG sensor are shown. Sensor leads are marked with two connected circles. For example, the potential difference between standard leads (V2-V1) can be measured by a body sensor, with its electrodes (marked with black circles in Fig. 1.) placed on standard positions of V1 and V2.

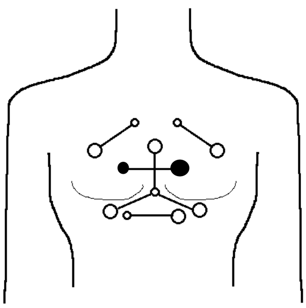

Fig. 1. Several possible positions of ECG body sensors.

If the body sensor is equipped with a small rechargeable battery and radio it can be implemented as a minimally obtrusive wireless body sensor [13]. We use a prototype sensor shown in Fig. 2., termed as PCARD sensor in the rest of the paper, that is able to measure the ECG for three days without charging. The acquisition of ECG signal is implemented with the sampling rate of 125 Hz and the resolution of 10 b/sample. For details about the recording device and procedure please refer to [14].

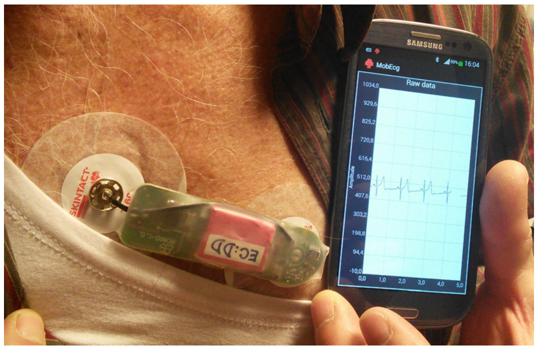

Fig. 2. An example of PCARD sensor.

B. Patients selection

Thirteen volunteers (8 male, 5 female, mean age ± SD = 50.6 ± 9) with no previous medical record related to arrhythmia problems were included in the initial study for validation of the measurement protocol, and for testing the usability and acceptance level of the ICT equipment.

In January 2016, general practitioners (GPs) in Health Centre Ljubljana started to identify patients with potential periodic heart rhythm problems which are difficult to be confirmed by the outpatient electrocardiography (ECG). Indicated problems were: palpitation, attacks of atrial fibrillation, and occasional disturbance of hearth frequency. After detection, patients were asked to permit reporting their name/surname and mobile phone number to the contact person in the Simulation Centre (SIM) in the CHC. All candidates were informed by their GP that the study is a pilot and that they can refuse contribution in any moment during the study. All pilot participants have signed a written consent.

The contact-person in SIM systematically contacted every patient on the list and discussed with them all aspects of usefulness, technical data, reporting, health related side-effect, writing diary and handling the sensor. Additionally, every patient got written information about the use and handling of the ECG sensor.

Twenty volunteers out of 37 wanted to participate in screening and no one had a heart related health problems earlier. Protocol of the study was sent to the Ethic Committee for consideration.

C. Measurement procedure

A trained medical technician explains and shows patients how to fix the body sensor on a most appropriate position from Fig. 1., how to apply skin electrodes and how to connect the ECG sensor on them and how to start the measurement with the mobile application on the phone. Additionally, they are instructed how interrupt and start a measurement.

Pilot participants received a diary to note observed difficulties and troubles. They were also asked to record their wellbeing and mark unusual events. They received contact data of the assigned professional, whom they can contact if necessary. In case of urgent/life threatening situations they were advised to call 112.

III. Results

Up to date, thirteen healthy volunteers ECGs have been recorded. Additionally, five patients return their sensors with the recorded long term ECG measurements. Participants wore the sensor from few hours to more days depending on the rhythm disturbances. The summary of pilot participants is given in Table I.

	Actul No.	Planned No.	Avg. age ± SD (min, max)	Avg. duration of measure. ± SD (min, max) in h
Volunteers	20	100	52.4 ± 14.3 (25, 82)	8.8. ± 23.7 (0.03, 90)
Patients	5	50	48.2 ± 11.4 (34, 60)	1.2 ± 0.4 (1, 2)

Table I. Summary pilot participants data.

A typical history of a ten-day measurement, as visible for the GP in the custom ECG analysis program, is shown in Fig. 3. We can see that the measurement is composed of more files, represented as colored rectangles, which is a consequence of measurements interruption, because the participants have been instructed to stop the measurement, for example, before taking a shower, or if they noticed that the sensor has lowered the battery level, etc.

