World Academy of Science, Engineering and Technology
International Journal of Health and Medical Engineering
Vol:15, No:2, 2021

The Integration of Patient Health Record Generated from Wearable and Internet of Things Devices into Health Information Exchanges

Dalvin D. Hill, Hector M. Castro Garcia

***Abstract*—**A growing number of individuals utilize wearable devices on a daily basis. The usage and functionality of these wearable devices vary from user to user. One popular usage of said devices is to track health-related activities that are typically stored on a device's memory or uploaded to an account in the cloud; based on the current trend, the data accumulated from the wearable device are stored in a standalone location. In many of these cases, this health related datum is not a factor when considering the holistic view of a user's health lifestyle or record. This health-related data generated from wearable and Internet of Things (IoT) devices can serve as empirical information to a medical provider, as the standalone data can add value to the holistic health record of a patient. This paper proposes a solution to incorporate the data gathered from these wearable and IoT devices, with that a patient's Personal Health Record (PHR) stored within the confines of a Health Information Exchange (HIE).

***Keywords*—**Electronic health record, health information exchanges, Internet of Things, personal health records, wearable devices, wearables.

I. Introduction

THE traditional way of recording a patient's health record and medical history was primarily done in a paper-based format. This way of storing patients' information was effective at the time, but it limited a patients' medical history to that particular medical provider's office. This created a problem of accessibility, as it took a long time for patients to get their records if they needed to solicit the services of another healthcare provider. To make a more efficient way of storing patients' information, Electronic Health Records (EHRs) and Electronic Medical Records (EMRs) were introduced. Some drawbacks of paper-based-records include record misplacement, an insurmountable amount of time to retrieve patient's information, illegible handwriting, and the probability of the ink fading away from the paper [1].

EHRs are an electronic format/version of a patients' medical health data. Unlike EMRs, which focus more on the patient's medical symptoms and issues, EHRs provide a more in-depth analysis of the patient's health record. EHRs include medication, physical assessment, hospitalization record, past medical history, diagnoses, lab results, procedures, and more.

Dalvin Hill is with the City University of New York - Stella and Charles Guttman Community College, United States (e-mail: dalvinhill@hotmail.com).

II. PHRs

Traditionally, obtaining a patient's health record required the patient to visit a hospital or medical provider and make a request. This request may be honored immediately, or it could take several days for the medical provider's office to supply the document(s) to the patient; the typical practice is that the records are prepared for the patient at a later date and time. PHRs are an electronic system in which patients can access, share, and manage their own health information. PHRs are composed of the history of the patient's medical history (such as illnesses, allergy data, immunizations, major illnesses etc.). PHRs provide patients with a complete view of their medical history in a way that is understandable and give patients the ability to manage and be able to electronically share their health data [2]. PHRs also allow for better communication between patients and doctors with additional functionality such as electronic messages, the ability to view medications, prescription renewal forms, and appointment making capabilities.

The introduction of PHRs provides many benefits to patients. By having an easy way to access one's own health record, it is easier for patients to manage and improve their health. PHRs can also allow patients the ability to track their symptoms and ailments [2]. Furthermore, the data contained within PHRs have the capability to be included in HIEs, which would allow clinicians to have a more comprehensive log of the patient's record which can help improve decision making.

To gain access to a PHR, a patient must subscribe to a PHRs provider. This subscription can be provided by healthcare providers, employers, or independent vendors [3]. Once patients have access to a PHR, he/she can request a copy of their health record from individual medical providers and can make manual or automatic entries to their PHR account. It is important to understand that the PHRs are a personal way for patients to manage their health record, and it does not change any of the legal records of any healthcare provider [3]. Some examples of PHRs software are: Microsoft Health Vault, American Medical ID, Access My Health, and Global Patient Record. Microsoft Health Vault will be discussed in the proceeding paragraph.

