COULD INTEROPERABILITY BETWEEN IOT AND EHR MAKE HEALTHCARE MORE EFFICIENT?

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Introduction

As cell phone use increases over laptop and desktop use, interest in using Internet of Things (IoT) to assist with healthcare monitoring and diagnosing is increasing as technology promises instant access to live monitoring. IoT data may soon be transferred directly to Electronic Health Records (EHR) systems and accessible by multiple medical organizations. This paper discusses the benefits of IoT data transferring directly to EHR systems, the challenges that are impeding implementation of using IoT data in EHR systems and determine if the effort and cost associated with proposed solutions to existing barriers will result in more efficient healthcare.

Efficiency is defined as achieving the desired results with minimal waste. When relating efficiency with healthcare, the definition is vague. This article defines efficient healthcare as reducing waste while increasing the positive outcome of patient care. Positive outcome can be described as the managing, diagnosing, and prescribing of patient care that results in fewer misdiagnoses, fewer mistakes, and reduced levels of negligence to the patient. The results of this article may decide if addressing the barriers to IoT and EHR interoperability is worth pursuing resulting in more efficient healthcare.

Systematic Literature Overview

IoT device used in healthcare is expanding as an increased number of applications track and monitor heart rate, blood pressure, medications, and sleep patterns. Although IoT currently doesn't transfer data directly to EHR systems, EHR systems have been implemented amongst organizations around the world to increase efficiency and manageability of health records and have proven to help physicians diagnose more quickly and accurately by storing information in a central location. Lab results and scanned images at a single location eliminate problems of lost and misplaced paper folders and X-Ray films (Ahmad & Kartiwi, 2016).

Currently, physicians and patients can exchange and view information through a shared portal which patients can access on their mobile devices. Having information stored on the cloud and

receiving live data via IoT devices will "provide fast and real time communication" (Alasmari & Anwar, 2016, p. 198). Live data exchange between IoT devices and EHR will increase accuracy. Errors manually transcribing data are reduced significantly as information is updated automatically. More accurate data leads to better diagnoses resulting from clearer understanding of patients' health. These accurate findings can also be studied as group data to get a better idea of how to handle the disease globally (Zaouiat & Latif, 2017).

Medical errors continue to be the number three killer each year (Figure 1), which is roughly 400,000 people annually, 250,000 in the United States. The causes of these errors include missed and delayed diagnoses, negligence, failure to order appropriate tests, failure to initiate follow up, prescribing incorrect drugs or dosage, prescribing drugs without knowledge of the patient's drug history or allergies, or an inability to access patient records. These errors can be avoided by increasing efficiency by implementing IoT with EHR (Tyagi et al., 2016).

