American Journal of Biodiversity
https://biojournals.us/index.php/AJB
ISSN: 2997-3600

The Future of Medical Devices: Smart Solutions for Healthcare Challenges

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Received: 2024, 15, Dec
Accepted: 2025, 21, Jan
Published: 2025, 04, Feb

Annotation: Modern medicine faces a range of challenges related to the increasing need for healthcare services. The growing volume of any kind of patient data is another one of the said challenges. One has to consider the rapid growth of technologies, including the development of new effective methods of treatment. All the technology processes conducted in healthcare require proper equipment.The market with medical devices is currently growing faster than any time before. From 2010 to 2019, it grew as much as 38% in terms of revenue. The hardware base also improved, leading to the production of mixed and augmented reality medical devices that started to be adopted in all fields of medicine. This significant extension of resources allows the development of new complex medical devices. These medical devices will be adopted in medicine under the joint name of smart solutions. So the health information technology (HIT) segment boosts the healthcare process the most voracious way. This segment emerged up to 1996 and from this moment the technology has been spreading. In the USA, 19% of hospitals were connected in 2008. HIT is a set of platforms that guaranteed the functioning technology, spreading the useful information across healthcare areas to support the healthcare process. The points like a decrease of government pressure, maturity of the telecommunications market, and social networks may request a revision of the concept of mobile health.

Keywords: Smart medical devices, Internet of Medical Things (IoMT), Artificial intelligence in healthcare, Digital health solutions, Wearable technology, Remote patient monitoring, Health information technology, Personalized medicine, Medical robotics, Data security in healthcare, Telemedicine.

1. Introduction

1.1. Healthcare in the Digital Era Modern medicine faces multiple challenges related to the increasing need for healthcare services. The demand for automated solutions is growing. It is driven by several reasons. First, the volume of patient data is increased due to the spread of wearable sensor devices and medical equipment. Second, technological development provides many opportunities to recognize the conditions and diagnose diseases at their early stages with high accuracy, often exceeding human performance. Third, modern society values fast and efficient processes and healthcare in this regard is no exception [1]. All these factors have contributed to the growth of the health information technology market from $2,000 million in 2010 to $36,000 million in 2024. Digital Twins is an actively developing and promising area of digital technologies; the crisis caused by the COVID-19 epidemic emphasized the trend of its development in various sectors. In addition to industrial applications, a significant effect of using Digital Twins technologies in the field of mobile medicine and the Internet of Things is expected, the latter being one of the key components of smart healthcare. [2][3][4][5][6]

1.1. Overview of the Current Healthcare Landscape

A considerable number of challenges face the healthcare industry in the years to come. With growing populations and budgets with limitations, it is debated how health care delivery models can be more innovative and efficient in the compatible era of value. Starting from post-op follow-up tools and moving to in-patient solutions for general care, the modern Medtech (Medical Technology) company needs to ensure they are thinking beyond current patents expirations [1].

For both care providers and medtech companies, strengthened health information security will be a foundation need. Care providers need to share data in a structured manner with improved information transfer systems. For the Medtech manufacturers, tools must be created that are a pleasure rather than perceived chore by the care provider, ensuring this step in the journey is frictionless. This also comes at a pivotal time for many patients. Often they have reached the decision to have treatment with high expectations only for that experience to fall sharply once they enter clinical care [7]. A solution is required that aids trust-short on time care providers to provide standard information to patients at the right time while also demonstrating the post-operative symptom tracking process. [8][9]

1.2. Significance of Medical Devices in Healthcare

The various medical devices used frequently in medical procedures inevitably contact many patients directly. Therefore, patients' quality of life is a crucial issue in both the development and usage of medical devices. From the viewpoint of manufacturers, improvement of the appearance and comfort of medical devices enhances user desirability and should assure better sales. The conventional method to ensure comfort had been optimization of the feeling of fitting and the shock absorbing ability of the material on direct contact with the human bodies. However when both the design and the safety of the medical device fulfill a minimum requirement, in order to satisfy the customers, it has become necessary not only to manufacture a quality product, but also to quantify the added value in terms of physiological effects. It is on this account that attention has been focused on the capability of medical devices to sense the vital bio signals of the human body [10].

