A Review of Remote Patient Monitoring System: Potentials, Challenges and Current Issues

[1]Amritjot Kaur and [2]Shimi.S.L,
[1]M.E Student, [2]Assistant Professor,
[1 2]Department of Electrical Engineering, National Institute of Technical Teachers Training & Research, Chandigarh, India

Abstract: Physiological parameters are often considered as critical information to assess initial health condition and underlying health issues. These signs can contribute towards early detection, early diagnosis and risk reduction of fatal incidents. Today's advanced monitoring systems incorporate the balanced combination of clinical and technological aspects to give an innovative healthcare outcome. Remote patient monitoring systems are rapidly becoming the core of today's healthcare deliveries. The paradigm shifted from traditional and manual recording to computer based electronic records and further to smart phones as versatile and innovative healthcare monitoring systems. Moreover, a comprehensive review of related literature in the context of acceptability, mobility, reliability and efficiency of patient monitoring systems in healthcare delivery and handling physiological measurements is presented. The outcome of this study indicates that despite some limitations commented by patients and clinicians, these systems should be more compact and simple to operate and they should be available to healthcare professionals with minimum interruption to normal daily life activities.

Keywords: *Patient Monitoring, Medical Devices, Wireless Medical Applications, and Remote Monitoring.*

I. INTRODUCTION

Physiological parameters are among critical factors in determining health status. Prolonged physiological signs measurement was used as a very first diagnosis tool. It was performed by counting the number of pulses in a minute and checking forehead palpation for body temperature manually. The most commonly monitored signs are: blood pres-sure (BP), heart rate (HR), pulse rate (P), respiratory rate (RR), oxygen saturation (SpO2) and body temperature [1]. There have been continuous improvement and enhancement towards the vital signs collection equipment, transmission protocols and graphical presentation for clinicians in an in-formative and easy to understand way. Vital signs are considered important in early detection of health related issues only if they are collected and presented accurately [2].

Today, vital signs are incorporated into every basic health assessment plan, as a simple measurement of physiological parameters that represent a set of objective data used to determine general parameters of a patient's health and viability. These values influence the medical professional's Interpretation of a patient's overall condition and affect the course of treatment for each patient individually. Although vital signs monitoring is one of the most commonly per-formed tasks in healthcare, the majority of literature reported that the frequency of obtaining vital signs depends on hospital policy, nursing judgment, or written physician instruction and is commonly based on the patient's health complained. For example, primary stroke centers have guidelines that require vital signs monitoring of every 15 minutes during the acute phases of care and most intensive care units require a minimum of hourly record of vital signs [3].The fast growing older adult (65+) population during the last two decades has ascertained to be a major challenge in providing healthcare worldwide. Consequently, the number of patients requiring continuous monitoring has been also increased which makes healthcare providers adopt new measures to reduce the associated cost. Moreover, adoption of mobile phones (smart phones) and the trends of 'being online' and 'always connected' are some of the motivating factors for engineers, medical professionals and scientists towards continuous enhancement and development of advanced vital signs monitoring systems. In depth information and review of vital signs monitoring with current systems in practice using state-of-the-art devices and technologies are discussed in the following sections. It aims to carry forward the intense work of survey, analysis and literature review carried out by healthcare researchers, engineers and clinicians [4].

II. EXISTING SYSTEM USED FOR PATIENT MONITORING

A. In-Home Wireless Monitoring of Physiological Data for Heart Failure Patients

This system is an integrated system (hardware and software) for real-time, wireless, remote acquisition of cardiac and other physiologic information from HF patients while in the home environment. Transducers for measurement of electrocardiogram (ECG), heart rate variability (HRV), and acoustical data are embedded into patient clothing for unobtrusive monitoring for early, sensitive detection of changes in physiologic status. Sampling rate for this system is 1 kHz per channel. Signal conditioning is performed in hardware by the patient wearable system, after which information is wirelessly transmitted to a central server located elsewhere in the home for signal processing, data storage, and data trending. The dynamic frequency ranges for the ECG and heart sounds (HS) are 0.05-160 Hz and 35-1350 Hz, respectively. The range-of-operation for the current patient-wearable physiologic data capture design is 100±10 feet with direct line-of-sight to the home server station. Weight measurements are obtained directly by the in-home medical server using a digital scale. Physiologic information (ECG, HRV, HS, and weight) are dynamically analyzed using a combination of the LabVIEW (National Instruments, Inc.; Austin, TX) and MATLAB (Math Works, Inc.; Inc Natick, MA) software strategies. Software-based algorithms detect out-of-normal or alarm conditions for HR and weight as defined by the health care provider, information critical for HF patients. Health care professionals can remotely access vital data for improved management of heart failure.

