Applications of Wearable Sensors: Continuous Monitoring and Healthcare Management

Eng. Thair Akram Haddad, Eng. Ahmad A. Alslaihat

Royal Medical Services, Amman – Jordan

DOI: 10.29322/IJSRP.9.12.2019.p96116
http://dx.doi.org/10.29322/IJSRP.9.12.2019.p96116

Abstract- wearable sensors devices combined with smart phones applications play a significant role in better healthcare management for chronic conditions. As well as, communication technology and data collection and analysis provide a broad medical application for remote health care management.

Index Terms- Wearable Sensors, Vital Signs Monitoring, Flexible Sensors Array, Wearable Artificial Pancreas, Wearable Cardioverter-Defibrillator.

I. Introduction

The great development and improvement in modern technology offer a significant promise for digital healthcare system including cost reduction and patient care improvement. Implantable and wearable sensors as a major part of new medical technology which are contributing to switch healthcare facilities into mobile and wireless health era. Mainly, implantable and wearable sensors aim to provide and record real time data which enable healthcare providers to monitor, record, tracking, evaluate and prevent diseases. Implantable and wearable sensors have the ability to sense and detect various vital parameters and could be combined with transmitter to send collected data over remote healthcare centers. Enabling healthcare providers to direct their patients to specific actions or automatically perform medical action based on sensors reading.

In addition to that, implantable and wearable sensors have diagnostic properties based on physiological, biochemical sensing or motion sensing [1]. Leading to improve both diagnosis and treatment options for wide range of diseases related to neurological, pulmonary or cardiovascular disorders such as seizures, hypertension, dysrthymias, and asthma. On the other hand, implantable and wearable technology is useful for rehabilitation treatment and diagnosis specially for elder patients in independence community.

Furthermore, early detection of disorders and clinical complications is a growing interest in medical field. Implantable and wearable sensors have the ability to detect any clinical changes in patient's status. For example, COPD patients can be managed successfully by wearable sensors to perform early detection of exacerbation episodes which is commonly defined by increased dyspnea, cough, and change in amount and character of sputum. Therefore, the significant aim is to prevent worsening of patient's medical status and reduce the need for emergency and hospital admission. In parallel, remote monitoring technology may be applied with wearable sensors to send collected data from patients to central stations of healthcare provider to perform continues monitoring and assessment for clinical conditions [2].

II. Methodology

Implantable and wearable sensors are mainly composed of three subsystems including; hardware sensor to collect physiological and movement sings, communication system based on software and hardware components to transfer collected data to remote clinical center, data analysis work station to extract clinical information from collected physiological data. In advance, recent development in sensing technology based on microelectronics, biochips, flexible microelement and telecommunication play a significant role to improve the design and manufacturing of implantable and wearable sensors.

III. Applications in Healthcare Management

The technology of implantable and wearable sensors covers a wide range of medical applications. Despite that the applications depend on clinical situations and conditions of patients. Clinically, implantable and wearable sensors aim to perform significant role in digital healthcare including; tracking, recording and monitoring the vital signs. Also, special care and management of diseases and disabilities could be achieved. As well as, different body parts may be monitored or evaluated during physical activity [3].

- **Vital Signs Monitoring**

Practically, vital signs monitoring, recording and tracking represent the major field of application of implantable and wearable sensors in healthcare. Essentially, heart rate, ECG, blood pressure, respiration rate, body and skin temperature are the most common signs that detected and measured. Commonly, heart rate can be measured and detected by special sensors placed on different parts of patient's body. Typically, Heart rate can be detected from patient's chest [4], modern technology of wearable sensors based on optical transducer, accelerometers and pressure sensors improve detectability of heart rate from ear, finger, wrist and rest [5]. Enabling monitoring and recording of heart rate during walking, running, sleeping and any other physical situation. In parallel to that, wearable and implantable sensors offer an advanced recording of heart rate with time-based plotting and history with global position system to improve analysis of collected data [6]. Furthermore, blood oxygen saturation which