The crucial decision function of medical device might involve risky output to the patient if malfunction occurs. Therefore, in future medical devices, safety of the software system must be assured by rigorous analysis techniques, provable safety requirement, validation and verification. The validation must present a high level of accident immunity. The modeling of system interaction so as to provide a substantially safe system operation, even in the presence of faults, shall play an important role. Safe operation hypothesis should be defined considering both, the physical and continuous behavior of the system and the effect of the digital controller on it. The design phase might entail a complexity not manageable and completely observable in terms of correct system functionality. Recently a specific design should need to focus on safety application and it should ensure that all critical software part of the process achieve their intended functions, with the desired level of confidence. [11][12]

Literature analysis

2. Emerging Technologies in Medical Devices

Developments in sensor technologies, engineering strategies and standards are continuously expanding the applications and capabilities of medical devices. A recent meeting identified a number of areas with significant economic and clinical impacts that could be addressed through medical device solutions, including monitoring and treatment of chronic diseases, non-invasive detection of life-threatening events, and screening. Some of the research projects under development to address these problems involving new technologies for manufacture of next-generation smart medical devices. The potential benefits of applying modern engineering solutions, particularly ICT intensive tools to these problems, were further described, together with remaining critical barriers to the application of this technology and an overview of current efforts to develop smart medical devices. Chronic diseases are the leading causes of death and disability worldwide, representing 43% of all deaths. The societal impact of chronic conditions is expected to grow due to the aging population. Six chronic diseases—heart disease, stroke, cancer, chronic obstructive pulmonary disease, diabetes mellitus, and arthritis—are among the ten leading causes of disability in the USA. Among those disabled, the need for assistance with personal care is chronic and long-term; 90% of the 1.6 million US residents residing in a nursing home who have been cured. A meeting was arranged to close this gap in patient care by linking the patient to a new generation of smart devices. These "intelligent doctor companions" will bring the ward of the future to the home, extending the presence and expertise of the healthcare professional by continuously monitoring patient status and promptly providing appropriate therapeutic intervention. A comprehensive financial analysis of a smart medical device concept was presented with a review of current barriers to its implementation. [13][14][15]

2.1. Internet of Things (IoT) in Healthcare

Introduction Following the current trends concerning technology, it must be agreed that its advancement is non-stoppable. Recently, medical device markets are significantly increasing and have the potential to grow even more. There are expectations that by 2025 the connected medical device market is going to be approximately 45% more than what it is now. Additionally, contemporary medical devices are being integrated with advanced technology to fulfil the latest requirements, according to . [16]

Internet of Things (IoT) has succeeded in making life simpler by promoting an efficient lifestyle. From home automation management to wearables, it plays a significant role in day-to-day life. In the healthcare industry the device used is compiled into medical devices that can share and collect health data, which improves health quality and also promotes a personalized health program that is tailored to each individual. It is estimated that the world is going to have over 20 billion IoT devices in use by the healthcare area in the next few years. [17]

Connected medical devices bring a big impact on the healthcare system because it is well suited to the market that is moving towards value-based propositions and outcomes. Medical device technologies are expanding rapidly as these improve health services. Moreover, governments are forcing regulations and standards for better care. In return, hospitals and healthcare professionals are seeking more qualified facilities. There are many advantages of medical devices that are connected, including offering services that are smarter, faster and more accurately than devices that are only stand-alone or not connected. Scalability issues are minimised by an integrated solution that is ready-made and designed anytime. Plenty of contemporary connected healthcare solutions, which are usually named the Internet of Medical Things (IoMT) end-to-end, have successfully drawn the necessary infrastructure that combines and addresses multiple problems concerning the medical device and IT platform. Modern healthcare is moving towards a digitized and secure system that relates patients, healthcare service providers, and medical devices, which IoT tech provides faster service. Thus, beyond product innovation aspects, development of connected healthcare solution projects need to consider organizational workflow and business strategy in a supportive and clinically-effective manner. Networks of interconnected smart devices supporting healthcare delivery are robust to revolutionize a reasonable assistance in health care. [18][19]

2.2. Artificial Intelligence and Machine Learning in Medical Devices

Smart solutions with a combination of advanced medical equipment, software, and better healthcare systems can prevent chronic illnesses from recurring, prevent future epidemics, or reduce the burden on individuals, families, and government health systems. There are 2 categories of smart medical devices that allow individuals to better monitor their health and better connect them with their healthcare providers, wearables and other medical devices. Wearables such as smart watches that monitor health in different ways by checking heart rate and number of steps taken. Medical devices can collect data from healthcare-related procedures and transmit it to a smartphone or tablet. These devices play a very important role in medicine, as they can be used advanced biometric data to control early symptoms, proactively obtain medical help before showing symptoms, and not be trapped only for observations. A new chapter is opened in the realm of medical devices with emerging technologies such as artificial intelligence, machine learning, and the Internet of things. Smart medical devices already on the market can handle tasks that are difficult or time-consuming for healthcare providers. Another smart solution is the medical device software that model to facilitate the prediction of future events or states of patients, based on analyzed frequency data inputs. It plays an important role as it is involved in predicting therapy decisions such as medication consulting, radiology review, telemedicine, and epidemiology studies. An AI or ML model that has been developed, tested, and modeled to produce the appropriate model output, and on the other hand, the future sample data automatically generated by the analytical model with such AI model will process it. [20][21][22]