B. Wireless Surface Electromyography System

Surface electromyography (SEMG) systems are utilized throughout the medical industry to study abnormal electrical activity of the human muscle. Historically, SEMG systems employ surface (skin) mounted sensors that transmit electrical muscle data to a computer base via an umbilical cord. A typical SEMG analysis may exercise multiple sensors, each representing a unique data channel, positioned about the patient's body. Data transmission cables are linked between the surface mounted sensor nodes and a backpack worn by the patient. As the number of sensors increases, the patient's freedom of mobility decreases due to the lengthy data cables linked between the surface sensors and the backpack. An N-channel wireless SEMG system has been developed based on the Zigbee wireless standard. The system includes N-channels, each consisting of a wireless Zigbee transmitting modem, an 8-bit microcontroller, a low-pass filter and a pre-amplifier. All channels stream data to a central computer via a wireless receiving modem attached directly to the computer. The data is displayed to the user through graphical development software called LabVIEW. The wireless surface electromyography (WSEMG) system successfully transmits reliable electrical muscle data from the patient to a central computer. The wireless EMG system offers an attractive alternative to traditional wired surface electromyography systems as patient mobility is less compromised.

C. Automatic Mental Health Assistant: Monitoring and Measuring Nonverbal Behavior of the Crew during Long-Term Missions

This system presents a method for monitoring the mental state of small isolated crews during long-term missions (such as space mission, polar expeditions, submarine crews, meteorological stations, and etc.) The research is done as a part of Automatic Mental Health Assistant (AMHA) project which aims to develop set of techniques for automatic measuring of intra- and inter-personal states in working groups. The method is focused on those aspects of psychological and sociological states that are crucial for the performance of the crew. In particular, we focus on measuring of emotional stress, initial signs of conflicts, trust, and ability to collaborate. The developed method is also currently tested by usage of a web-based platform.

D. Mobile Applications in Vital Signs Monitoring

Mobile health applications are beginning to emerge as a useful technology for healthcare delivery. For example, by using a basic cell phone calling service or short message service (SMS), people with type 1 diabetes mellitus are assisted in self-management, by sending a text message on their mobile phone. This method has produced favorable changes in diabetes self-efficacy and adherence to treatment [5] and their behavioral changes [6]. There is also an effective and positive response from smokers, which is one of the world's current biggest problems. This is done through mobile phone based projects such as 'Text2Quit' and 'txt2Stop' [7,8]. Today m-health applications are avail-able in every area of healthcare such as; physical activity [9], anti-obesity [10], Diabetes self-management [11] and Asthma self-management [12]. Airstrip Technologies [13] has developed an innovative patient monitoring solution, using AppPoint^{TM} software development platform, which is compatible with mostly all handheld smart phones, tablets and PCs. Airstrip Technologies' remote continuous vital sign monitoring via iPhone is developed for the general population and for emergency cases as well. According to Topol [14] acceptance of mobile phone in healthcare is possible because of; ever-growing use of smart phones, enhanced bandwidth with third and fourth generation (3G and 4G) mobile data networks and smart phones with computing power equal to that of a personal laptop computer. Variety of smart phone based personalized monitoring applications currently in use and/or available in today's market today are developed by Farmer *et al.* [15], Tatara *et al.* [16, 17], Cho *et al.* [18] and AgaMatrix [19].

III. POTENTIALS AND CHALLENGES OF WIRELESS MEDICAL APPLICATIONS

With the advancement of wireless technology, wireless devices can be used to reduce medical errors, increase medical care quality, improve the efficiency of caregivers, lessen the caregiver-lacking situation, and improve the comfort of patients. Although the technology has found ways into various fields, medical domain has very strict quality and assurance requirements, which causes many challenges that are faced when implementing and operating the systems. The following part of the paper will be reserved to identify potentials and challenges of healthcare system using wireless technology.