Microsoft Health Vault is an application created by Microsoft that allows businesses and consumers to store, manage, and share information between health-related devices, applications and clinical systems [4]. With Microsoft Health Vault, businesses can create personalized applications using a Software Development Kit (SDK) provided by

Microsoft. This allows businesses to build an online tool, specifically made for their community or employees. Microsoft Health Vault also provides a PHR tool, for consumers that allow access to medical records, the ability to track health by using personal devices or IoT devices, capable of sharing data with healthcare professionals, family, or anyone the patient desires to share their information with. IoT devices are also referred to as Internet of Everything or the Industrial Internet and can be defined as a global network of machines that can communicate with amongst themselves [5].

III. Comparison of Various Health and Activity Monitoring Devices

Ten healthcare monitoring/testing devices were evaluated as a part of this study. The results are summarized in Table I, and as a part of this research, we include both wearable and IoT devices which were made by various manufacturers. The record keeping column (rightmost column) outlines how records are maintained. Some of these devices have their own databases and maintain their data in a standalone fashion, while other devices automatically sync their data with other entities/systems.

TABLE I
Health and Activity Monitoring Devices

Name of Device	Device Type	Platform	Record Keeping
UC-324NFC	Personal scale	Android	Automatic
UA-767 NFC	Blood pressure monitor	Android	Automatic
UW-101NFC	Activity monitor	Android	Automatic
Ideal life Gluco-Manager	Glucose meter	Android	Automatic
Fitbit Charge 3	Heart rate monitor/Sleep tracker	Android/ IOS	Automatic
Aria 2	Weigh scale/BMI and Body fat measurer	Android/ IOS	Automatic/Sync Wirelessly
Galaxy Watch	Heart rate monitor/ Sleep tracker	Android/ IOS	Automatic/Sync Wirelessly
WristOx2, Model 3150 BLE	SpO2 monitor and Pulse rate		Bluetooth
WristOx2, Model 3150 with USB	SpO2 monitor and Pulse rate		Manual
Apple Watch Series 4	Heart rate monitor/ECG	IOS	Automatic

IV. Standalone PHRs vs. Tethered PHRs

There are two ways in which data can be stored in PHRs: Standalone and Tethered. Standalone PHR devices are most popular and they allow the patient to request a copy of their records which they can use to input to a web-application or the patient's computer. Furthermore, standalone PHRs, although they operate in solo and are independent, can also accept data from external sources which include laboratories and medical providers. Standalone PHRs give patients the ability to share their information with family members, care providers or anyone who might be involved with their well-being. Additionally, standalone PHRs allow patients to add exercise information, and dietary restrictions [6]. As the name *standalone* suggests, these are independent devices that are independent and are not connected with any other devices or systems.

Tethered PHRs, also known as portals or connected PHRs, are directly connected to the healthcare organization's EHRs. Like standalone PHRs, tethered PHRs allow patients to access their records; see lab results, immunization history, medication list, allergy data, and more [7]. The difference between standalone and tethered PHRs is that tethered PHRs do not enable patients to manually enter or self-report, as the devices are able to write directly to the organizations EHRs [7]. Tethered PHRs also improve patient-provider relationship by introducing the use of electronic messaging. Medical providers and patients can use electronic messaging functionality to communicate with each other. Additionally, tethered PHRs allow patients to renew prescriptions, and schedule appointments [7]. The record generated from both tethered PHRs and standalone PHRs can provide invaluable data to a medical provider.

V. Privacy Concerns

In the process of adapting this new way of sharing, storing, and managing patients' information, many patients are rightfully concerned about their privacy and are worried about the impact if their information is hacked. Since PHRs are usually managed by the patient, it is often cumbersome to understand how secure these records are. Most PHRs can also be interconnected to a medical providers' EHR. This poses additional security risks since data are communicated across various systems. To ease the concern, most EHRs are directly connected with the corresponding organization's server, which means there are extra levels of security.

Another security measure that might deter people from adopting PHRs is that Health Insurance Portability and Accountability Act (HIPAA) does not support individual PHRs. The HIPAA Act was passed by the United States Congress in 1996 to ensure that an individual's health information is properly protected, and to protect the public's health and wellbeing [8]. HIPAA is set out to protect the privacy of a patient's information. Standalone PHRs are not covered by HIPAA, because standalone PHRs are governed by the regulations of the specific manufacturers.