represent the efficiency of breathing and blood circulation in the vessels. Detection principles of blood oxygen saturation commonly known as pulse oximetry, which is based on two light-emitting diodes (LEDs) at two wavelength 660nm and 940nm [7], that can be placed at different parts of patient's body such as ear or finger. On the other hand, body and skin temperature can be detected by wearable sensors from different part of patient's body such as mouth, rectum, eardrum, under the arm, and through the skin. However, preferred location to measure body temperature is near hypothalamus which controls body heat. Significantly, increase body temperature reflects disorders in the immunological system. Typically, body temperature measured by wearable sensors such as patches or earpieces [8, 9]. Furthermore, early detection and continuous monitoring of blood pressure is significant criteria to prevent and manage cardiac diseases. Therefore, wearable sensors aim to perform this role via wrist- and arm-based blood pressure monitors.

Recently, the advanced technology of wearable sensors combined with advanced design of semiconductors and flexible electronics materials which improve compact design for sensors with transmitter technology based on Bluetooth or wireless signal to transfer collected data to mobile application software or to remote clinical station. Flexible sensors array improves the ability of wearable sensors to collect data for various types of vital signs from one part of patient's body as shown in figure 1. The schematic diagram represents flattened bio sensors array with their integrated circuits that amplify and filter the detected signals, in addition to that transmitter integrated circuit was added to the flexible sensors array [10].

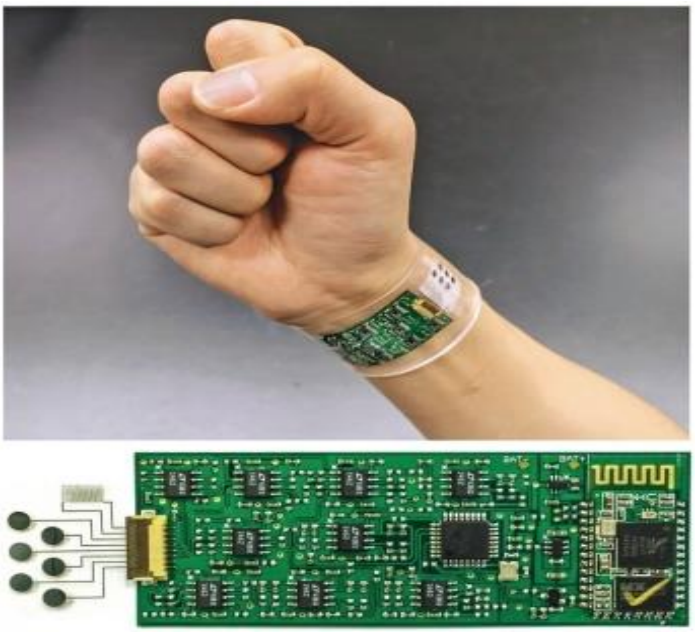

Figure 1: Flexible Sensors Array

Figure 2 shows a wearable sensor device using flexible sensors array that collect vital signs including ECG, Heart rate, NIBP and oxygen saturation from patient, then collected data transfer to mobile application which can monitor, record and analyze the collected data. In addition to that, the application has the ability to share the collected data to remote clinical station.

Figure 2: Wearable Device for Continuous Monitoring of Vital Signs Using Flexible Sensors Array

- **Management of Diabetes Mellitus**

Diabetes Mellitus is a chronic disease caused by pancreas disorders characterized by insufficient production of insulin leading to uncontrol level of blood glucose. Therefore, control and continues monitoring of glucose in blood is a significant role in clinical management of Diabetes Mellitus [11]. Recently, wearable artificial pancreas is commercially available to perform the function of monitoring and controlling. Mainly, the system is composed of three main parts including, measuring sensor which continuously detect the level of glucose in patient's blood, transmitter integrated circuit to send collected data from patient to mobile application which records real time data and analyzes the clinical situation of patients to determine and calculate insulin delivery based on computational algorithm, insulin injection pump that deliver calculated amount of insulin through patient's blood. Figure 3 represents wearable artificial pancreas.

