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Real Time Telemedical Health Care Systems with Wearable Sensors

Fawwaz E. Fajingbesi[1], Rashidah F. Olanrewaju[1], Bisma Rasool Pampori[2], Sheroz Khan[1] and Mashkuri Yacoob[1]

[1]Department of Electrical and Computer Engineering, IIUM Malaysia, Malaysia; fawwazfajingbesi@yahoo.com, frashidah@iium.edu.my, sheroz@iium.edu.my, mashkuri@iium.edu.my
[2]Department of Information Technology, Central University of Kashmir, Ganderbal - 191201, Jammu and Kashmir, India; bismarasoolhr@gmail.com

Abstract

The time between detection and response to chronic diseases could go a long way in saving lives. The current trend in health monitoring systems is to move from the hospital centered device to eventually portable personal devices. Hence, Telemedical health care involves the remote delivery of medical care service to either out-of-hospital or admitted patients through wireless network and computer information technology. This paper systematically reviews the most recent works in telemedical health care system to propose a more efficient model. The focus is more on wearable sensors and devices with most attention given to cardiovascular patients in recent times. The huge literature available reflects the size of activity and attention given to telemedicine. The reviewed works are published within the last five years. Furthermore, the proposed systems are compared in terms of their connectivity, targeted application, type of sensor used, etc. Our study reveals Telemedicine to be a profound field with researchers from multidisciplinary sectors. However, there are still many gaps that need to be filled before maturity. Factors such as efficient wireless transmission, cyber data security, sensor design and integration, device miniaturization and intelligent algorithm for multi parameter data fusion require further considerations.

Keywords: Physiological Health Parameters, Telemedicine, Telehealth, Vital Signs, Wearable Sensors, Wireless Communication

1. Introduction

As the older population grows higher across the globe, so do chronic ailments and the need for more adequate and constant attention they require from medical practitioners and their loved ones. Across the globe, this constant medical attention might either be too expensive or inaccessible. For vast population with or without chronic ailment, the need for affordable and accessible medical care technique for constant monitoring is paramount via a method entirely different from the traditional hospital centered medical care[1,2].

Irrespective of the medical condition, age and size of a patient, a few vital signs and physiological parameters are common that require constant monitoring. These vital signs and physiological parameters include Blood Pressure (BP), Body Temperature (TEMP), Heart Rate (HR), Pulse Rate (PR), Electrocardiogram (ECG) and Respiratory Rate (RR)[3–5].

As collaborative advancement hits through multidisciplinary fields such as information technology, computer science, electrical and electronics engineering, biomedical engineering and medicine, healthcare systems are experiencing enormous drift from the traditional hospital centered care to patient centered healthcare delivery systems commonly referred to as telemedicine or telehealth[4,6,7].

Telemedicine is a technology-based alternative to traditional health care system. The delivery of health care services and clinical information to improve, maintain, or assist patients' health status are done remotely by means of information and telecommunications technology[3,8].

** Author for correspondence*

Simply put, telemedicine involves monitoring and collection of patient's vital data using state-of-the-art medical devices or sensors. They collect and transmit this data to a remote server or processing unit for analysis, storing and generating alerts to other devices such as mobile phones, desktop and laptop computers or generally alerting patients' healthcare givers or emergency contact personnel[3].

Telemedicine can be classified to be either mobile (e.g., Mobile phone health systems, wearable sensor systems, etc.) where the device can be moved from one location to the other with convenience or Semi-mobile where some parts of the device are mobile and wirelessly connected and the other parts are stationary or fully Stationary as seen in rural primary health care centers or some home health care systems where a dedicated room is used for acquisition of vital signs and parameters.

The fundamental parts to a telemedical system include the medical measuring devices (e.g., instruments or sensors), a processing device or subcomponent (e.g., mobile phone, computer) to process the readings obtained for transmission, a medical practitioner or intelligent server (neural fuzzy logic servers) to which the data is transmitted, a database for storing raw and analyzed data, and a device to display this data obtained from the server (Medical web portal) to the medical practitioner and/or the patient[3].

Although customized telemonitoring and diagnostic systems are underway and some available for children adults and older adults with disabilities and special healthcare needs at home, in the hospital or even outdoors[9]. In all this systems, the design of a more efficient system in terms of device integration, miniaturization, reliability and acceptability still requires adequate research.