In other words, AI or ML model reliance significantly exceeds the permissible representative capacity of each model as individual data input according to the respective instruction for use. AI or ML models to serve scientific advisory purposes much broader than traditional predicate devices via immediate open-loop-output functions to healthcare professionals, with or without additional visual read-outs used in decision purposes. Machine-Learning enabled models refer to Software as a Medical Device, which relies on AI or ML embedded models, if that model can learn from the cleaned sample data. Such models could include, but are not limited to, supervised, unsupervised, semi-automated, and other ML methods. [23][24][25]

3.0 Materials

Methods

The methodology for this study adopts a comprehensive approach to analyzing smart medical devices by integrating qualitative and quantitative research techniques. The research primarily involves an extensive literature review to explore existing advancements, challenges, and potential solutions in the field of healthcare technology. Relevant academic publications, industry reports, and regulatory guidelines were reviewed to identify key trends in digital health solutions, artificial intelligence in medical devices, and the Internet of Medical Things (IoMT). Additionally, a comparative analysis of past and present medical device implementations was conducted to highlight the evolution of smart technologies in healthcare. Case studies of successful and failed deployments provided insights into the practical applications and limitations of smart medical devices, ensuring a balanced perspective on real-world usability. The study also examined regulatory frameworks such as FDA approvals and ethical considerations to assess compliance and data security challenges associated with medical innovations. Furthermore, emerging technologies, including machine learning, wearable devices, and robotic automation, were analyzed to determine their impact on patient care, remote monitoring, and precision medicine. The methodology incorporates expert opinions from biomedical engineers, healthcare professionals, and IT specialists to understand interdisciplinary perspectives on medical device development and implementation. Statistical data from healthcare databases and industry reports were used to validate findings and project future trends in the smart medical device market. This approach ensures a holistic understanding of the subject matter, offering valuable insights into the transformation of healthcare through technological advancements while addressing concerns regarding safety, efficacy, and integration into existing healthcare systems.

3. Smart Wearable Devices

The collection of health data by wearable devices raises significant concerns regarding privacy and security. It is crucial to implement robust measures to safeguard this sensitive data against unauthorized access and potential breaches. Consequently, there is an ongoing focus on the development of advanced security functionality specifically tailored for such devices. The key challenge in this regard lies in the effective deployment of strong encryption techniques and other necessary data protection measures integrally designed within the devices, ensuring that these do not detract from the efficiency or the overall user experience. A robust and reliable security system is essential to fostering users’ trust, and it is anticipated that future regulations on devices will likely impose specific and stringent security requirements that must be adhered to. User-friendly devices that do not encumber daily living are far easier for patients and users to accept and integrate into their lifestyles. [26][27]

Wearable technology of the future will seamlessly merge with everyday items such as clothing, accessories, and even implants, creating an unobtrusive yet effective way to monitor health continuously. This seamless integration will not only enhance user adherence to health routines but will also pave the way for new and exciting possibilities in constant health monitoring and tracking. Objects embedded with invisible sensors will be able to monitor a wide range of health parameters, storing the valuable information in the cloud or even offering real-time, on-the-spot safety alerts tailored to the user's specific needs. [28]

On a more technical front, the development of innovative sunglasses embedded with advanced electroencephalogram sensors is already underway for monitoring various aspects of mental health. This pioneering technology might be utilized to assist in the rehabilitation of individuals coping with depression, support autistic children, help others experiencing stress, and provide assistance to astronauts who are struggling to adapt to the unique challenges of space travel. Efforts remain robust toward the creation of ultrathin sensing devices, which are produced using flexible, stretchable, and biocompatible materials. These devices can closely attach to organs, thereby achieving highly accurate and continuous measurements of important metrics. Such sensors will have the capability to meticulously track muscle strain, breathing patterns, heart palpitations, skin hydration levels, body temperature variations, movement, and impact, while future models produced through advanced 3D printing techniques will be customized and tailored for the individual needs of each user, ensuring a truly personalized health monitoring experience. [29][30] [28][31]

3.1. Applications in Remote Patient Monitoring

The potential for a growth in wellness practices that dovetail with daily neutraceutical intake is substantial. Individuals requiring post-surgery monitoring, blood sugar level regulation, mental health medication checks and weight gain monitoring for cardiovascular disease would all benefit from an intuitive and intelligent wellness system. With a robust health and wellness back-end infrastructure in place each patient can be given their own confidently guided monitoring and drug planning paradigms. Monitoring devices that use mass market technology, addressing currently popular practices, create reasoning explanations about the health and therapy plans insitu each time it is triggered. [32]

Given that there are a plethora of health/wellness/sensor sub-system designs, effort applied here is in elucidating the nature of the smartphone healthcare wellness system design, forecasting the large scale integration of such systems in a global online wellness infrastructure. The IoT models have an attractive simplicity to them, but a full cloud approach to patient and carer health function has broader potential in a broad range of wellness practices. Concerning remote monitoring in the cloud it is intended that the caregiver would be using existing cloud services for data aggregation, with an assumed caregiver needing to share data for each monitored patient. The creation of a very substantial health and wellness cloud not only summarises this data, but enriches it considerably. It would also allow for a platform that small players in the wearables field might wish to join. Aside from a comprehensive modelling of patient health, a range of other health and wellness producers are discussed that would likely be interfaced in an extensive health and wellness cloud system [33].