For a successful implementation of writing PHR data generated from wearables and IoT devices to HIEs, these privacy concerns must be addressed. HIPAA will not support the inclusion of PHR generated data unless concrete evidence outlining a solution to these security concerns is implemented. Once this is done, there is a possibility that PHR-generated data will be considered on par with the data created at a medical provider's office. As discussed in previous sections, PHR data can provide any number of benefits when delivering holistic care to a patient and as such, the goal is to include this data in a patient's health record.

VI. IoT and PHRs

The introduction of PHRs presents new opportunities for having a more interconnected healthcare industry; not only by having interconnected HIEs, but by also including IoT devices. The Internet has been around for a long time but it was not until recently that it became an IoT. As stated by the

International Business Machines (IBM) Corporation, a popular American multinational information system company, IoT refers to having devices that communicate with each other as well as with the Internet [9]. The introduction of IoT enables these connected devices to bring a lot of benefits to the world, but more importantly to the way we store and access health records. As shown in Table I, there is a wide variety of Internet connected devices. This includes: scales, blood glucose meters, blood pressure meters, and more. One type of device that has been making the most impact is known as wearable devices or wearables. The Fitbit Charge 3, as listed in Table I, is a wearable device that is worn around the wrist like a watch. This device can track exercise, sleep patterns, and automatically check heart rate. The datum that is generated by these devices can be uploaded into the Fitbit IOS/Android application. The Fitbit application holds the data gathered, which can then be transferred to other fitness apps and even some PHRs [10].

Tactio is a mobile application that is compatible with the Fitbit application. Tactio allows consumers to gather all their health records and store them in one secure location; more like a PHR. The application allows consumers to track their health records, lab results, vaccination history, blood glucose readings and more [11]. Tactio also allows the patient to share their records with healthcare providers. Additionally, it can be used to provide consultations as well. Tactio allows patients to connect health applications like Apple Health, Google fit, Fitbit and more into their system, permitting health data collected by IoT devices to be uploaded into the patients' health record.

As time progresses, these wearable devices are increasingly equipped with health and safety features. A recent article reports that Apple Watch fall detection helped an 87-year-old woman involved in a car accident [12], where the emergency services were automatically alerted after the accident. Her Apple Watch detected there was a crash or a fall and alerted first responders, as well as the woman's family. There is a feature called Emergency SOS that allows a user can specify the name(s) of individuals who should be contacted in the event of an emergency. Emergency services and individuals designated as In Case of Emergency (ICE) contacts are contacted with a notification of the location of the potential incident. Another incident involved two hikers in New Jersey, USA. They were hiking in a park when they fell off the ledge of a cliff. One of the hiker's Apple Watch called 911 after detecting the nearly 100 foot fall. The hiker's GPS coordinates were sent to 911 along with an emergency alert message [13]. These IoT devices are increasingly providing more and more functionality which can be used to assist in the generation of health records that can be beneficial to the user.

VII. Proposed Solution

Wearable devices capture and store a great deal of health-related data on a daily basis. This generated information is continuous for the most part since the user wears the device(s) for a majority of the day. As such, this information is continuous and is reflective of activities done over a span of time, compared to the routine monitoring that is often conducted once each visit at a medical provider's facility. For example, your wearable is able to capture heart rate at multiple intervals for the day and can alert when there is an abnormality. The same is not necessarily true with a visit to a physician's office; the patient is not afforded this continuous monitoring unless they were to visit a medical provider's office multiple times of day. Even then, it would not provide the continuous monitoring and feedback that is afforded to users of wearable devices.

Our proposal is to include wearable and IoT generated data as a part of a patient's health record and within the HIE. It will allow the medical provider to see the trend daily, weekly, and over a specific span of time. This prolonged data will provide a much needed view of a patient's activities since the medical provider can analyze a more granular data (even down to the minute) on a daily basis. This can allow the medical provider to see trends they would have otherwise not been able to see during a single visit to their office. Currently, a physician may see this information on the patient's wearable device, or a report can be generated on an accompanying device of the respective wearable device. What we are proposing is to create an infrastructure that will write directly into the medical provider's record as a PHR subset of data, and ultimately it will be written to the corresponding HIE as well.