The focus of this review paper is on the most recent trend in telemedicine, telehealth care systems as related to cardiovascular health care. Keyword search combined with other comprehensive techniques have been employed in delimiting article size. The rest of this paper is organized as follows: Related work, Discussion and Conclusion.

2. Method

This paper systematically reviews current trend in cardiovascular telemedical health care system with wearable sensors over the last half decade. One hundred and ten articles from ISI and Scopus indexed Journal were retrieved using relevant keyword search. Ten magazine articles were also considered. We excluded articles mostly over five years for comprehensive reasons and articles with low impact factor and less relevance to cardiovascular telehealth for critical reasons. Also, delimitation of the sample size was further carried out by eliminating articles that fall in the year range but have been reviewed by a more recent article in the pool. Following the initial abstract review, full-text evaluation of eighteen articles was then considered. The summary of this has been presented in the next section.

3. Results

The field of telemedicine, telehealth care system has attracted vast number of researchers both from professional bodies and academics from various areas of specialization. Over the decade, they have shared the same goal, worked mostly with the same set of basic vital signs and physiological parameters, however there is still a lot more to be covered to create the perfect system[8].

The ability to detect and alert patients about ailments would result in a decrease in sudden death and outbreaks experienced around the globe, both in developing and developed nations where medical care is either too expensive or inaccessible at patients' current location[2].

Professionals[3] have researched monitoring Heart disease and diabetes using a network of wireless medical sensors connected to a mobile device (PDA). The PDA connects the sensors to a medical server where the measured parameters such as temperature, respiration rate, blood glucose and electrocardiograph are further processed and stored. However, their architecture is not a complete wireless system therefore compromising user's mobility.

A more reliable mobile wireless sensor based on non-invasive smart cloth technology for continuous monitoring of cardiovascular health has been designed in recent times[1]. It is comprised of a fabric electrode for signal acquisition, sensor nodes for translation, Android tablet to display results and as a gateway server to the health cloud that linked patient's information to the hospital. Such architecture could support long-term monitoring of cardiovascular health as it is washable with lower power consumption. However, this system has failed to address the issues of patients' privacy and data protection, and a more efficient algorithm for system functionality.

Although professionals[6] have proposed a real-time monitoring system addressing the issues of integrating a wireless wearable sensor with mobile technology in extracting basic medical multiple parameters contrary to the single parameter as seen in the work of other reserchers[1]. This system is still deficient in having a special algorithm for early detection and constant monitoring of critical or abnormal physiological parameters that would help mitigate or manage cardiac related diseases effectively.

The design and implementation of a wireless telemedicine system where physiological vital signs are transmitted to a remote medical server have all surfaces in recent time[10]. In this design, cellular network is used in emergencies and internet connection in normal cases for long-term monitoring. This system features a mobile care unit comprising of the sensors, processor and communication module to improve patient mobility. However, Sensor size is still too large; and the system lacks sophisticated algorithm for critical condition alarms and efficient power savings.

With new generation smart-phones, the capability of running powerful applications is more popular with built-in sensors. A direct consequence is smart-phone-based health care applications rapidly being developed.

Similarly, researchers have proposed systems for Heart Rate Variability (HRV) extraction using smart-phone Photoplethysmograms (PPG).[11] A new technique has also been practiced as replacement for traditionally calculated HVR from dedicated medical Electrocardiograph (ECG)[2]. It offers low-cost, ease-of-use in and outside the hospital. The required sensor for data acquisition is a smart-phone's built-in camera[12]. Such a technology can be integrated with other sensors such as fall detection systems powered by complex algorithm[13]. This will deliver efficient, affordable and more robust health care monitoring system for much older patients with chronic cardiovascular disease as suggested in[14].

Researchers have also proposed complex algorithm in building a system that scans for symptoms prior to asthma attacks from biomedical data they obtain[15]. This ensures patients take precautions from conditions that trigger critical response of their chronic case. This could be implemented for all other chronic cases.

Other holistic systems include body sensors which are linked to tablet PC enabled for rural telehealth applications[16]. In such systems, an embedded platform acquires the biological information from the sensor and transmits it to a mobile phone/tablet PC running on Android platform which is monitored by medical staff. Sensors employed include blood pressure sensor, pulse rate sensor, temperature sensor, and accelerometer sensor for fall detection.