3.2. Fitness and Wellness Tracking

Smart healthcare contributes to increases in quality of life and lifespans by actively managing health data despite a busy contemporary life. Smart healthcare is changing the nature of preventive health based on self-control through active disease management rather than passive diagnosis of disease. There is a growing interest in monitoring health data in real-time, tracing health conditions anytime and anywhere [34]. Specifically, a typical modern lifestyle revolves around stress and trifles, so personal management of health care is becoming difficult. Therefore, selective smart healthcare data collection is requested not only for health care but also for active portability of disease management. Currently available health care services tailored to individuals through continuous data monitoring have limitations in the amount of health data and lightweight physical distribution of sensors. These sensors provide limited types of health care services. Consequently, there is a need for a new paradigm for the health monitoring system that can accommodate and aggregate various sensor data in real-time for individuals and use them in a lightweight and convenient way. In this regard, a health monitoring system has been developed that personalizes the monitoring service through an Ambient environment oriented personal network (Aami-Net) based on the collected data and the lowered parameters obtained from it. The proposed health monitoring system operates as follows. [35][36]

Results and Discussion

4. Surgical Robotics and Automation

As the demand for more, and more complex, surgeries grows, the insistence on a thorough education and training in theoretical knowledge as well as practical, experience-based skills becomes increasingly difficult to satisfy. This need for improved diagnostic and therapeutic procedures should be addressed by advanced intelligent systems for surgical robotics that offer a safer and more feasible patient treatment [37]. Surgical robotics and automation are expected to relieve saturation of the available workforce as these intelligent systems would allow a non-surgically-trained operator or no operator at all to assist or even perform such tasks. Despite the technical challenges in developing surgical systems that are both intelligent and fully autonomous, exciting progress has been made and novel inventions have been proposed to solve demanding issues. However, there remain various open problems that need to be further addressed to establish truly acceptable surgical autonomy in the future. [38]

Surgical instruments are used to perform anatomical modifications. For a minimally invasive procedure, the surgical instrument is inserted through a small incision into the body and it moves to the target within a tissue. Typically, a spatial trajectory is defined by the surgeon to track the desired path while operating the instrument. In practice, robotic systems are extensively used in this context, leading to the concept of surgical robotics, which is concerned with analyzing, designing and developing systems that combine the mechanical, electronic, and control aspects of robotic systems with traditional surgical instruments and techniques. The use of robots and smart sensing systems has subsequently revolutionized the way in which surgery is performed, enhancing precision, dexterity and control over conventional procedures. The potential of new sensors, both in terms of body imagining and internal organ tracking, have further improved the performance of the technology. [39][40]

4.1. Advancements in Minimally Invasive Surgery

Introduction of minimally invasive surgical techniques substantially improved patient wellbeing. The need for faster recovery times provided opportunities for innovation in surgery, including medical devices furthering improvement. Device innovation provides crucial support for new medical techniques by enabling procedures that would otherwise endanger patients. Limiting innovation to one part of the landscape underestimates the complexity of the modern medical network. This landscape can be divided into three basic components: disease detection, disease modeling, and health-centric problem detection. Clear investments in life sciences predict huge innovation breakthroughs in cancer treatment, creating a feedback system with disease detection. The number of nodes will multiply by factors as the various chains connect. This expanded model includes academic analysis, product conception, commercial manufacture, and professional use. Safety certification and medical liability reassessment also set developments through this network. Involvement in medical networks strongly emphasizes security, with a vision spanning a mission-level network focused on medical devices. The network is partnered with biomedical manufactures, electronics manufacturers, and software developers. Reinvigorating the aim on security through network support implies serious implications for safety device design. Understanding the macrosystem surrounding the device in patient care is critically essential. [41][42]