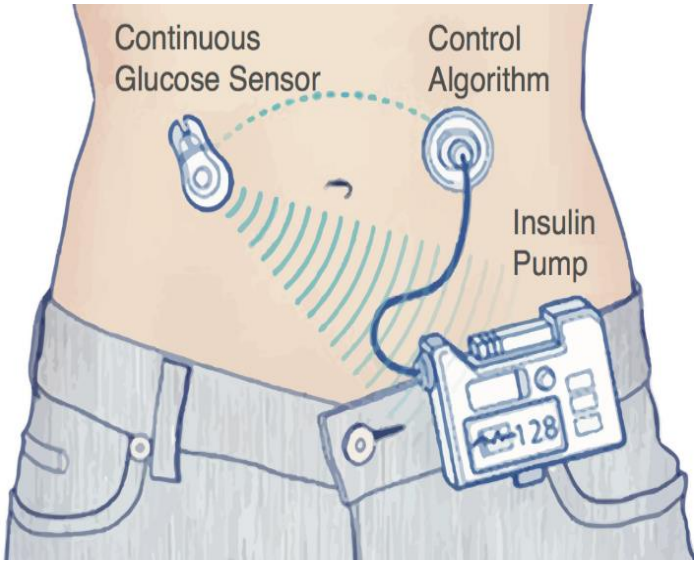

Figure 3: Wearable Artificial Pancreas

- **Management of Cardiovascular Diseases**

Cardiovascular diseases according to World Health Organization (WHO) consider as a major cause of death around the world, about 17 million people died every year because of cardiac disorders. Recently, the advanced technology of wearable devices improves monitoring and recording of ECG and blood pressure. Leading to improve patient's health and clinical diagnosis. Wearable smart patches based on flexible semiconductors materials and sensors play a significant role to detect and analyze ECG, blood pressure, heart rate and blood oxygen. Figure 4 represents a smart patch that detect and record heart vital sins in real time then the collected data send to smart phone via Bluetooth.

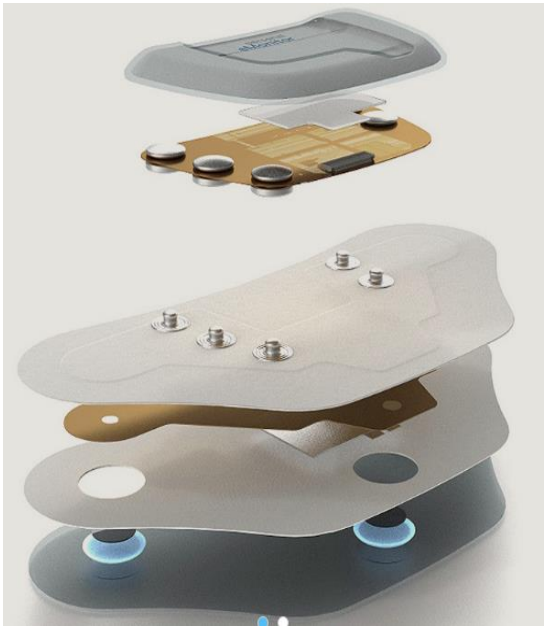

Figure 4: Smart Wearable Patch

In addition to that, it is widely believed that wearable cardioverter-defibrillator (WCD) improved the results of outpatients and increase survival ratio between patients suffering of cardiovascular diseases. Basically, WCD composed of device battery combined with defibrillator capacitor and signal processing unit that analyze and transmit the collected data from dry ECG electrodes, monitor unit works as loop recorder for continuous monitoring and recording of cardiac signs with real time. WCD looks like vest as shown in figure 5 which is worn under clothes [12].

Figure 5: Wearable Cardioverter-Defibrillator

IV. Conclusion

Recent advancement of semiconductors, flexible electronics sensors, communication and smart phones application play a significant role to provide compact design of biosensors and wearable devices that improve continuous monitoring and recording of vital signs during routine physical activity. However, application of wearable sensors improves continuous monitoring which facilitate better option for clinical evaluation and clinical management of diseases. As well as, early detection of disorders could be recognized based on real time data collected by wearable sensors.

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Authors

First Author – Eng. Thair Akram Haddad, Royal Medical Services, Amman – Jordan

Second Author – Eng. Ahmad A. Alslaihat, Royal Medical Services, Amman – Jordan