Research Article

IT Medical Team
https://www.itmedicalteam.pl/

Health Science Journal
ISSN 1791-809X

2023
Vol. 17 No. 6: 1029

Wearable and Implantable Medical Expedients: Potential and Challenges for Modern Health Care

Mastagenis K*, Prazerekos P

Department of Health and communication, Greece

***Corresponding author:**
Mastagenis K

Charles_L@gmail.com

Department of Health and communication, Greece

Citation: Mastagenis K, Prazerekos P (2023) Wearable and Implantable Medical Expedients: Potential and Challenges for Modern Health Care. Health Sci J. Vol. 17 No. 6: 1029.

Abstract

The concept of wearable medical technology was first introduced by Edward O Thorp, a mathematics professor at the Massachusetts Institute of Technology in the United States, about 6 decades ago. The first implantable medical device developed was a pacemaker for arrhythmia patients in 1958. Since then, various types of pacemakers and implantable cerebellar stimulators have been developed and used. Wearable technology has received considerable attention from worldwide researchers. With the advancement of communication technology including internet, hardware fabrication, and big data analytics, wearable technology has made rapid strides of progress in health care and health monitoring. This technology resulted in manifestation of smart watches, armbands, and glasses.

Keywords: Wearable medical devices; Implantable medical devices; Wearable health monitoring; Implantable health monitoring; Wearable medical technology

Received: 02-June-2023, Manuscript No. Iphsj-23-13827; **Editor assigned:** 05-June-2023, Pre-QC No. Iphsj-23-13827 (PQ); **Reviewed:** 19-June-2023, QC No. Iphsj-23-13827; **Revised:** 24-June-2023, Manuscript No. Iphsj-23-13827(R); **Published:** 30-June-2023, DOI: 10.36648/1791-809X.17.6.1029

Background

Portable medical electronic devices that can be worn on the body to perceive, record, analyze, regulate, and intervene for maintaining health and can even be used to treat diseases via integration with other technologies. The capabilities of identification, sensing, connection, cloud services, and storage enable expansion of health monitoring beyond individual to community and public health level. By integrating mechanical attributes with microelectronics and nanotechnology, wearable devices can be advanced to achieve real time detection of patient biological signals, pathological symptoms, biochemical and biophysical indicators and can provide guidance, drug administration reminders that are pivotal in self-diagnosis and self-health monitoring [1].

Various features of wearable devices include wireless mobility, interactivity, artificial intelligence, sustainability, durability, simple operation, miniaturization and portability. Wearable technologies will play a significant role in advancing precision medicine by enabling measurement of clinically relevant parameters and monitoring of the real time health status of individuals. Modern wearable technologies include sensor technology, medical chip technology, wireless communication technology, power management technology, display technology, and information feedback technology. Real-time medical data from these devices can be transmitted via internet for clinical decision making or providing feedback to the patient by a health care provider or physician [2].

With extension of the life expectancy and expansion of the elderly population, the medical industry focused on the development of biosensors that enable real-time health monitoring for prevention and personalized health care addressing a variety of chronic and acute diseases. This point-of-care technology provides rapid patient-centred diagnostics, especially under the conditions of limited access to health care services. As healthcare regimes shift more toward personalized medicine, globally wearable sensors will have an average compound annual growth rate of approximately 38% from 2017 to 2025.

The biophysical signals such as heart rate, blood pressure, skin temperature, respiratory rate and body motion can be sensed to extract clinically relevant information. These non-invasive biosensors allow continuous monitoring of individuals, and thus provide sufficient information for determining general health status, and even basic medical diagnosis. Wearable biosensors also allow health care providers to monitor the physiological traits of patients after administration of therapeutics or other treatments.

Modern wearable biosensors are fabricated as watches, clothing, bandages, glasses, contact lenses and rings, that are conveniently worn, and provide a function that distinguishes them from other devices in terms of portability, ease of use and environmental adaptability. Wearable devices have gradually been developed in the form of accessories, integrated clothing, body attachments and body insertions. Over the past few decades, the rapid advancement in electronic, biocompatible materials and nano material has led to the development of implantable devices that enable diagnosis and prognosis through small sensors and biomedical devices, thus greatly improving the quality and efficacy of health care.

Despite motion artefacts, one of the major problems associated with wearable sensors is the development of stretchable and skin-attachable devices that can continuously monitor biological activity and vital signs without any disruption by the user's movement. In recent years, flexible and stretchable electronic devices have allowed implantable systems to be deployed in the deep brain, the intravascular area, the intra-cardiac area and even within the single-cell.

Currently wearable devices have their own receiver, signal processor, powered by the battery, enabling them to be operated as a "microcomputer" with connection to all processes, and functioning from information collection and processing, to communication and power supply. These devices connect to other smart devices via Bluetooth, infrared, radio-frequency identification and near-field communication technology. This connectivity has led to the development of wearable systems for remote and long-term monitoring in homes and communities as well. Wearable devices are expected to make a significant contribution in reducing medical and healthcare costs in countries with a large population of elderly people and with high prevalence of chronic diseases.

Miniature wearable devices have been receiving a great deal of interest due to their health care applications with minimized risk of cross-infection, which has the potential to replace conventional hospital-based lengthy medical procedures. In particular, the integration of material science into health care devices allows the rapid development of point-of-care sensing and implantable devices with special functionalities. Materials selection, device structure and integration, and biomarker detection strategies play key role in development of such devices [3].

Patient-friendly diagnostic and treatment approaches are in great demand with minimally invasive insertion and mounting, *in vivo* electrical and optical modulations, and post-operation health monitoring. Specific challenges related to each biological fluid for wearable biosensor-based applications need to be addressed. Advances in implantable devices, including recent materials development and wireless communication strategies, role needs to be evaluated.

Wearable and implantable electronics are becoming attractive for general public health monitoring, and they have had positive influences on all aspects of lives with immediate results and shorter hospital stays. The sensor technology has evolved to a very advanced level with the rapid progress of advanced materials and nanotechnology, most of them still need external power supply, like batteries, which could cause problems such as difficulty in tracing, recycling, and miniaturize, as well as possible environmental pollution and health hazards. Based upon piezoelectric, pyro-electric, and tribo-electric effect, various kinds of nano-generators were proposed which are capable of responding to a variety of mechanical movements, such as breeze, body drive, muscle stretch, sound, ultrasound, noise, mechanical vibration, and blood flow, and they had been widely used as self-powered sensors and micro or nano-energy and blue energy harvesters [4].

Wearable health monitoring systems

Wearable health monitoring systems are considered as the next generation of personal portable devices for telemedicine practice. They can monitor different kinds of biological signals released by human beings through saliva, urine, breathing and epidemic skin perspiration. Advances in materials science, chemical analysis techniques, equipment design and manufacturing methods have laid the foundation for a sophisticated wearable technology. Wearable technology not only aids in pursuing a healthier lifestyle but also provide a constant stream of health care data for disease diagnosis and treatment by actively recording physiological parameters and tracking metabolic status. Therefore, wearable medical devices have the potential to become a mainstay of the future mobile medical market [5].

Conclusion

Wearable technology in recreational and sporting activities is well documented however data on broad clinical usefulness are still being gathered. Wearable medical devices developed so far have been designed for use on all parts of the human body, including the head, limbs, and torso. These devices aid in health and safety monitoring, chronic disease management, disease diagnosis and treatment, and rehabilitation. However, the wearable medical device industry currently faces several important limitations that prevent further use of wearable technology in medical practice, such as difficulties in achieving user-friendly solutions, security and privacy concerns, adherence to International industry standards and guidelines, and various technical bottlenecks.

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