For easier and faster evaluation, the rectangles are colored in order to indicate the standard deviation of RR intervals (RRI), which is in some rough correlation with potential arrhythmias or extreme dynamic changes in the hearth beat as a consequence of physical activity.

The GP can simply click on a selected rectangle to visualize a particular measurement. In Fig. 4., an one hour segment of the encircled measurement from Fig. 3. is shown. The ECG signal is in red, while its RRIs are marked with blue crosses. The y coordinate of each cross represents the difference in time between current and previous R-time. Several non expectable changes in RRIs are easily noted. Some of them are a consequence of false detected R waves, but some of them indicate an actual abrupt change of heart rhythm. Now, the user can zoom the interesting parts, e.g., significant changes in RRI marked by left arrow in Fig. 4., or a discrete drop in RRI (from 1.2 sec → 1 sec) marked by the right arrow.

Zoomed ECG around the left arrow discovers a series of premature atrial beats shown in Fig. 5, again with ECG signal by red curve and RRI by blue crosses. In Fig. 6 further zoom around the start of this sequence is applied to visualize details of premature beats morphology. It is clear that based on this record we can exclude atrial fibrillation as one of the most important reason for arrhythmia and/or other danger arrhythmia at that very moment and diagnose palpitation further, if needed according to patient's clinical condition.

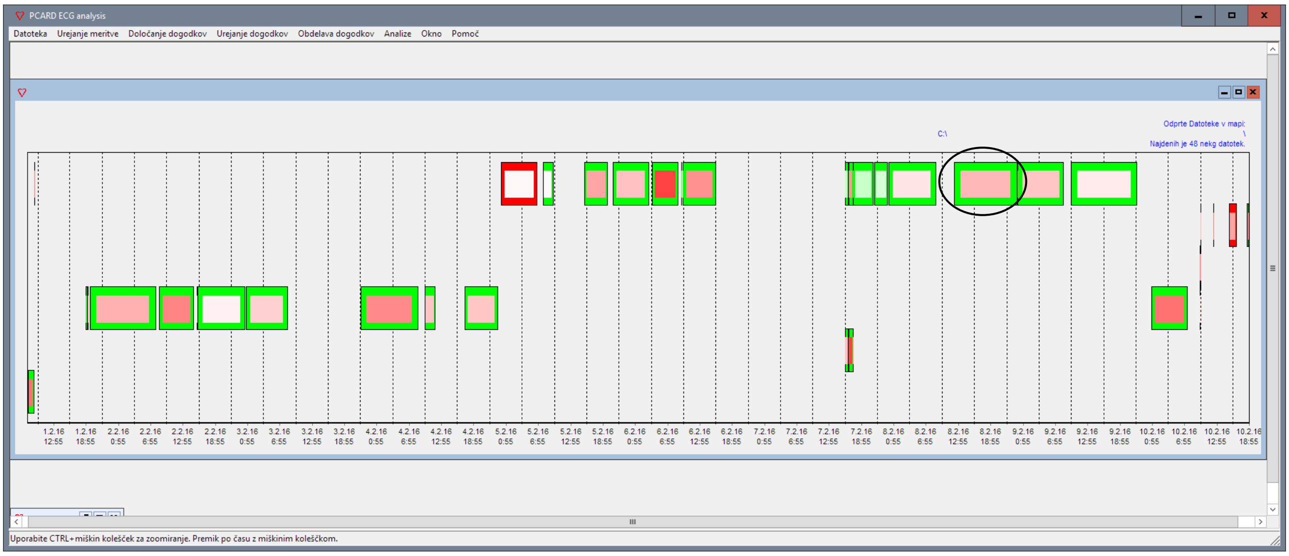

Fig. 3. A typical longterm measurement overview recorded by PCARD sensor.