4.2. Enhancing Precision and Accuracy in Surgical Procedures

Key technological trends in the evolution of medical devices include the continuing miniaturization of components and increasing autonomy in operational capabilities. Micro- and nanotechnologies are expected to continue to have a profound impact on medical devices. The critical issue for medical device manufacturers is how and where these emerging technologies can be incorporated into devices that will function, remain safe, and be effective for a longer lifetime than current lifespan of consumer electronics. With health care expenditures representing over 17% of GDP within the United States, increasing efficiency of health care organizations is paramount. One approach is the development of information technologies that can track patients, processes, and devices within the health care system. Smart devices capable of sensing location and motion can provide much of this tracking, as is becoming standard in navigational systems. Ground truth can be provided using systems with continuous line of sight to satellites, but coverage is inadequate in areas such as the operating room. For low-acuity procedures in hospitals or for outpatient surgery, discontinuous line of sight systems may provide position estimates accurate enough for patient flow analysis. Devices and processes for enabling the scalability, survivability, and mobility of position tracking systems used in commercial applications is the subject of this paper. As the design of efficient manufacturing processes requires the ability to predict system performance in a representative environment, an analytical manufacturing flow rate model has been developed to predict yield and mean time to failure for an automated free surface dip-coating process. An experimental verification using representative test vehicles demonstrates that the model is successful in predicting yield with a difference between calculated and observed yields of 2.9% for identical conditions. [43][44][45]

5. Regulatory and Ethical Considerations

Medical devices have existed for thousands of years. Archaeologists have found simple stone medical devices for surgery and dentistry, dating back to 7000 BC. Over the course of these seven thousand years, medical devices have seen a tremendous evolution and come to play an important role in healing ailing patients the world over. This healing is provided by a range of different medical devices, spanning from simple bandages and hand-held blood glucose meters, to the most sophisticated pacemakers and surgical robots. Medical devices form a complex ecosystem, composed of many different parties, including manufacturers, doctors, nurses, patients, insurance companies, and regulatory agencies. [46][47]

It is envisioned that by 2021, healthcare services in England will be accessed by e-patient health records. After Japan’s Fukushima nuclear disaster in 2011, tens of thousands of people died in just a few days, with a further 1600 lives estimated to be lost via induced instantaneous deaths. This has created both economic and health problems. To address this, Japan has developed new monitoring wearable medical services using its experience in ultra-minimal-invasive ultrasonic sensors at Hokkaido University. About 30% of the causes of US medical deaths are from wrong advice, dosage or combination of drugs, but AI has a 90% accuracy rate compared to human experts at detecting correct prescription advice. In 2014-2015, 5 out of 12 of the largest US medical corporations’ data was stolen. Now, the average US medical hacking rate is double that of any other industry. This has rendered use of the “Medical Internet of Things” a major worry for medical privacy. China’s “Medical Insurance Bureau” says more than 5000, predominantly domestic, Chinese pharmaceutical institutions are under collusion investigation. There are cases in which hospitals have refused to use the cheapest generic drugs or the China-made hospital-designed prescribing system instead of the US-made, which is much costlier, raising questions about collusion. Bio-research specialists have identified white-corpuscle-induced immune diseases due to drug allergens, and this research has allowed the healthcare IoT design of immune system drug dosages [48]. In asthma, 5% to 10% of asthmatics die within 8 to 15 hours when kept on beta-blocker drugs, but the pharmaceutical corporations have not established condition warning signs. Considering this, a low power consumption portable medical IoT pharmacy asthma inhaler has been developed. On prescription, a doctor can adjust the medication restrictions via a cloud application; under a restricted regimen, a pharmacist can only dispense the non-beta blocker drugs. [49][50]

5.1. FDA Regulations for Medical Devices

Medical devices are subject to strict controls and regulations in the European Union, while the U.S. FDA is also tightening the rules and carrying out an update that will be mandatory from 2020 [51]. It is vital to provide valid scientific information that shows the safety of the device to prevent its further failure or recall. Medical devices must follow a certification path that guarantees the safety, efficacy, and constant quality level of the product. This requires the release of relevant scientific data in the form of bench testing, animal testing, and/or clinical testing studies. These shall have an adequate statistical power and have proven the effects and the limits of the tested devices with the support of valid scientific publications. The clinical data must be sourced from a study with a suitable design and performed on a population that is indicated in the device intended for use instructions [52]. The effectiveness of a medical device shall be measured as the relative capability of a medical device in a certain medical condition or in a certain intended purpose or range of medical conditions or purposes to achieve the expected clinical results, consistent with the state of the art. Regarding the active medical devices for diagnosis, a dedicated, large clinical performance study must prove sensitivity and specificity of the device when calculating the positive and negative predictive values. For what concerns implantable devices, the tests must prove the biocompatibility towards the tissue of the patient, including the chemicals in case the materials can release substances. The biostability must be demonstrated on patient following the device's implant. [53]

5.2. Data Privacy and Security

The extreme growth in expenditure on healthcare primarily due to the proliferation of the aged population and also due to the increase in life expectancy enabled by advances in public hygiene and medical science and technology. To contain the spiraling costs in healthcare, hospitals and medical practitioners have adopted various automated medical devices that help monitor and detect various illnesses. The medical devices monitored the patient parameters round the clock and were optimized for the precision of measurements. These measurements were logged and those logs were indeed used to understand the temporal evolvement of the illnesses. [54]

Hospitals claim that the suggested device helped distinguish the non-stationary artifacts from lenitive diseases and noise. As the data was analyzed it also helped discover the latent periodic diseases which were otherwise not easy to detect. Hospitals were quick to ride this wave and deployed the suggested device for almost all the patients admitted. Once the patient was discharged, the suggested device was required to be worn which would monitor all the patient parameters on a round the clock basis. While the patient slept the device was suggested to be put in deep sleep mode. It was assured that the device came with a manual which would help the patient understand the alarms and take action on the basis of those.