An article published in IEEE spectrum magazine features a research on sweat-sensing patches capable of measuring biomarkers from the body. Doctors can rely on such measurement for diagnosis of stress, disease, poor nutrition, injury, and other conditions[17]. This could be incorporated into telemedicine for miniaturization, efficiency and system integration as seen in the work of professionals[18]. This is also featured in the same magazine[19].

A commercialized product called *Hypoband* has been designed in the form of a wrist watch for hypoglycemic conditions which utilizes precipitation (cold sweat) as its physiological parameter to be sensed. This device features Bluetooth connection to an Android mobile phone application. The mobile application during emergencies would send alerts and initiate phone emergency phone calls to preregistered contacts[20]. However, this system is only dedicated to one out of many cardiovascular healths.

A real time cardiovascular telehealth system would benefit from arrays of wearable sensor paired with a mobile device for data processing and transmission. However, a complex algorithm is required for such system in other to mitigate data loss, ensure data security, efficient power consumption, and reliable data fusion techniques for more accurate reading, all of which are not fully addressed from this review.

Table 1 provides a tabular summary of our findings for telemedical health care services as related to cardiovascular health and wearable devices in recent times. Other such review out of our year of study could be found in some of the works referenced[8–10,16].

Table 1. Characteristics summary of selected study articles

Reference	Vital signs	Specific Target	Indoors or Outdoors		Connectivity	Sensor Description	Strength in Design	Weakness
			In	Out				
[16]	BP., PR., TEMP F.D.	Primary Health care Center	*		Bluetooth,	ICs (LM35)	Seamless integration with smartphones.	Large size, Not totally wireless, No algorithm for multiple parameter assessment.
[19]	Sweat, TEMP.	General Health	*	*	Bluetooth	Single chip IC	Miniaturized, Seamless connectivity via Bluetooth.	Requires complex algorithm and data library for useful interpretation of biomarkers.
[12]	HR	General Health	*	*	Nil	Smartphone camera	Availability, easy to use.	Not a complete system for real time health monitoring, Requires integration with other systems.
[6]	BP, HR, TEMP.,	Cardiac Patients	*	*	Bluetooth, GPRS/GSM	Zephyr BT, Omron BP monitor, GP Temp monitor.	Web interface, Mobile interface wearable system, Critical alert algorithm, GPS location trigger algorithm.	Power consumption, lack intelligent algorithm, Portability, Response time delay. No data protection algorithm.
[11]	HRV	General Health	*	*	Nil	Smartphone Camera	Availability, easy to use.	Not a complete system for real time health monitoring, Requires integration with other systems
[1]	ECG	General Health	*	*	Bluetooth, Internet.	Fiber Electrodes,	Intelligent Transmission algorithm, Power efficiency, washable vest, Seamless connectivity to medical server and tablet device.	Requires complex algorithm for other physiological parameter extraction, external power source, No ECG recognition algorithm, No data protection algorithm.
[10]	ECG, BP, TEMP., SpO2	General Health	*	*	Bluetooth, GSM/GPRS, Internet		Intelligent data analysis algorithm, Intelligent Transmission algorithm, Power efficiency, Seamless connection with PDA to remote Medical server, Emergency contact functionality, Web and mobile interface.	Large size, No Data fusion algorithm for pattern recognition, No data protection algorithm.

[4]	BP, HR, SpO2, BG, TEMP,	General Health in Older Adults	*		Bluetooth, Infrared, 3G	Omron Thermometer, Accu-Check BG meter, Nonin Onyx II, Boso-medicus BP monitor	Real time monitoring of bio data, intelligent fuzzy logic for pattern recognition, warning algorithm for critical conditions.	Large size, No geo location service algorithm, No data protection algorithm.
[14]	HR	Elderly, Heart Diseases	*	*	Bluetooth	Zephyr HxM	Mobile and Smartphone integration, Medical cloud connectivity, Energy estimation algorithm, stress algorithm for critical alert.	Algorithm requires user's manual input, not fully autonomous and Simulation technique was used for system test.
[5]	TEMP BP, HR, R	General Health			ZigBee	Simulation	Algorithm for efficient transmission of medical data wirelessly Using ZigBee technology.	No real life implementation with real sensors and patients.
[2]	TEMP HR, ECG	General Health	*	*	IEEE 802.1 wireless protocol, GSM	ICs (LM35, LM358, AD624)	IC sensors, mobile computing entity and display, and remote monitoring entity.	Remote display of ECG signal are absent, no intelligent algorithm for critical condition warnings.
[3]	TEMP HR BP R	Hearth diseases and diabetes	*	*	ZigBee, Bluetooth, WIFI, 3G		Data security algorithm, User interface integrated with PDA, access to clinic server, trend analysis algorithm, early warning algorithm.	Require user to physically answer question.
[17]	Sweat, TEMP	General Health	*	*	Bluetooth	Ion detection sensor array.	Portable, stress detection algorithm, efficient power consumption.	Integration into full Telemedical device is required.
[20]	Sweat	Diabetic, Hypoglycemic patient	*	*	Bluetooth	*Trade secrete	Wrist Wearable device, Seamless connectivity to Android smart phone, Emergency routing, SOS button.	No autonomous SOS algorithm only during excess precipitation (cold sweat) and manual button press, No additional functionality.