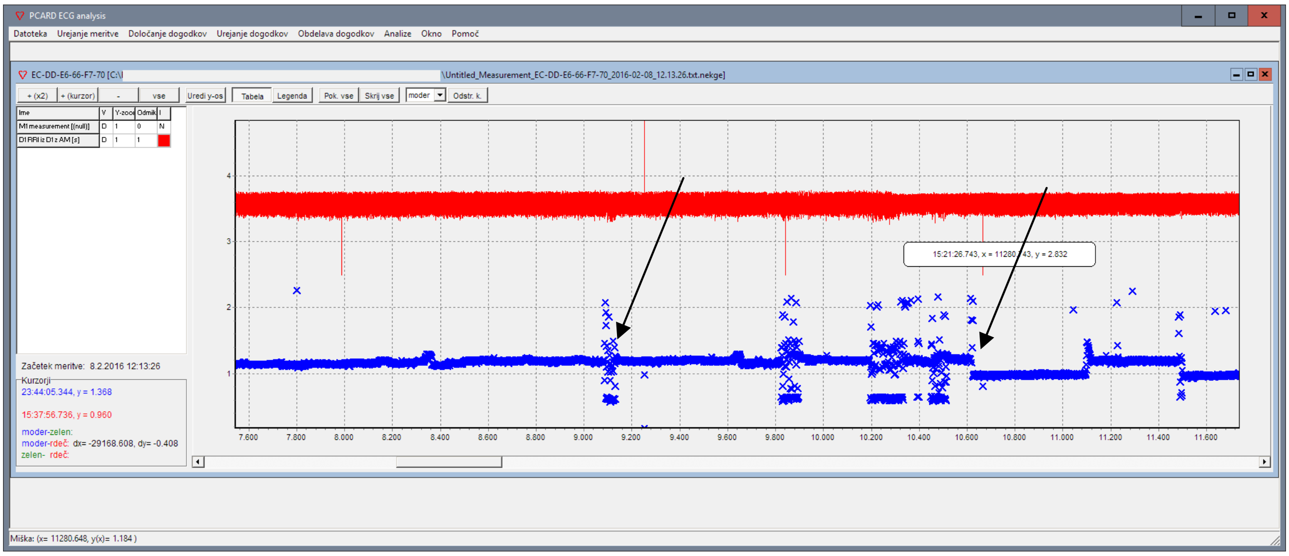

Fig. 4. One hour segment of the encircled measurement from Fig. 3.

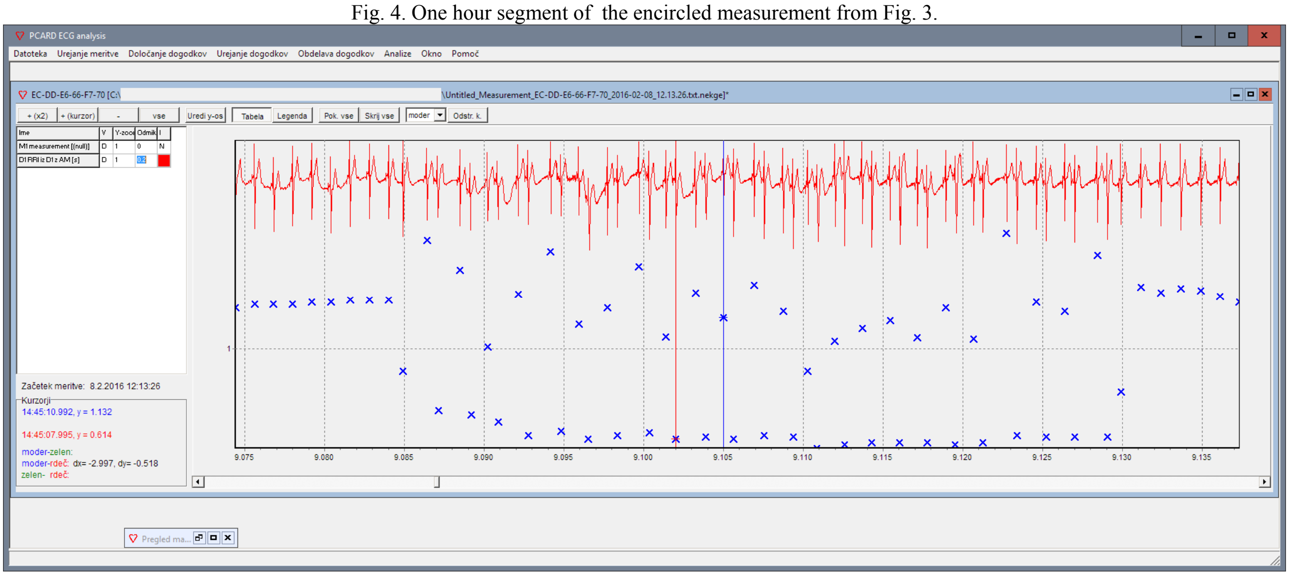

Fig. 5. Zoomed section around the left arrow from Fig.4.