A. Potentials of Wireless Technology in Medical Applications

(i) Wireless inside-body monitoring is a hot application of wireless network in patients' monitoring. Using WBAN technologies to transmit data from monitoring devices, such as Capsule Endoscope, to outside body, these applications used to monitor the digestive organs such as the small intestine by video or successive image data. The system uses IEEE 802.15.6 and wearable WBAN to guarantee the quality of system.

(ii) Operation assisting is very new application of wireless network. In an operation, doctors have to

(iii) Monitor the patient's vital signs to have timely actions. These signs can be obtained by applying to the patient adhesive electrodes so that the signs are transmitted over wires to display monitors. The large number of wires used around the operation table prevents the medical team's access to the patient. Moreover, the adhesive can be detached from patient what is caused by strong enough impact to the wires. To help surgeons and medical teams operate more freely, the Smart pad is presented. A device displays patient's signals without adhesives or wires.

(iv) Although real-time patient monitoring field is not a new topic in wireless medical applications, researchers and industries are investing a lot of effort and money to it. These applications basically use biomedical sensors monitor the physiological signals of patients such as electro-cardiogram (ECG), blood oxygen level, blood pressures, blood glucose, coagulation, body weight, heart rate, EMG, ECG, oxygen saturation, etc.

(v) Home monitoring systems for chronic and elderly patients is rapidly growing up in quantity and quality. Using the system can reduce the hospital stay of patient and increase patient safety and mobility. The system collects periodic and continuous data and then transmits it to the centralized server. Patients' information is accessed by physicians remotely. These applications save large amount of time for doctors as well as patients. The doctors can monitor several patients simultaneously which cannot be done by traditional monitoring, in which the patients are monitored directly by the doctors. The patients are no longer required to be present at the hospitals periodically.

(vi) Wireless sensor network can be applied to medical applications to build up databases for long-term clinical uses. It also can be used for emergency medical care and many other applications. The section presented the fields that wireless networks can contribute. The following part will identify challenge of deploying wireless networks based solutions in medical care.

B. Challenges of Wireless Technology in Medical Applications

(i) The use of wireless technologies in medical environments is bringing major advantages to the existing healthcare services. However, these have several key research challenges such as various types of network communication infrastructure, fault-tolerance, data integrity, low-power consumption, transmission delay, node failure, etc.

(ii) Reliability is one of the most important factors in a successful healthcare system. To ensure this factor, system designers have to care about adaptation of nodes when its location, connection and link quality is changed. Different network communications infrastructure should be used in appropriate situation. For example, with high-risk patients, the services with higher Quos should be used.

(iii) The integrity of distributed data system and fault-tolerance should be given a proper consideration also. Every device can operate differently at different times, especially sensor-based devices. One node in a system can be failure at anytime for number of reason including natural issues, human-related issues or batteries exhaustion. Ensuring a seamless service during life time of the system could be a big challenge.

(iv) How to manage the transmission delay of various types of communications in the system is an undoubted challenge. With the system using WBAN or wireless sensor network, data must go through a number of hops before it reaches the sink. In addition, these hops are sometime located in very critical conditions, such as magnetic field or areas bearing interference of radio waves. As a result, various delays occur and require extra effort of system designer to synchronize the whole system.

(v) In many mission critical applications, it is vital that devices do not fall into battery exhaustion. As the matter of fact, most wireless network based devices are battery operated; therefore, the design of a system must not require devices to expend excessive energy. The developers have to consider the longevity of the devices and extend it by using such scheduling algorithms and power management schemes that energy consumption should be shared over the whole network, rather than having a few devices or nodes carrying the whole network's load.

(vi) From patient's aspect, one of the most important issues is how comfortable they feel when using these new applications. Therefore, the applications must be not only helpful but also unobtrusive, specifically small, lightweight, etc.

(vii) Last but not least, patient's information must be private and secure, but remain accessible to authorized persons. Power and process availability of wireless-based network is very limited while to ensure privacy of information, extra power and computation must be used to encrypt transmitted data. Thus guaranteeing information security can be an issue and challenge for system developers.

The mentioned challenges are associated with technical implementation. However, there are many other challenges associated with deployment of a new technology. Specifically, the new system should be low cost and not interfere with existing infrastructure. So managing interference between the old system and the new one and using spectrum properly are challenges of wireless technology applied to medical applications.