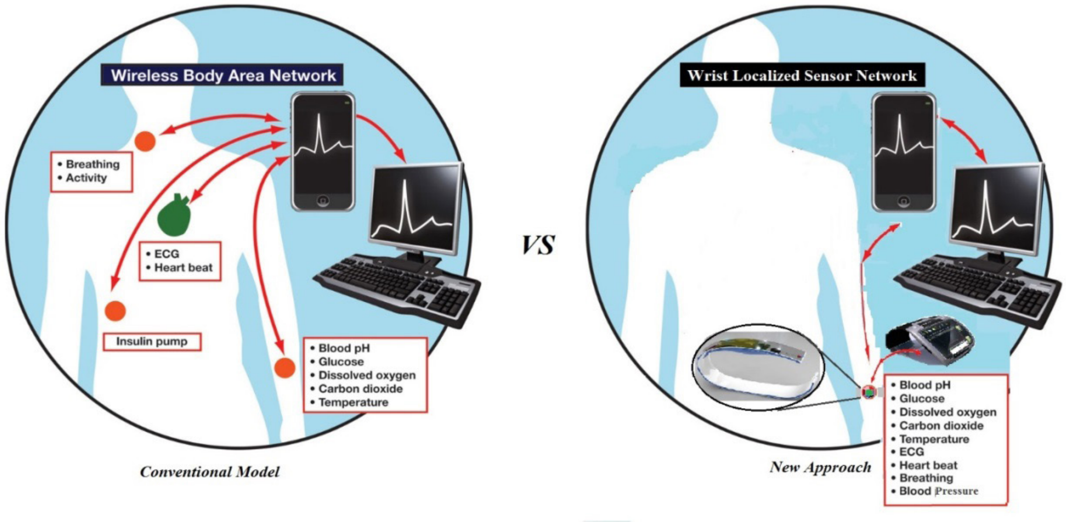

Figure 1. Conventional vs. proposed model.

4. Discussion

This study indicates that despite the efforts of researchers in the field of telemedicine as related to cardiovascular and general health, only but a few of the great potential in telemedical healthcare systems has been achieved. Open issues from our review show critical and perspective effort is still required in the aspects of telehealth for cardiovascular and general health care system.

Such areas include miniaturization of multiple bodily distributed sensor arrays with a much localized system for efficient power consumption as distant inter-sensor connectivity would drop to minimal. A more intelligent adaptive algorithm for simultaneous analysis of physiological parameters in real time would account for a larger decrease in sensor size and integration thereby minimizing exposure to detrimental effects of constant exposure to transmitting wireless power. Also, adequate response time to identifying and alerting appropriate destination prior to user critical break down. Implementation of Geo-location feature, self-sustaining green power source are also some features implementable through this new wrist localized sensor network model shown in Figure 1.

5. Conclusion

In this paper, a systemic review to propose an optimized model for real time cardiovascular and general health care system with wearable sensor was conducted. This review reveals that although Telemedicine has the potential to change the medical care as we know it, from hospital centric to patient centric where medical health care service could be available to every patient in any part of the world. Earlier warning or continuous monitoring for managing chronic diseases would be accessible. However, this area of study still lacks more than what it offers and would benefit more with ground breaking research outcomes like implementation of the proposed model. Telemedicine becoming a profound field that involves researchers from multidisciplinary sectors would allow the possibility of such proposed model with such an efficient wireless technology transmission, data security, Sensor design and integration, device miniaturization and intelligent algorithm for multiple parameter data fusion for a complete health care system on the go.

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