

Disruptive Technologies for Next-Generation Healthcare Practices and Sustainable Development

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Abstract

The future of healthcare will be heavily influenced by the growing use of digital health technologies. However, there are a number of barriers which limit the adoption of these technologies at present; such as, lack of available infrastructure for technology integration into current systems. An interdisciplinary review of the literature has been undertaken using an analytical model that includes emerging digital health technologies: AI, internet of things (IoT), blockchain, big data, telemedicine, robotics and other digital health technologies. The findings indicate that AI could provide diagnostic and predictive capabilities, that IoT and wearable devices can allow for real-time monitoring and that blockchain could facilitate trusted exchange of information. These challenges include ensuring that different health care systems and services can interoperate, protecting against cyber threats to electronic data. To address some of these challenges, a comprehensive and integrated framework was developed that integrates various aspects including technology, infrastructure and interoperability, healthcare practices, and sustainable healthcare outcomes. The overall purpose of this framework is to support accessible, affordable, effective, safe, patient-centered, and sustainable healthcare, especially in low-resource settings.

Keywords: Disruptive technologies; Artificial intelligence; Internet of Things; Blockchain; Big data analytics; Sustainable healthcare

Introduction

Digital technology has a major impact on the global healthcare industry. Many healthcare organizations have implemented artificial intelligence, the Internet of things, blockchain, big data analysis, telemedicine, wearable device tracking, robotics and many other forms of digital technology to improve the quality of their diagnosis, treatment and patient care and management. With these new technologies healthcare providers are moving away from older methods of care towards integrated, smart, data based and patient centric care delivery models. Healthcare technology has evolved over time in several ways. In the early days of healthcare, most processes were done by hand with minimal use of technology. Electronic Health Records and Telemedicine began to be used when the first stage of digital healthcare developed. When the second stage, "Smart" Healthcare was developed it included AI, IoT and Wearable Devices that could monitor patients' conditions and help make decisions about treatment. Stage three, "Healthcare 4.0", emphasized data based and predictive treatments for better outcomes. Stage four, "Healthcare 5.0", places a focus on meeting the needs of humans, creating sustainable practices within the healthcare system and creating an environment where patients receive high-quality, patient-centered care[1].

Next generation health care systems are not easy to adopt by healthcare organizations. They also face other barriers such as poor infrastructure in their healthcare environment, technological complexity of the technology itself, data security risks for patient information and health records that need to be protected, regulatory requirements for each type of disruptive technology (AI) and its application in healthcare practice, limited technical skills of staff members responsible for maintaining and updating these technologies, policy-related challenges with accessibility and affordability of health services provided to all citizens. The primary research gaps as indicated by the literature reviewed were (i) the limited amount of research focusing on disruptive technologies, health care practice, and sustainability; (ii) an emphasis on studying each individual technology versus analyzing the entire health care system; (iii) limited empirical evidence regarding the long term sustainability of the technology; (iv) the need for a framework(s)

that clearly measures the sustainability benefits associated with each technology; and (v) the lack of focus on addressing the challenges of implementation in developing nations [2]. Therefore, this study will investigate disruptive technologies in next generation health care; analyze major applications of Artificial Intelligence (AI), Internet of Things (IoT), Blockchain Technology, Big Data Analytics; assess how these technologies contribute to sustainable health care development; identify potential opportunities and implementation challenges; and provide insight into the future direction of Smart Health Care Systems and Human Centered Health Care Systems.

Related Work

Recent research indicates that digital technologies in healthcare have made improvements in diagnostic and predictive abilities, personalized treatment options, remote patient monitoring, data management, and automated services. AI is being used to identify diseases (diagnosis), predict disease progression (prediction), develop personalized treatments (personalized treatment), and support clinical decisions (clinical decision making). Blockchain technology has received attention as a method for improving data security in healthcare, increasing the transparency of healthcare data, and creating trusted exchanges of information among stakeholders. Internet of Medical Things (IoMT) applications such as wearables and other connected medical devices enable patients to be monitored remotely and their health tracked in real time. The use of big data analytics will assist with predicting disease, developing plans for healthcare, allocating resources more effectively, and supporting better-informed decision making. The use of robotics in surgery, rehabilitation, and automating aspects of healthcare delivery is becoming more common. As digital healthcare expands, issues related to cyber-security, patient privacy, interoperability of systems, governance of these new systems, and regulatory compliance have emerged as critical areas of concern [2-7]. More recent research has started looking at how AI, IoT, blockchain, and human-centered innovations will come together to create future models of healthcare systems [3-5]. Much of the current body of literature describes the potential of each separate technology. As a result there continues to be a need for a comprehensive view that integrates the technological capabilities of digital healthcare with its required infrastructure; governance; healthcare practices; and sustainable outcomes.