IV. REMOTE PATIENT MONITORING DEVICES

A. Blood Pressure Monitor

Blood pressure (BP) refers to the pressure exerted by blood against the arterial wall. BP is an important physiological parameter to measure the reflection of blood flow when heart is contracting (systole) and relaxing (diastole). Changes or trends in BP often give the medical professionals an early indication to start appropriate medical treatment. For example; a drop in BP, has been found to be a common sign in patients prior to cardiac arrest. The importance of measuring BP accurately cannot be over emphasized; and yet, it is one of the most inaccurately measured vital signs. If a BP reading consistently underestimates the diastolic pressure by 5mmHg, it could result in two thirds of hypertensive patients being ignored for a preventative treatment [20]. Furthermore, "A fall of more than 20 mmHg in systolic blood pressure and/or more than 10 mmHg in diastolic blood pressure when standing (compared to the sitting blood pressure) indicates risk of fall" [21]. Fig. 1, shows the evolution of BP measurement devices; Fig. 1a shows a traditional manual sphygmomanometer [22]. Fig. 1b shows an automatic Bosomedicus prestige BP monitor which is used for the acceptability evaluation, it is a wireless Bluetooth (BT) device which measures BP and pulse rate and wirelessly transmits the recorded data to any computer via BT [20]. It can record the BP data at user defined time intervals using a simple user interface feature. Similar devices have been used in many clinical trials with clinically accurate and reliable measurement. Fig.1c shows a latest automatic wrist BP monitor [23] which has large memory to store the recording, but lack in wireless transmission. It is often reported that such de-vices are in the start of their clinical validation and medical trial and therefore the adoption of these devices in a clinical settings requires some time. The patient's mobility would be limited using these devices due to the cuff inflation feature, which makes the arm immobile.

Figure 1: (a) A manual sphygmomanometer [22], (b) An automatic Boso-medicus prestige BP monitor [20] and (c) A latest HL-168B automatic wrist BP monitor [23].

Bosomedicus prestige blood pressure monitor [20] has achieved the mobility of 70% (7 out of 10), usability of 80%, and comfort of 80% and acceptability of 70%. The mobility score is given as seven, because the participants felt con-strained when carrying devices' base unit and cuff attached to the participants arm. We selected this device for its clinical accuracy, easy availability and low cost.

B. Pulse Oximeter

Critical factors that affect the pulse are; age, existing/on-going medical conditions and medications. Duration of pulse monitoring for achieving an accurate reading is a debatable topic often reported in the literature for 15 sec or 30 sec or longer [24]. It is reported that counting the pulse for 30 seconds or less is potentially problematic as an irregular pulse may not be detected during this interval. However, there are contradictory findings reported on relationship between length of pulse assessment and accuracy. It was suggested that some other factors such as irregular pulses or a person with cold, play significant role in inaccuracy of reading [25].

Pulse oximeters use red and infrared lights to measure SpO2. These devices apply light near to a finger or body part and measure the amount of light received by a sensor under the body part. The difference or the absorbed signal can be mapped to a SpO2 value. This also provides a plethysmographic signal, from which heart rate and further blood flow information can be derived. The SpO2 reading may also be misleading if the person is anemic (decrease in the number of red blood cells), because an oximeter does not measure the patient's hemoglobin level, and an anemic patient may have a normal SpO2 [26]. Therefore, using an accurate pulse oximeter often increases the chance of early detection of illness or any other related underlying health issue. It gives medical professionals the opportunity to identify and perform further clinical assessments.

Fig. 2 shows the pulse measurement devices, (Fig. 2a) shows a traditional manual way of pulse measurement which is still considered as a gold standard because of 100% accuracy and this is usually performed by health practitioners [27]. Fig. 2b is an accurate and hospital grade portable hand-held pulse oximeter [28] and Fig. 2c shows a Nonin's Onyx II finger clip oximeter, which is used for the acceptability evaluation. It is a wireless Bluetooth device which records and transmits the pulse rate and oxygen saturation continuously to any BT enabled machine [29].

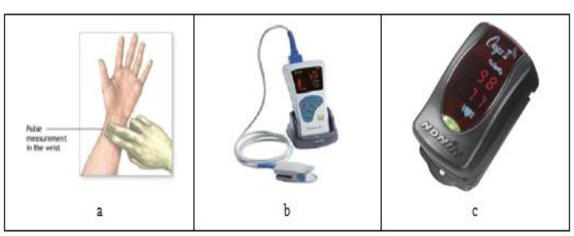

Figure: 2 (a) A manual pulse measurement [27], (b) portable hand-held pulse oximeter [28] and (c) Nonin's Onyx II finger clip Bluetooth oximeter [29].