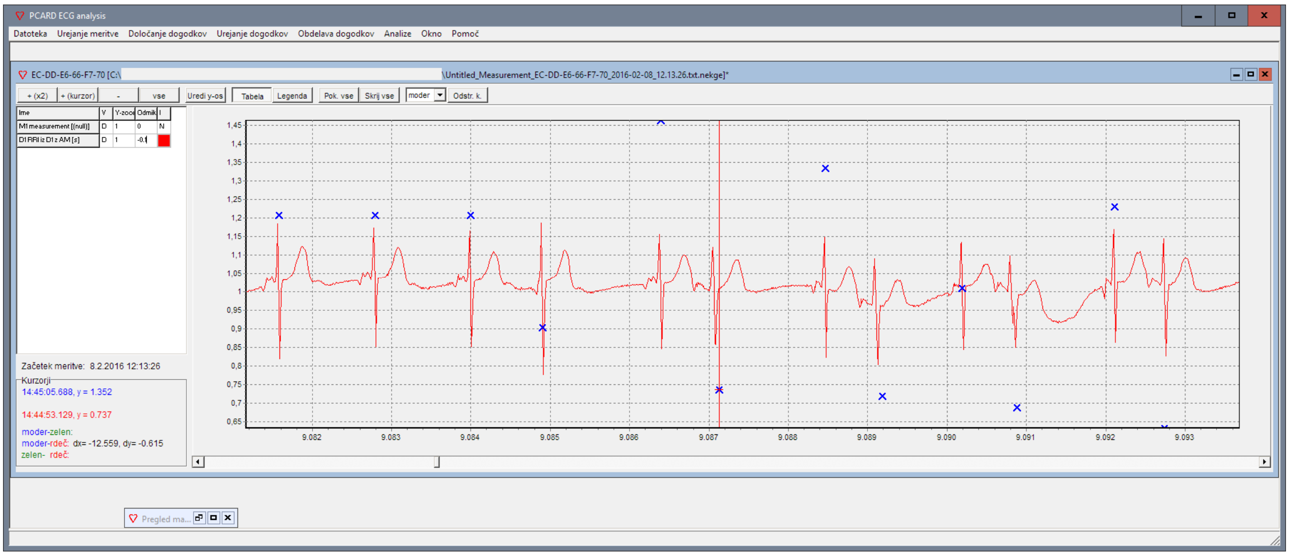

Fig. 6. Further zoom of Fig.5. for detailed view of premature beats morphology.

Patients did not fulfill their diaries with time of emergence of palpitation although they were strongly asked to do that. They reported to feel safe with ECG sensor and nobody complained about side effects. By removing the patch no redness or/and itching of the skin was observed. With no significant reason, one of the patients wanted to prolong the period of wearing sensor and it was allowed. After finishing recording ECG, patients were asked for their feed-back and there wasn't any suggestion to improve the methodology of the planned pilot.

IV. Discussion

Clear benefits of the proposed pilot on the primary level is in usefulness of the sensor for the family physicians since it guarantees better evidence-based diagnostic process, in optimizing health care resources and in fast diagnosis. Most noticeably, waiting list could be shortened and less time could be used to conclude diagnostic process (time and money saving treatment). First feedback from the pilot participants indicates that ECG body sensor does not disturb patients nor their family members. It enables patients centered medical care and early diagnosis and will in this way substantially influence the patient treatment in the near future.

Potential limitations are in the personal response of patients to the ICT equipment. Some patients are interested and eager to manage their measurements alone and to follow their ECG on their phone. Other patients are either not interested or not able to actively follow the measurement therefore they can just make a measurement. According to some reports [4], following the ECG parameters on the screen can disturb patients and make them nervous. These kinds of volunteers decided for "recording without seeing" and totally believed in the purpose of the study. After the measurement they bring the sensor to the medical centre or sent the recorded files from the phone to their doctor, who analyzes them.

Analyzing the first measurements, we can hypothesize that arrhythmias and atrial fibrillations, as one of the important cause for the stroke or sudden dead, can be excluded or confirmed by this sensor at the point of care without the need to refer patients for diagnostic process to the secondary care level.

The sensor can be worn longer (typically 3 days) compared to the Holter monitor (24 hours). The time is limited by the lasting of battery, which can be easily charged at home. The ECG sensors are not expensive and therefore available for all. The sensor can be removed if no problems are observed. Even that some data can be lost, because of interruption of measurements or occasional lost radio connection; the recordings still provide significant evidences about long term health state from patients' everyday environments.

The light and unobtrusive ECG sensor does not disturb patients, and can be applied also to disabled people at home. The sensor enables patients' centered and personalized medical care provided by the team of different experts, e.g., physician, practice nurse, home care nurse or emergency nurse, technicians, engineers and researchers.