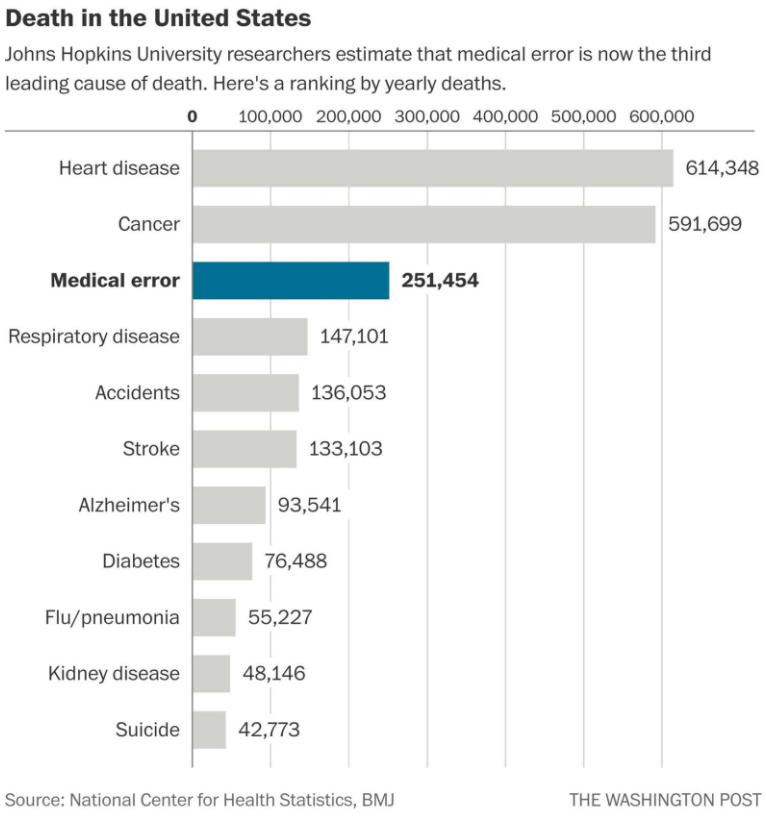

Figure 1: Medical errors third lead killer from "Researchers: Medical errors now third leading cause of death in United States" by Ariana Eunjung Cha, (2016) The Washington Post, 2016 https://academynet.com/knowledge-article/reducing-medical-errors-leading-health-systems. In the public domain

Methodology

Research for this systematic literature review was managed and assessed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) which focuses on thorough gathering

and analyses of health care articles. Steps include narrowing down results to an inclusive list of relevant articles. The flow diagram in Figure 2 illustrates how the research articles were filtered.

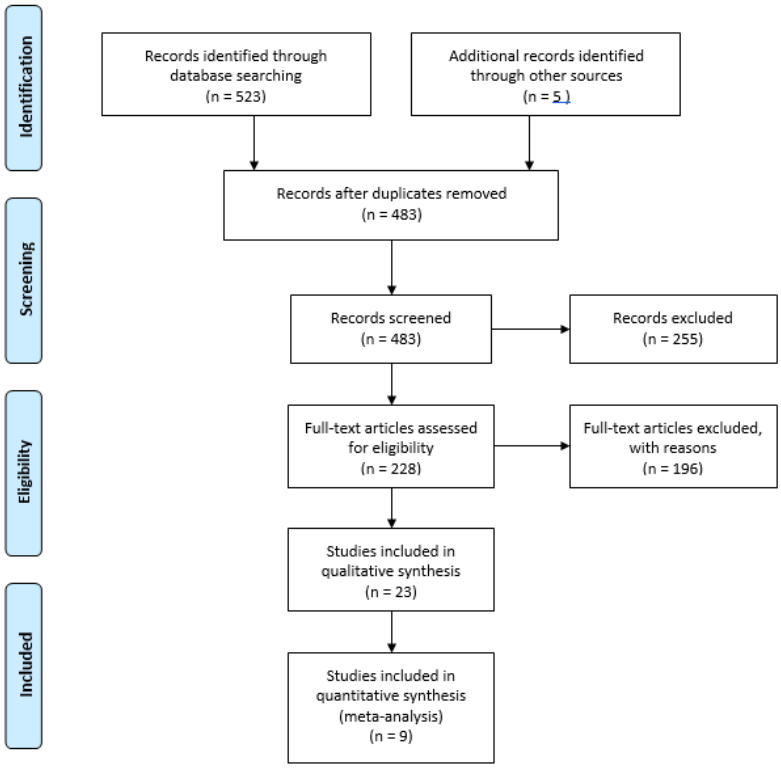

Figure 2: PRISMA flow diagram

The total number of records were gathered tracking search date, database, searched phrases, and restricted criteria such as year ranges. Duplicates were removed and abstracts screened for relevancy. Full-text articles were assessed for eligibility as it pertains to the topic. The remaining results were then filtered and divided into qualitative and quantitative findings, with qualitative articles conveying barriers and proposed solutions and quantitative findings illustrating statistics. Figure 3 shows the databases used, search criteria, search dates, search terms, and terms used to filter content for relevancy.