Nonin's Onyx II finger clip pulse oximeter [29] has achieved the mobility of 90%, usability of 80%, and comfort of 90% and acceptability of 80%.

C. Body Temperature

The balance between heat generated and heat lost is represented as body's temperature with the affect factors such as; skin exposure or age. Other factors that may not affect the body's core temperature but can contribute to the inaccuracy of measurement are; consumption of hot or cold fluids or wearing warm clothes. There are several factors that need to be considered in order to have an accurate and reliable Temperature measurement. A study found significant differences in the accuracy and consistency of several commonly used devices for measuring temperature including tympanic, oral disposable, oral electric and temporal artery [30]. Fig. 3 shows the change in the temperature measurement devices over the past years. Fig. 3a shows a mercury in glass thermometer which is treated as a gold standard measurement because of its 100% accuracy [31]. Fig. 3b shows the Omron's instant ear thermometer measurement device which is an instant, reliable and compact ear temperature device and is now in use in many medical centers [32]. Omron's instant ear thermometer measurement device is used in the accept-ability evaluation in this study. Fig.3c shows the G-plus wireless remote body temperature used for continuous body temperature measurement which transfers the temperature readings remotely to its base unit [33].

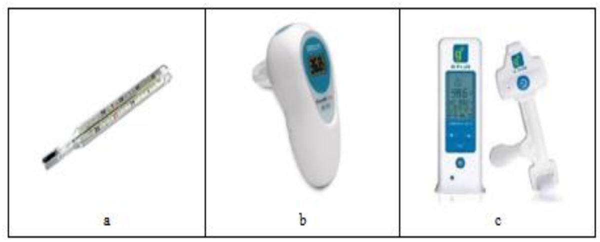

Figure:3 (a) A mercury in glass thermometer [31], (b) The Omron's instant ear thermometer measurement device [32] and (c) The G-plus wireless remote body temperature used for continuous body temperature measurement [33].

Omron's instant ear thermometer [32] has achieved the 70% score for mobility, usability, comfort and acceptability. It is reported that initially it was difficult to understand how to use the device, especially on which beep the device should be removed from the ear while pressing the top button.

nSpire's Piko-6 meter [34] has achieved the mobility of 70%, usability of 50%, and comfort of 50% and acceptability of 60%. In order to achieve high measurement accuracy user have to be in standing position, have to take deep breath in and then have to blow out fast in the mouth piece of the de-vice, which participants experienced to be difficult to achieve correct results initially. Accu Chek Compact plus blood glucose meter [35] has achieved the mobility of 80%, usability of 70%, and comfort of 60% and acceptability of 80%. Participants felt difficult not only to take the measurement but also to transfer the readings remotely, comfort rate is low because of the use of needle. Gulf Coasts Data Concept's accelerometer/magnetometer data logger X8M-3mini [36] has achieved the mobility of 80%, usability of 60%, and comfort of 80% and acceptability of 80%. In some body positions participants felt uncomfortable while mobile but suggested changing the body position for the better mobility, finally chest or upper back side was comfortable for the users. Operating the device was found to be difficult, especially switch on and off using the external magnet and its exact timings.

V. RESULTS AND DISCUSSIONS

It is observed that majority of monitoring systems lack the justification of their use in some challenging yet possible scenarios, such as; (1) monitoring in remote areas with minimal or no network , (2) monitoring system used by older adults with limited ability, (3) system's effectiveness when used by people with disabilities, (4) power consumption of battery operated systems, (5) system's testing and usability in case of an emergency and (6) data quality and reliability of the overall system. Recently, there has been a great deal of research and development going on to address the current limitations and overcome the existing challenges of monitoring systems. Smart Vest [37] and LOBIN [38] share similar approach as wearable physiological monitoring systems in using wearable textile, wireless monitoring and patient track-ing. Smart Vest uses wireless transmission from the textile to a remote station and LOBIN uses wireless transmission boards and distribution points in patient living areas (in-doors). Results show that both systems satisfy medical and usability conditions. Despite the advantages of such systems in health monitoring, there are some concerns with the smart wearable devices as they must be worn continuously and be restricted to a specified range of coverage. Therefore, there is a need for further research to improve the characteristics of wearable monitoring systems as well as their real time clinical features.