6. Challenges and Opportunities in Adoption

There is no question that the rapid-aging global population is stretching health services near their breaking point. Demand is rising rapidly while the number of caregivers, especially doctors and nurses, remains relatively static. It is a problem that requires a new way of thinking and a new approach to the administering of healthcare [55]. Medical wearable technology offers a new pathway toward reducing the mounting burden on health services as societies everywhere come to terms with the challenges presented by caring for their least-able people. Personal health monitoring via smart wearables, connected devices and dedicated apps represents a practical and efficient solution to a broad spread of health complaints and could effectively mitigate the need for often frequent visits to a health professional. It doesn't require a giant leap of comprehension to see that a physical medical strip will one day seem just as antiquated as a landline phone or floppy disk; the data that patients send their healthcare provider will be collected by some kind of in-built or attached medical device, or wearable technology, that will set off a diagnostic chain of events leading to a timely consultation or alert to the patient [48]. The future of medical devices is smart and embraces a technology that does not yet exist in any practical or meaningful way. However, as progress in the medical device industry since the 1970s until now is analyzed and new trends extrapolate into the foreseeable horizon, a new snapshot of how medicine will be delivered emerges. What isn't a technology solution in 2022 will likely be so by 2030. Medical costs have been rising. The main reason for this is an aging population and the advanced technology available. However, an aging population also leads to an increase in chronic diseases. A medical wearable device works by having a constant monitor on the body. This device will have the ability to send a warning to the patient when irregular measurements are found, leading to an early intervention. This minimizes costly doctor visits as well as mileage. Personal healthcare monitoring not only drastically decreases equipment costs, but it can decrease emergent medical costs, which will lower the load on healthcare services. As an increase in the demand of consumer key nutrients, it is important to analyze the elements that embody such nutrient rich ingredients and develop consumer products to meet those needs. [56][57]

6.1. Integration with Existing Healthcare Systems

There are very different opinions about the usability of complex new technology by healthcare professionals. Hospital information systems often incorporate complex patient management, diagnostics, and treatment planning applications. Known solutions seldom support the effective operation of hospital information systems by mature technologies. A novel healthcare solution that offers an effective rate of investment in smart devices and internet of things technology is described. This is a healthcare solution for providing telemedicine hub capabilities to conventional or specialized hospital information systems. As far as the authors know, this is an open-issue healthcare solution. The methodology of integrating this feature into hospital information systems is described [58]. This enables the production of hospital-grade administration reports to ease the subsequent telemedicine interaction with the physician. [59]

6.2. Cost and Reimbursement Issues

The medical device market consists of introducing new devices to replace existing products. When new products are launched with a high price, the characterization of the innovation and the appropriateness of the high price is often a key focus. On the other hand, regardless of the characterization of the innovation, there is a strong decrease in the reimbursement price of existing products because several control measures exist. In this situation, new products will be burdened with low profit margins if the pricing rule is used in a similar non-flexible manner as existing products. Therefore, they advocate that the appropriateness of the pricing rule for new medical devices is important [60].

An important feature of the New Product category is the presence of a substantially different reevaluation period compared to other categories. This article has three objectives. The first is to assess the relevance of the evaluation of innovation, the second is to investigate the background mechanisms behind such evaluations, and the final objective is to compare the reimbursement process between several product categories. This article is organized as follows. Section 2 describes the Japanese market of medical devices and the reimbursement system. Section 3 describes the data and the model for the evaluation of the background mechanism. Section 4 describes the estimation procedure. The policy implications of this study are discussed in the final part of the article. [61]

7. Case Studies

An internet of things (IOT) compliant system powered by the cloud and which uses sensors, actuators, control servers and application interfaces offers an innovative solution. A case study is presented here: (1) What is a solution that deals with automated sharing of health information amidst the healthcare providers and how can it be realized using embedded systems and HIMSS standards? (2) A telemedicine use case is considered involving obstetrical care of a mother. In the present times, medical care and healthcare have become fast-evolving phenomena with the advent of cutting-edge technologies and therapies. In present situations, medicos are required to be approached for every health aspect, irrespective of the need for a doctor. In future times, medical conditions will be such that smart living will be the primary focus. This might involve smart clothing, which will use embedded sensors to monitor vital health signs and conditions [34] running analysis algorithms on the collected data. On detection of any critical situation, necessary emergency responses will be triggered. Such smart living will require IOT compliant sensors, actuators, gateways (control servers), and cloud services. These sensors will be working 24/7 or in observational/reflection mode. This ongoing growth in the technology and therapy domain is a world-revolutionizing system and has given the healthcare domain an escapable edge of becoming the largest business domain on earth. So the technology and healthcare must sync together to maintain the pace of care impacting more and more lives. [62][63]