Key Contribution

This study's major contribution is that it views the disruptive technologies as interrelated elements of health systems ecosystems rather than simply as separate tools. This study integrates AI, IOT/IOHT, Blockchain, Big Data Analytics, Telemedicine, Wearable Devices, and Robotics, while relating them to the necessary factors to be able to implement them practically. The study presents an integrative view of disruptive technologies to support future generations of healthcare.

- A five layer structure (technology, Infrastructure & Interoperability, Governance & Trust, Healthcare Practice, Sustainable Health Outcomes) is suggested.
- Each layer will relate the technological innovations to Accessibility, Affordability, Quality, Efficiency, Equity, Patient-Centred Care, Long-Term Sustainability.
- Major barriers to successful implementation include Cybersecurity, Privacy, Interoperability, Governance, Regulatory Compliance, Scalability, Affordability and Skills.
- The Discussion places significant emphasis on developing nations due to potential barriers such as the lack of infrastructure, skills and affordability and/or the ability of governments/policymakers to develop policies to facilitate the adoption of new technologies.

Methodology Adopted

This study used a multi-disciplinary literature-based research strategy to assess the role that Disruptive Technologies will play in Next Generation Sustainable Healthcare Systems. The research methodology included Literature Synthesis, Technology Analysis, and Framework Development. The Research Study began by identifying and reviewing research

Articles, research journals, Books, Book Chapters, and Government Publications on Digital Health, Disruptive Technologies, and Healthcare Initiatives. A thematic analysis was conducted using the reviewed literature to identify technological applications, technological benefits, barriers to adoption/implementation, issues of governance, and sustainability-related aspects. These themes were then placed within an Integrated Framework which connects the capabilities of Disruptive Technologies to the Infrastructure and Interoperability of health systems; Governance and Trust in health systems; the Practice of Healthcare; and Sustainable Outcomes in healthcare. As Future Work, it is planned to conduct Empirical Validation via Surveys, Questionnaires, and Interviews of the Practical Use and Perceived Benefits & Challenges of Disruptive Technologies. In order for the current study to report a Literature-Based Synthesis and Proposal for an Integrated Framework rather than providing Completed Primary Data Results.

Proposed Integrated Framework for Sustainable Healthcare

The main idea of this study is that Disruptive Technologies need to be viewed as integrated subsystems of a larger whole rather than separate individual DTs. For example, Artificial Intelligence (AI) could analyze an individual's health data, assist in making decisions about their medical treatment; Internet of Things (IoT)/Internet of Medical Things (IoMT), collect, and send a person's medical information continuously; Wearable Devices, allow for continuous remote monitoring; Blockchain, secure trustworthy communication and storage of medical information; Big Data Analytics, help convert massive amounts of data into actionable knowledge; Telemedicine, expand access to healthcare services; Robotics, enhance surgical techniques, rehabilitation processes, and automation.

In addition to being seen as integrated subsystems, the proposed model has several layers. The first layer, the Technology Layer, includes the Disruptive Technologies themselves (i.e., AI, IoT/IoMT, Blockchain, BDA, Telemedicine, Wearables, Robotics) and all other digital tools that support these DTs. The second layer, Infrastructure and Interoperability Layer, encompasses the ability to connect technology platforms, enable data exchange, provide computing power, integrate systems, and increase scale. The third layer is Governance and Trust Layer which defines the cybersecurity measures needed to protect confidentiality and integrity of information and ensure privacy for individuals while also providing regulatory oversight and accountability measures. Finally, the fourth layer is Healthcare Practice Layer which integrates technology with diagnostic practices, predictive modeling for disease prevention and early detection, treatment planning assistance using artificial intelligence algorithms, remote patient monitoring capabilities, methods for managing patient information flow from diagnosis through discharge or death; decision-support for both clinicians and administrators. The fifth layer is Outcome Layer which assesses whether access to care has been improved by virtue of greater availability and long term sustainability.

Applications of Disruptive Technologies in Next-Generation Healthcare

- *Artificial Intelligence:* AI can support disease diagnosis, prediction, personalized treatment, analysis of health information, and clinical decision-making. Its value depends on data quality, appropriate governance, explainability, security, and responsible implementation.
- *Internet of Things and IoMT:* IoT and IoMT enable connected healthcare devices and systems to collect and transmit health information. These technologies can support continuous monitoring and remote health tracking, extending healthcare beyond traditional clinical settings.
- *Blockchain:* Blockchain can contribute to secure, transparent, and trusted healthcare information exchange. Successful implementation requires interoperability, governance, scalability, and appropriate regulatory arrangements.
- *Big Data Analytics:* Big data analytics can support disease prediction, health planning, resource utilization, and healthcare decision-making by converting large volumes of healthcare information into actionable insights.
- *Telemedicine and Wearable Devices:* Telemedicine can make healthcare services available outside traditional hospitals and clinics. Wearable and connected devices can support continuous monitoring and remote tracking. Together, they can contribute to more accessible and patient-centred healthcare when adequate connectivity and affordability are available.