VI. CURRENT E-HEALTH SCENARIO IN INDIA

E-health is a relatively recent term for healthcare practice which is supported by electronic processes and communication. E-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. E-Health describes the application of information and communications technologies across the whole range of functions that affect the health sector, from the doctor to the hospital manager, via nurses, data processing specialists, social security administrators and of course the patients. Corporate healthcare is gearing into fast track growth using latest technology to provide best quality service to face the competition. Overburdened and collapsed public health care system (Govt. Hospitals) is also taking ICT route in various part of the country. Changing the dynamics of healthcare is the prime objective. Development gateway foundation provides web based information sharing platforms for developing countries. It holds an online community for professionals working on e-governance initiatives. Health care ICT helps in increase productivity (use of OT, equipments, Doctors, Nurses and live saving drugs), It helps for maintaining stock and store, patient satisfaction, delivery of quality care and abolish outdated procedures. It reduces red Taoism, delay, chaos encountered in big Government hospitals. Web services are essential for medical professionals, administrative members and patients to organize, share and access medical services.

CONCLUSION

In this article, we have discussed the major aspects of Remote Patient Monitoring System in terms of information gathering, processing data, and storing data from and monitoring of patients. This article also presents various monitoring devices provide patient health data in real-time. This article can be considered as a source of motivation for future research dimensions. Researchers have been developing signaling for very low power consumption. The specific absorption rate is also estimated from the safety point of view. The scope of our work is to minimize the health hazards from radiation because measuring devices consists of multiple sensors. So good communication is needed between doctors and engineers dealing practically with the Remote Patient monitoring platform. The hybrid authentication model is also needed to handle the large amount of data.

References

[1] U. Kyriacos, J. Jelsma, S. Jordan. Monitoring vital signs using early warning scoring systems: a review of the literature. J Nurs Manag 2011; 19: 311-330

[2] K. D. Johnson. Patients' Vital Signs and the Length of Time between the Monitoring of Vital Signs during Times of Emergency Department Crowding. Doctor of Philosophy, Frances Payne Bolton School of Nursing, Case Western Reserve University, Cleveland, United States, 2011.

[3] G. B. Smith. In-hospital cardiac arrest: Is it time for an in-hospital 'chain of prevention'?. Resuscitation 2010; 81: 1209-1211.

[4] J. Bergmann and A. McGregor. Body-Worn Sensor Design: What Do Patients and Clinicians Want?. Ann Biomed Eng 2011; 39: 2299-2312.

[5] V. L. Franklin, A. Greene, A. Waller, S. A. Greene, C. Pagliari. Patients' engagement with "Sweet Talk"–a text messaging support system for young people with diabetes. J Med Internet Res 2008; 10(2): e20.

[6] B. S. Fjeldsoe, A. L. Marshall, Y. D. Miller. Behavior change interventions delivered by mobile telephone short-message service. Am J Prev Med 2009; 36: 165-173.

[7] L. C. Abroms, M. Ahuja, Y. Kodl, *et al.* Text2Quit: Results From a Pilot Test of a Personalized, Interactive Mobile Health Smoking Cessation Program. J Health Commun 2012; 17: 44-53.

[8] C. Free, R. Knight, S. Robertson, *et al.* Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. The Lancet 2011; 378: 49-55.

[9] J. R. Kwapisz, G. M. Weiss, S. A. Moore. Activity recognition using cell phone accelerometers. ACM SIGKDD Explorations Newsletter 2011; 12: 74-82.

[10] R. F. Moghaddam, F. F. Moghaddam, M. Cheriet. The BlueNetwork Concept. Cornell Univerrsity Library, cite as: Arxiv preprint arXiv:1110.0436, 2011.

[11] D. Preuveneer, Y. Berbers. Mobile phones assisting with health self-care: a diabetes case study. MobileHCI '08 Proceedings of the 10th international conference on Human computer interaction with mobile devices and services Amsterdam, The Netherlands, 2008; 177-186.

[12] M. A. Bayira, M. Demirbasa, N. Eagleb. Mobility profiler: A framework for discovering mobility profiles of cell phone users. Pervasive and Mobile Computing 2010; 6: 435-454.

[13] AirStrip Technologies. (2012). Airstrip Technologies remote continuous vital sign monitoring via the iPhone. Available: http://www.airstriptech.com/

[14] E. J. Topol. Transforming medicine via digital innovation. Sci Translati Med 2010; 2(16): 16cm4.