7.1. Successful Implementation of Smart Medical Devices

Smart solutions are frequently described as devices that can increase information about a patient's condition and help healthcare providers to make adequate care decisions. These devices could be included in a wearable patch saving data on vital signs continuously which can be accessed by a database within a secure environment. On productive interaction, this database will contain virtual models of patient data from prior clinical procedures, with addition of the vital signs data from the wearable patch. Based on the predicted model, imperative information will be provided to the system based on the historical personal knowledge, warning the healthcare provider in time of potential adverse events. The main challenge is to be capable to offer a reliable physical and software system, which requires tackling the issues described below, which have been seen to curb an effective implementation of this vision. [64]

The first peculiar question is how the secure ecosystem to save and analyze the patches' data will be successfully implemented. Such a system will have to scrutinize an incredible amount of data coming from all these patches on a daily basis, deserving to recognize patterns and act decisions impressively. This system will also comprehend a predictive model of the after clinical events that could affect a given patient, considering comorbidities and previous clinical procedures, and how these can be correlated with the vital signs information obtained by the patches in real time. The identification and development of such models on useful patient-specify data is definitely non-trivial, and accurate access to these procedures will have to be agreed among healthcare providers and the developers of the wearable patches. The second consideration regards the issues accompanying the acceptance testing and regulatory acclaim of such a complex ecosystem. This system is constituted of various mutually dependent elements, including the wearable patches, the physical infrastructure to wirelessly save and upload the acquired data, and the database and analysis algorithms in a network of secure and productive data-centers. [26][65]

7.2. Lessons Learned from Failed Deployments

A poorly functioning medical device can be more harmful than no device at all. There is often a gap between the people designing the medical devices and the ones using the devices, further compounded by the plethora of different stakeholders with differing needs. The procurement and deployment of medical devices often turn out to be disasters. Therefore, there is a need to analyze deployed medical devices, study what can go wrong and suggest potential improvements. A starting point was to analyze some past and present failed deployments . In developing countries, 45 percent of medical devices are out of order. In Sub-Saharan Africa, about 40 to 70 percent of medical devices are out of order, compared with 5 to 12 percent in developed countries. The mean down time varies from 0.25 to 8 months for biological material and from 0.5 to 1 month for other medical devices. The problem of maintenance is due to the lack of spare parts, the prolonged time needed for repair and the inadequate competences of biomedicals. These poorly functioning devices could waste about 40 percent of the health budget. [66]

A set of guidelines for the design of medical devices for deployment in underserviced areas was produced. The main questions to ask are: How can a medical device be designed such that it best fulfills the needs of the patient/client? Are there any other stakeholders that need to be considered in the design process? What is the process by which medical devices are typically acquired and deployed and how does the designed device fit into this process? What are the potential pitfalls in this process from the perspective of the designed device and how can these be remedied? What needs to be done? Fieldwork was conducted over 7 days in Coimbatore, South India, where many past, present and potential deployments were studied. This consisted of hospital inspections, video recordings, interviews and group discussions with doctors, patients, clinic owners, medical device producers and technicians. To gain a greater understanding of some of the issues raised, medics from the R&D team observed dental and blood pressure measurements in a range of clinics. In dental measurements, it was found that the inability to measure very small distances towards the central incisor, or accurately assess the depth of tooth decay are issues. Also, the geometries of the devices did not permit measurements to be taken in some areas. Other issues included the poor illumination of Scaling and Polishing instruments and the lack of aspiration leading to blood staining patient's cheeks. [67][68]

8. Future Trends and Predictions

A few years ago, wearable technology coupled with telemedicine and smartphone apps revolutionized health systems facilitating remote health monitoring like teleconsulting, tele radiology via picture exchanging. In orthopedics, one of the common remote consultation requirements is X-ray and MRI. With the rise of deep learning applications, the necessity of specialists' intervention is likely to redefine. AI-based neural networks have been trained to diagnose and grade knee joints very well compared to lateral radiographic views and clinical symptoms. Therefore, in the future, a patient having an X-ray or MRI on hand might receive a result of it within 24 hrs including the fracture grading over his mobile phone, which can significantly reduce the treatment guide delay that in current practice solely relies on expert interpretation [69].