Database Names	ACM IEEE Google Scholar
Search Dates	9/28/2019 - 10/2/2019 10/22/2019 - 10/25/2019
Search Criteria	Article year 2015-2019 Sorted by relevance ACM, Google Scholar - 1st three pages IEEE - 1st fifty results
Search Terms	Could IoT help make Healthcare more Efficient Making healthcare more efficient Define efficient healthcare Current benefits of IoT in Healthcare Concerns IoT in Healthcare Benefits of IoT to EHR Challenges of IoT to EHR IoT to EHR challenges Existing apps IoT to EHR Existing IoT apps that work with EHR Public opinion of IoT in healthcare IoT in healthcare
Relevancy for filtering articles	Efficient definition Efficient healthcare Current healthcare apps Future healthcare apps Goal of IoT in Healthcare Benefits of IoT with EHR Challenges of IoT with HER Proposed solutions for challenges

Figure 3: System literature review search protocols

Determining the results of the findings involved assessing the obstacles and the proposed methods for addressing those challenges, along with statistics and patterns. The conclusion is determined by the proposed solutions of addressing the barriers compared with the perceived benefits. An implication with this process is measuring qualitative along with quantitative facets; improving quality of healthcare may not always appear efficient relating to the value on life. Statistics were used whenever possible in addition to expected benefits and consequences.

Results and Implications

Introduction

The obstacles faced are due to concerns about privacy and security, technical barriers, and social acceptance. An article by (Mavrogiorgou et al., 2019) states that IoT devices are categorized by as being either medical or consumer-grade devices and can be noted in EHR systems, indicating that medical grade devices may have higher standards than consumer-grade devices.

Barriers

The results of a study done by (Gaylin et al., 2011) shows that most Americans choose efficient healthcare and the integration of IoT with EHR, even if it means privacy and security risks. The same study shows that favor toward IoT devices is correlated with daily technology use along with availability which is higher in higher income families. Another study by (Achituv & Haiman, 2016) shows that amongst doctors, most young doctors are in favor of IoT with EHR, and female doctors are more in favor over male doctors. According to an article by Murad, Y. (Murad, 2019), 34% of adults in America in 2019 use mobile health apps. Of those who currently don't, 52% would consider in the future. A study referenced in Morning Consult, 2019 illustrates from a sample of 393 female respondents shows that most apps are focused on disease prevention such as heart rate monitoring (Murad, 2019) (Figure 4).

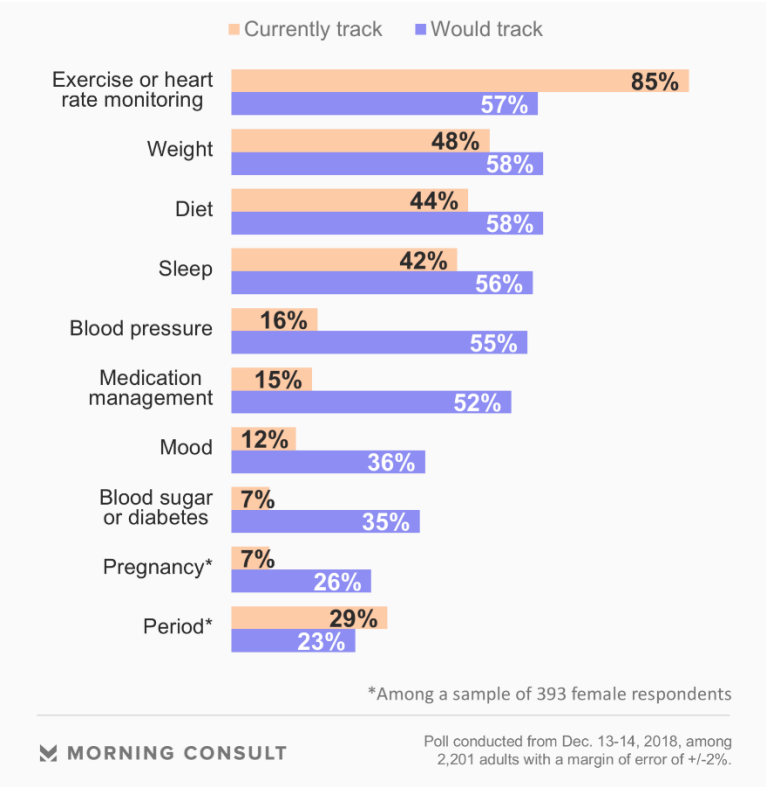

Figure 4: Tracked now versus consider tracking from "Wearable and App Users Tracking Health Tech's Next Step" by Yusra Murad, 2019, *Morning Consult* p. 1. Copyright 2019 by Morning Consult.