- *Robotics*: Robotics can support surgery, rehabilitation, and healthcare automation. Its contribution is closely connected with efficiency, precision, and the appropriate integration of technology with healthcare professionals and patient needs.

Discussion

The literature review demonstrates that there is a need to consider Disruptive Technologies (DT) as part of a whole health care system; DT's are not just tools. AI will assist in the processing and assessment of health data for decision making purposes. IoT and wearables enable continuous collection of data from patients. The incorporation of blockchain technology enables secure data sharing and trusted exchanges of data. Big Data Analytics will convert vast amounts of health related data into meaningful insight. Telemedicine and remote monitoring expand health care delivery outside of traditional clinic environments. However, integrating DTs create many challenges. Poor Internet connectivity within a health care setting hinders effective communication among stakeholders. Different systems cannot communicate with one another regarding exchanging patient data. Trained professionals may not be available to provide assistance. Many individuals who require services created by these new technologies are unable to access them due to cost [1][2][6] . In addition to the above, increasing dependence on digital health data has created concerns over cyber security, privacy issues, ethical uses, accountability and regulatory compliance [7][10] . Challenges such as those mentioned are often amplified in less developed countries where differences in infrastructure and access to technology can vary significantly throughout the country.

Therefore, the authors propose that assessing the performance of DTs does not simply rest on their ability to perform technologically. Assessing the impact of DTs requires consideration of other factors including but limited to; accessibility, affordability, quality, efficiency, equity, patient centeredness, and sustainability. The Healthcare 5.0 perspective is particularly relevant here as it addresses both the needs of people using these technologies and the importance of balancing technological innovations with human need; ultimately promoting a more balanced approach to digital transformations.

Table 1. Comparison of Related Work and the Present Study

Related Work	Core Theme	Major Finding	Relevance to Present Study
[1], [3]	AI, blockchain and healthcare	Integration can support intelligent and secure healthcare.	Integrated technology perspective.
[2], [6], [10]	IoMT and blockchain	Connected healthcare requires security and reliable data exchange.	Infrastructure and trust layers.
[6]	Blockchain-based healthcare	Implementation involves practical and governance challenges.	Governance and interoperability.
[5], [7]	AIoT/blockchain and IoT ecosystems	Highlights integration potential and challenges.	Integrated framework.
[8], [9]	Healthcare data and blockchain	Emphasizes data protection and healthcare applications.	Cybersecurity and sustainable healthcare.

TECHNOLOGY LAYER AI • IoT / IoMT • Blockchain • Big Data Analytics • Telemedicine • Wearables • Robotics
INFRASTRUCTURE & INTEROPERABILITY Connectivity • Data Exchange • System Integration • Computing Resources • Scalability
GOVERNANCE & TRUST Cybersecurity • Privacy • Ethics • Data Governance • Regulation • Accountability

HEALTHCARE PRACTICE Diagnosis • Prediction • Treatment Support • Remote Monitoring • Decision Support
SUSTAINABLE HEALTHCARE OUTCOMES Accessibility • Affordability • Quality • Efficiency • Equity • Patient-Centred Care • Sustainability

Figure 1. Proposed Integrated Framework for Disruptive Technologies in Sustainable Healthcare

Conclusions

There is a growing need for understanding how emerging, disruptive technologies (such as AI, IoMT) could support development of future health care systems; however, there are numerous barriers in terms of cost, sustainability, privacy, training, and technology that would have to be overcome before these technologies can provide value to patients and providers. An interdisciplinary, literature based approach to synthesizing evidence was used to develop an understanding of AI, IoMT, Blockchain, Big Data Analytics, Telemedicine, Wearable Devices, Robotics and other digital health care technologies. Based on this synthesis, an Integrated Framework of Five Layers was developed to help address the barriers and enable widespread adoption of new digital health care technologies. The findings of this research are that technology (disruptive) has a potential to be a good tool for increasing access to health care, improving the cost of care, the quality of care, the efficiency of care, remote monitoring, security of data, predictive decision making, and providing care to patients when it is supported by appropriate structure, interoperability, governance, skill, and cost. This study is mostly based on literature review and did not have completed original data validation. It would be helpful for future research to complete surveys, interviews, and some form of quantitative evaluation to support the validity and development of the proposed model as well as evaluate whether or not the proposed model will be applicable in India and other countries with low economic development.

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