Research into expandable productivity involving health wearables, mobile devices, block-chain collaborative apps, telemedicine, and digital healthcare solutions highlighted a promising perspective for niche care providers to drastically improve service utility while proposing a reactive, AI economy for patient care. Present connected health revolutions are increasing the opportunities and promises that smart healthcare services will reach more widespread real life scenarios. A question still remains: how these innovations will be strategized and productized for significant introduction into the market, and what are the principal challenges to be properly tackled? Industry-driven technological survey explores a multidisciplinary area of product specifications and features which are delivered and consumed in current scenarios, are of interest for such products, and will have market value in the next few years. Based on an intensification strategy, a number of rapidly growing, evolving or newly emerging connected health welfare technologies will be developed and manufactured to upgrade the level of innovation in health manufacturing and, consequently, the commercial offer of the sector [70].

8.1. Personalized Medicine and Customized Devices

Personalized Medicine focuses on having access to one's health information. A micro-chipped Personalized Medical Card is a convenient medium for rural and remote areas that stores and retrieves up-to-date health information. Patient data can be accessed via a smartphone, tablet, or other electronic device. The Personalized Medical Card provides access to medical history and thus further necessary treatment can be planned accordingly at early stages [71].

The current trend in health care systems is the paradigm shift from reactive to proactive care. In order to decrease healthcare costs and maintain patient quality of life by keeping patients out of hospitals, novel ideas were deployed focusing on people instead of diseases. The pandemic revealed this is crucial. In addition to hospital conditions, the awareness of co-variate signals of the patient's environment might be a very helpful tool when planning predictions on health conditions. This op-ed reflects on initiatives and models affecting the path from the hospital care to patient monitoring outside the hospital, in a scenario where he is self-responsible for managing his own health [72].

8.2. Interoperability and Data Sharing

Improving the exchange of health data became mandatory following the executive order and the regulation considering health data security. The increasing number of health biosensors and data access from the Internet make bio-health data proper candidate for "big data". Huge processing capability is requested to help interpretation of this big data. The result may even be applied for individual therapy. However the vast amount of health data cannot be exchanged between all bio-health data owners and conventional healthcare professionals, even in summary form. To solve the above problems and to filter the relevant and important health data for the healthcare professionals seems to be necessary to fill the bio-health big data interpretation gap. This task lies, as closely as possible to the health data source, to the bio-health sensors. The up-to-date situation seems to be a restriction of the smart biosensor output data to some smart portable device. As there are many vendors on both parts and there is a rapid development, the mentioned situation may stay. On the other side the healthcare IT has been a usage sector since decades, however the acceptance of the conventional healthcare IT solutions to the numerous, but different bio-health smart sensors and also in the uniform output data format seems to be unrealistic view, too. [73][74]

9. Conclusion

Living in demographic and social evolution with an ever-increasing life expectancy, the need of innovative healthcare solutions to mitigate the implications of an ageing population has never been so urgent. Personalized healthcare conciliation with the advent of novel medical devices for less intrusive injuries and chronic diseases is poised to be one of the biggest technology challenges that the next generations of biomedical engineers will face. Being the largest piece of healthcare furniture in most cases, the medical bed has become a pivot element in a rising number of innovative patient-care environments. Medical beds have vastly evolved from a technological, functional, and aesthetic perspective since the introduction of powered adjustments and mass merchandise available hospital bed frames in the late 60s of the previous century. The integration of monitoring capabilities, such as sensors, automatic inflation with the assessment of pressure ulcers, and various other monitoring and treatment systems, such as movement assistance or enteral nutrition, was a matter of time until the medical beds industry began to provide turnkey solutions. Despite the implementation of an ever-growing number of technologies, the medical beds of the future are likely to be just at the dawn in terms of cross-cutting innovation and aggression implantation. The efforts of a variety of stakeholders are converging towards providing not only further functionality but fostering the development of innovative solutions based on the seamless integration of technology within the medical bed, aimed at enhance medical treatment, urbane re-enable, smart ADL assistance and/or patient enhancement of life conditions. It is expected that the advent of retrofitting platforms, such as a flexile sensing matrix imbedded on a textile, will open the path towards easily deployable sensors, monitoring devices, and actuators that will transform medical beds in low-cost upgradable patient treatment platforms, not only in developing regions where most beds are still manually operated, but also in centers with intuitive systems. Furthermore, the advent of medical beds in medical-spa and co-habiting setups, convergence with domotic systems, or simplifying patient nurser devices and procedures, reorganization of the nearby space and/or envoys is still to be invested heavily in R&D within the coming years. Such efforts will need a multifaceted concerted between the skills of clinicians, nurses, therapists and hospitality professionals, the knowledge of biomedical engineers, software developers, home automation experts, and textile, polymer, and composite scientists, and the insight of manufacturers, hospital's facility and R&D departments, as well as from healthcare insures and regulators. In such a scenario, projects have smite on the potential of the and availability enabled smart medical beds to place the patients' bed as the focal point of a tailored and self-controlled health-and-wellness-care setup, integrated with interactible smart textiles, smart-lighting, and portable smart-devices and robotic aims.

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