With the benefits and social acceptance in favor of IoT in healthcare, the primary challenges are significant enough to put interoperability between IoT and EHR on hold due to privacy and security concerns, and technical barriers.

Privacy and Security barriers

Expanding capabilities of wearable IoT devices include monitoring and tracking heart rate, scheduling, medication reminders, and accessing health portals. IoT devices are available in

multiple manufacturers and versions, making security and privacy with IoT devices challenging. Data must be encrypted from endpoint to endpoint. Transfer between IoT and EHR must be secure, reliable, quick, accurate, without modification or subjected to malware prior to transmission. The IoT devices need to be secure around other nearby devices. With the introduction of IoT to EHR, "[s]everal Health information security and privacy challenges arise" (Alasmari & Anwar, 2016). Data communicating from IoT devices to EHR systems may increase chances of HIPAA security risks.

With variable traffic from various IoT devices with different packet and data types, one-size-fits-all security protocols that protect variable technologies is challenging. Finding technologies that provide security to all IoT devices is a struggle, especially for IoT with limited functionality (Choi et al., 2019).

Technical barriers

IoT devices are largely designed to work independently from other technologies, making intercommunication a dilemma. For IoT data to be transferred to EHR systems, the data gathered needs to be converted into the EHR interface in a format readable by EHR. Communication between IoT and EHR is either blocked by various computer languages and interfaces, or labeled as irrelevant, causing gaps in the data resulting in a misrepresentation of the health record.

Stated by DeWitt, et al., "[i]ntegration of health IoT within EHRs is not static and limited to the domains of Big Data and infrastructure such as Cloud or Edge computing; rather it also extends to additional technologies, such as network management, data analytics, software development, cybersecurity, and other information science domains" (DeWitt, 2019, p. 66). Most EHRs were not designed to integrate with IoT technology, and currently there isn't middleware available that converts IoT data to a format recognized by EHR's Cloud and Edge computing architecture (DeWitt, 2019). IoT devices were designed to be managed by patients rather than other vendors or Cloud management systems (Alamri, 2018).

Difficulty managing and accessing data is also linked to providers resistant to the learning curve associated with converting to EHR systems. Technological obstacles also affect patients in populations with lower income, lower education, or rural residents, who are less likely to have access to internet, a requirement of IoT devices (Shashank, 2017).

Potential Solutions

Privacy and security

The primary challenge of integrating IoT with EHR systems is preserving privacy and security. Yang et al., (2018) proposes a privacy-preserving e-health system that combines IoT, big data, and cloud storage. The IoT data is gathered to the EHR which are then encrypted and stored in cloud storage with strict access control that uses an innovative keyword policy update mechanism to allow record updates without compromising security (Yang et al., 2018).

Choi et al., (2019) proposed framework comprised of three centers that provide authentication, access control, and security. This architecture splits up the functions of authentication by

separating the information encryption from the center that's responsible for authentication (Choi et al., 2019).

Technical: Middleware

To support the integration of IoT data to EHR systems, Alamri et al., proposes a semantic middleware that assists with the issue of various data formats gathered by IoT devices and sensors. The middleware defines the data collected by IoT devices and sensors, and also defines and normalizes the structures and formats of the complex data collected from EHRs" (Alamri, 2018).

Technical: FHIR

A measure to address the obstacle of IoT data integrating with EHR systems is the introduction of FHIR, Fast Healthcare Interoperability Resources, which was introduced by the nonprofit organization Health Level Seven International in 2014. "FHIR provides a standard set of data models or resource definitions" (Hayhurst, p. 2) by using a common language, allowing communication between IoT and third-party applications to EHR systems.