As of now, wearable devices record data to their respective application. The application where the data are stored depends on the type of device the patient is using. If the patient is using an Apple product, e.g., Apple Watch, the data would be stored in Apple's stock application, Apple Health. The data generated by the Apple Watch are automatically stored and can be managed and controlled by the user [14]. Using Apple Health gives users' full control of exporting and sharing their data. The data can be exported as an .xml file or it can be shared through email. As of now the data can only be exported as an .xml file. This makes it difficult for the average user to make sense or understand these data.

Patients who use Android devices can also track their data generated by wearables using applications such as: Google Fit, and Samsung Health. Samsung Health allows users to track and record daily activities. These include physical exercises, running, steps, food and water intake. Equally important is Samsung Health; it allows users to manage their health by checking their heart rate, blood glucose levels, blood pressure, stress, and weight [15]. Similar to Apple Health, Samsung Health allows users to export the data. Exporting the data can be easily accessed via the app settings. Once the user exports the data, a Comma-Separated Values (.CSV) file is generated and users can email it to themselves, or upload it to Google Drive [16]. Similar to Apple Health, it is challenging for the average user to be able to understand the content of the .CSV file.

Each wearable/IoT device generates its own data. One of the challenges is determining how to port the data generated from these various devices into a central location. There are some third party applications in the market, but one commonality we have seen is that not all devices are able to

write to these applications. The format in which the information is recorded within these third party applications varies from manufacturer to manufacturer. This non-standardized data recording presents an opportunity to create a more streamlined process that will become a standard for medical providers. Our goal is to ensure that there will be a similar format that each wearable/IoT device will adopt and utilize in the recording of its data into a health record, PHR, and a HIE.

Our proposed solution will provide a central repository in which data will be written from the varying wearable devices. The HIE will serve as the repository and will be capable of storing information regardless of the Operating System platform, manufacturer, and the type of device. Fig. 1 provides a pictorial representation of the proposed solution. Our goal is to incorporate a dashboard within the HIE that can be used to provide a summary of all the recorded data; it will also provide the functionality to examine diminutive data generated from each device. For example, the medical provider will have the capability to review daily weight, or can use the dashboard to look at a patient's weight over a week, month, year, or a specific period. Similarly, the medical provider will be able to review blood pressure data generated from a wearable watch coupled with a blood pressure monitoring device to see similarities and differences. The medical provider can examine the data and trends generated from each independent device. These data can be reviewed in the presence or absence of the patient.

Fig. 1 Integration of PHR data generated by IoT devices into HIEs

The benefits to be had from having the data generated from wearable and IoT devices in a central location are astronomical. Previously, each device would have to be checked individually which is rather time consuming and is not optimal. With the proposed solution, the medical provider is able to see the data in one place, as opposed to logging into each device's portal, and is able to review each set of data that is in a unified format. A report can also be generated on the dashboard which can showcase performance and trends based on information generated from all the devices. This will allow a medical provider to be able to look at trends and anomalies based on the data contained within the PHR designated record of the HIE.

VIII. Conclusion and Future Works

The healthcare sector has gone through several transformations over the years; the sector has transformed from paper-based records, to electronically created and stored records. More recently, patients are also able to self-document their health data that are generated from various wearable and IoT devices. The data generated from wearable and IoT devices provide a more continuous snapshot of a patient's activity and health related data that can then be analyzed by a medical provider. The data generated for EHRs and EMRs, coupled with that of PHRs, allow a doctor to see a continuous record of the patient both while the patient is at the medical provider's office and even while not in the office.

This paper proposes a solution, which entails the integration of PHR data generated by wearables and IoT devices to existing HIEs. The integration of this data into a patient's PHR provides a better understanding of a patient's health trend. Since physicians do not typically see their patients on a daily basis, the contributed data from wearable devices would allow for a better understanding of a patient's health.