The socio-economic impact of the use of the wireless ECG sensor in primary care sector in the CHC cannot be estimated yet because of low number of pilot participants and even lower number of pathological records. However, more extensive and profound study will be implemented within the developing pilot (100 patients) in order to asses also other factors, e.g., processes' quality indicators, usability, clinical significance, and economic parameters.

Like majority of EU countries Slovenia is also challenged by its growth of aging population. This demographic shift is a serious problem for the government as the number of citizens needing medical care will increase very fast in the future and consequently the associated costs will rise. Some recent studies and projects [15], [4] demonstrated the cost-effectiveness of mHealth services could generate 50-60% reduction of hospital nights and re-hospitalizations and reduce overall elderly care expenditure by 25%.

The planned pilot study intents to gather experiences during the application of the ECG wireless sensors for prolonged remote cardiac monitoring of citizens/patients that are under medical care of GPs from CHC. It is expected that the benefit of the new approach will result in a reduction of visits in CHC and stimulate optimal prescription of medication and present new suggestions for healthier life style. The results from the pilot case will be used to demonstrate to the government and other decision makers how effective the mHealth technology can be. It will be demonstrated that by using the already available ICT technology the coverage of all Slovene regions can be achieved at affordable costs.

V. Conlusion

The ECG body sensor enables faster and economic diagnostic process for different kind of arrhythmias on the primary level. Further implementation will engage more patients and will be expanded through CHC in 2016. The size and influence of the CHC can contribute to the coordinated widening of the pilot on the national level and possibly expanded to other EU regions.

Acknowledgment

This work was partly financed by the Slovenian Research Agency under Grant P2-0095.

References

[1] "OECD Health Statistics 2015," 18. 2. 2016, 2016; http://www.oecd.org/health/health-data.htm.

[2] "WHO - Global Health Observatory (GHO) data," 18. 2., 2016; http://www.who.int/gho/publications/world_health_statistics/2015/en/.

[3] "Workshop EMZ, Proc. 18th Int. multiconf. Information Society," 2015.

[4] C. Klersy *et al.*, "Economic impact of remote patient monitoring: an integrated economic model derived from a meta-analysis of

randomized controlled trials in heart failure," *Eur J Heart Fail,* vol. 13, pp. 450-459, 2011.

[5] M. Depolli, J.M. Kališnik, T. Korošec, A. Poplas-Susič, U. Stanič, and A. Semeja, "PCARD platform fo mHEALTH monitoring," *Informatica,* vol. Accepted for publication, 2016.

[6] "Strategic Intelligence Monitor on Personal Health System, Phase2," *JRC Scientific and Policy Reports*, 2013.

[7] R. Trobec, and I. Tomasic, "Synthesis of the 12-Lead Electrocardiogram From Differential Leads," *IEEE Trans. Inform. Technol. Biomed.,* vol. 15, no. 4, pp. 615-621, 2011.

[8] I. Tomasic, S. Frljak, and R. Trobec, "Estimating the Universal Positions of Wireless Body Electrodes for Measuring Cardiac Electrical Activity," *IEEE Trans. Biomed. Eng.,* vol. 60, no. 12, pp. 3368-3374, 2013.

[9] S. S. Lobodzinski, "ECG patch monitors for assessment of cardiac rhythm abnormalities," *Prog. Cardiovasc. Dis.,* vol. 56, pp. 224-229, 2013.

[10] T. Poplas-Susič, I. Švab, and M. Kolšek, "Community actions against alcohol drinking in Slovenia - a Delphi study," *Drug and alcohol dependence,* vol. 83, pp. 255-261, 2006.

[11] V. Ivetić, J. Kersnik, Z. Klemenc-Ketiš, I. Švab, M. Kolšek, and T. Poplas-Susič, "Opinions of Slovenian family physicians on medically unexplained symptoms : a qualitative study," *Journal of international medical research,* vol. 41, pp. 705-715, 2013.

[12] L. Green, G. Fryer, B. Yawn, D. Lanier, and S. Dovey, "The ecology of medical care revisited," *N Engl J Med,* vol. 344, pp. 2021-2025, 2001.

[13] K. Bregar, and V. Avbelj, "Multi-functional wireless body sensor - Analysis of autonomy," in *36th International Convention on Information & Communication Technology Electronics & Microelectronics (MIPRO)*, 2013, pp. 322-325.

[14] V. Avbelj, R. Trobec, B. Gersak, and D. Vokac, "Multichannel ECG measurement system," in *Tenth IEEE Symposium on Computer-Based Medical Systems*, 1997, pp. 81-84.

[15] "mHealth in Europe: Preparing the ground – consultation results published," *Green paper*, 2014.