Conclusion

After analyzing the benefits and costs of addressing the security and technology obstacles, implementing interoperability between IoT and EHR systems would be worth pursuing. Medical facilities that have implemented EHR systems are already seeing an improvement in efficiency. Hospitals in Pennsylvania that adopted EHR systems have seen, "a 27% decline in overall patient safety events and a 30% decline in medication errors" (Hydari et al., 2015, p. 1). The main causes for medical errors can be prevented by implementing IoT with healthcare monitoring and diagnoses. IoT devices can aid in the prevention of medical errors (Figure 5) caused by misdiagnoses due to old or incomplete data, provide quick treatments by sending alerts for health emergencies, provide live monitoring, and constantly communicate the data to EHR systems for immediate access.

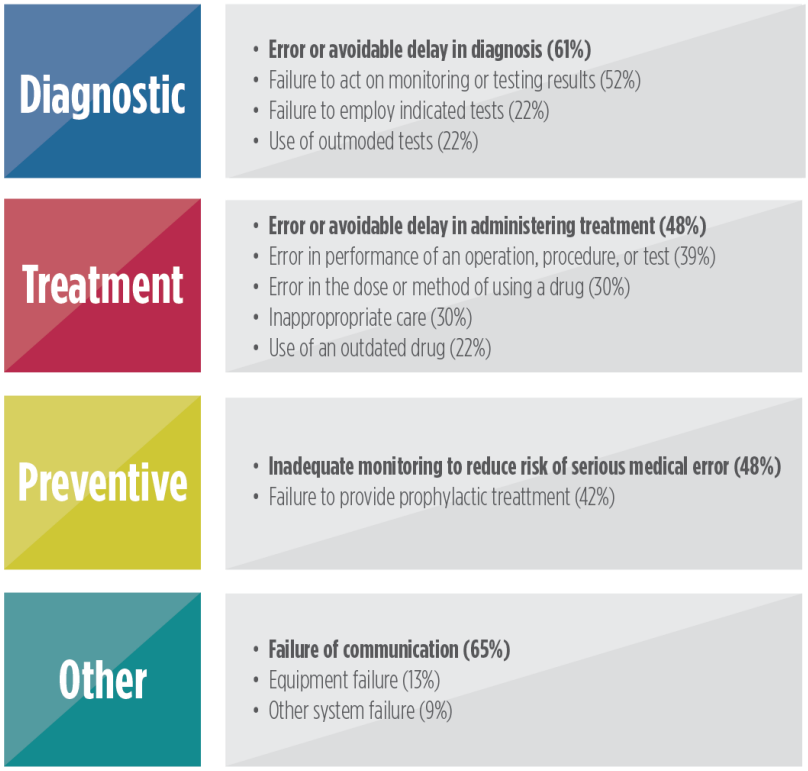

Figure 5: Types of Medical Errors from "Reducing Medical Errors at Leading Health Systems" by Melissa Stahl and Elizabeth Sloss, 2017, *The Academy* p. 2. Copyright 2018 by The Academy.

The numerous proposals to address the technical and security concerns have not currently yielded interoperability between IoT and EHR, even with proven benefits and reduced costs from lawsuits and increased organization and productivity.

Technical barriers may be addressed further as 5G technology allows more devices to connect without sync issues or delay. Some attitudes prefer IoT in healthcare at the sacrifice of privacy but is still too new to comprehend the implications of hacking into Fitbits nationwide or using IoT devices to access EHR systems.

An article by Bresnick, 2016 adds that the delay in the push between IoT in healthcare may be due to disinterest. The technical focus has instead been on entertainment and ease of everyday living. The population isn't interested in healthcare except in emergencies. Otherwise, healthcare takes a back seat. Although implementing IoT and EHR increases efficiency, until healthcare is a priority in the advancement of technology, barriers will continue to block development.

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