One of the other benefits of the proposed solution is that a medical provider will not have to access the PHR data from each wearable/IoT device. Instead, all the data will be written to the HIE and will be of a similar format, which will make it streamlined and easier to understand. Furthermore, the medical provider can view the PHR data from a high-level perspective, or can review data from a granular lens. By having all these data in one portal, the medical provider is able to see a more comprehensive view of their patient's health record. It will be easier to identify trends and anomalies.

As it pertains to future work, the next step in the process is to encourage HIEs to provide the needed infrastructure to enable wearable and IoT devices, and PHRs to record data to their systems. Concurrently, we should encourage manufacturers of these wearable and IoT devices to come to an agreement on a universal format of record keeping such that a standard data can be written to HIEs. HIEs already have the capability to analyze data that are stored within its repository, so the other recommendation is to create a portal that will provide the analyzing capability of the PHR generated data. Another recommendation is to create a plan that will allow medical providers to see the benefit of analyzing PHR data which are more continuous, coupled with the periodic data generated from an appointment at a medical provider's office. The final recommendation is to solicit the buy-in from patients by demonstrating the benefits to be had from writing the data generated from multiple wearables and IoT devices into one central location and the breadth of knowledge it can provide to a medical provider when administering care; this will require a proven architecture that

demonstrates proven security measures.

REFERENCES

[1] Hill, D., Du Fresne, L. J., Holder, I., Samudio, R., & Nallavadla, S. (2015). Interconnectivity of Health Information Exchanges Using Patient Access Number (PAN). Journal of Management Policy and Practice, 16(4). Retrieved from http://m.www.na-businesspress.com/JMPP/HillD_Web16_4_.pdf

[2] HealthIT. (2016, March 3). What are the benefits of personal health records? Retrieved from https://www.healthit.gov/faq/what-are-benefits-personal-health-records

[3] Electronic vs. personal health record. (2014, February 19). Retrieved from https://www.hsph.harvard.edu/news/magazine/fall08ehrpersonalvshealth

[4] JHutchings1. (2017, November 4). Why HealthVault? - HealthVault Development. Retrieved from https://docs.microsoft.com/en-us/healthvault/introduction/why-healthvault

[5] Lee, In, & Lee, Kyoochun. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. Business Horizons, 58(4), 431-440

[6] HealthIT. (2018). Are there different types of personal health records (PHRs) Retrieved from https://www.healthit.gov/faq/are-there-different-types-personal-health-records-phrs

[7] Vydra, T. P., Cuaresma, E., Kretovics, M., & Bose-Brill, S. (2015). Diffusion and Use of Tethered Personal Health Records in Primary Care. Perspectives in Health Information Management 12, 1c

[8] HHS Office of the Secretary, Office for Civil Rights, & Ocr. (2013, July 26). Summary of the HIPAA Privacy Rule. Retrieved from https://www.hhs.gov/hipaa/for-professionals/privacy/laws-regulations/index.html

[9] Clerk, Jen. (Nov 17, 2016) What is the internet of things. Retrieved from https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/

[10] Fitbit. (n.d.). Fitbit Charge 3. Retrieved from https://www.fitbit.com/charge3.

[11] Tactio. (n.d.). Digital Health Passport & Coach. Retrieved from https://www.tactiohealth.com/en/patients

[12] Dormehl, L. (2019, June 27). Apple Watch fall detection helps 87-year-old woman after car accident. Retrieved from https://www.cultofmac.com/634614/apple-watch-fall-detection-helps-87-year-old-woman-after-car-accident/

[13] NBC. (2019, October 23). Hikers in NJ Say Apple Watch Saved Their Lives By Calling 911 After Fall From Cliff. Retrieved from https://www.nbcnewyork.com/news/local/Hikers-NJ-Says-Apple-Watch-Saved-Lives-Calling-911-After-Fall-From-Cliff-563702871.html

[14] IOS - Health." Apple. Retrieved from https://www.apple.com/ios/health/.

[15] Samsung Health App. (n.d.). Retrieved from https://www.samsung.com/us/support/owners/app/samsung-health.

[16] Vishnevetsky, D. (2019, July 19). How to extract your personal Samsung Health data. Retrieved from https://medium.com/@dimshik100/how-to-extract-your-personal-samsung-health-data-514bbe2331f7