[15] A. Farmer, O. Gibson, P. Hayton, *et al*. A real-time, mobile phone-based telemedicine system to support young adults with type 1 diabetes. Informatics in Primary Care 2005; 13: 171-178.

[16] N. Tatara, E. Årsand, G. Hartvigsen. Patient-user involvement for designing a self-help tool for Type 2 diabetes. Therapeutic Strategies A Challenge for User Involvement in Design, Reykjavik, Iceland 2010; 53-55.

[17] E. Årsand, N. Tatara, G. Østengen, G. Hartvigsen. Mobile phone-based self-management tools for type 2 diabetes: the few touch application. J Diabetes Sci Technol 2010; 4: 328, 2010.

[18] J. H. Cho, H. C. Lee, D. J. Lim, H. S. Kwon, K. H. Yoon. Mobile communication using a mobile phone with a glucometer for glucose control in Type 2 patients with diabetes: as effective as an Internet-based glucose monitoring system. J Telemed Telecare 2009; 15: 77-82.

[19] AgaMatrix. (2012). JAZZ-Blood Glucose Monitoring System. Available: http://www.wavesense.info/wavesense-jazz

[20] CorScience. Boso-Medicus Prestige + BT: blood pressure meter Available: http://www.boso.de/produkte/blutdruckmessgeraete-fuer-die-selbstmessung.html

[21] J. E. Naschitz, I. Rosner. Orthostatic hypotension: framework of the syndrome. Postgraduate Medical J 2007; 83: 568-574.

[22] Manual Sphygmomanometer. Available: http://www.p-whole sale.com/cn-pro/10/458to1/sphygmomanometer-436521.html

[23] HL-168B automatic Blood Pressure Monitor. Available: http:// www.mymonitor.co.nz/

[24] M. A. D. Minor, S. D. Minor, S. R. Minor. Patient care skills (6th ed). France: Appleton & Lange, 1995.

[25] B. Wilson, H. Cowan, J. Lord, D. Zuege, D. Zygun. The accuracy of pulse oximetry in emergency department patients with severe sepsis and septic shock: a retrospective cohort study. BMC Emergency Med 2010;10:9

[26] R. Watson, A. Stimpson, A. Topping, D. Porock. Clinical competence assessment in nursing: a systematic review of the literature. J Adv Nurs 2002; 39: 421-431.

[27] Health Central. Pulse measurement in the wrist. Available: http://www.healthcentral.com/heart-disease/h/what-does-pulse-mean.html

[28] A to Z Hospital. Hand held pulse oximeter. Available: http:// www.atozhospitalsolution.com/hand-held-pulse-oximeter.htm

[29] Nonin. Onyx II, Model 9560- fingertip pulse oximeter. Available: http://www.nonin.com/PulseOximetry/Fingertip/Onyx9560

[30] T. Frommelt, V. Hays. Accuracy of Different Devices To Measure Temperature. Medsurg Nurs 2008; 17: 171-4.

[31] Mercury Thermometer. Available: http://www.mercury-thermo meter.com/

[32] Omron. Omron MC-510 Instant Ear Thermometer. Available: http://www.omronhealthcare.com.au/Omron-Instant-Ear-Thermometer.html

[33] G-max. G-Plus Wireless Remote Thermometer. Available: http:// www.g-plus.co.nz/

[34] D. Acharya, V. Kumar. Security of MBAN based Health Records in Mobile Broadband Environment. Procedia Comput Sci 2011; 5: 539-545.

[35] Accu-Chek. Accu-Chek Compact Plus Blood Glucose meter system. Available: https://www.accu-chek.com/us/glucose-meters/ compact-plus.html

[36] Gulf Coast Data Concepts. Accelerometer/Magnetometer Data Logger X8M-3mini. Available: http://www.gcdataconcepts.com/ x8m-3mini.html

[37] P. S. Pandian, K. Mohanavelu, K. P. Safeer, *et al.* Smart Vest: Wearable multi-parameter remote physiological monitoring system. Med Eng Physics, 2008; 30: 466-477.

[38] G. López, V. Custodio, J. I. Moreno. LOBIN: E-Textile and Wireless-Sensor-Network-Based Platform for Healthcare Monitoring in Future Hospital Environments. Info Technol Biomed 2010; 14: 1446-1458.