Can Blockchain improve Healthcare Management?

Consumer Medical Electronics and the IoMT

Abstract

We set out to examine the relevance of blockchain technology for healthcare management in general, and for consumer medical electronics and the portable devices connected in particular. After considering the shortcomings of private and centralized organizations for access to patient data in a fist part, we analyze the transformative role of blockchain for the management of electronic health records (EHRs). We evoke the role of public private partnerships for the design of healthcare blockchain strategies, and we address the fast-growing segment of consumer medical electronics and the Internet of Medical Things.

Keywords: Healthcare, Blockchain, Internet of Things, Electronic Health Records

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Introduction

A recent report from Deloitte showed that 35% of surveyed healthcare and life sciences organisations plan to deploy blockchain technology in the coming year: this would outpace blockchain adoption in other industries. And among executives with blockchain knowledge, over half (55%) said their company's competitiveness would be hurt if they failed to adopt blockchain. In this article, we examine the relevance of blockchain technology for healthcare management in general, and for consumer medical electronics and the portable devices connected through the so-called Internet of Medical Things in particular. After considering the shortcomings of private and centralized organizations for access to patient data in a fist part, through the example of the controversial NHS and Google partnership and other cyberattacks launched on several hospitals, we analyze in a second part the transformative role of blockchain for the management of electronic health records (EHRs). After shortly evoking the role of public private partnerships for the design of innovative healthcare blockchain strategies, we address the fast-growing segment of consumer medical electronics and the Internet of Medical Things whose salient features are highlighted. Finally, we conclude.

Shortcomings of private and centralized organizations for access to patient data

Google conglomerate, Alphabet Inc and the Royal Free London NHS Foundation Trust signed a five-year agreement in November 2016 to create a notification system for doctors whereby patient updates and test results are forwarded to physician's mobile devices, thereby helping them to reduce paperwork, and improve patient care. Capella (2017) reports on the recent mismanagement by Google's DeepMind's management of NHS patient data during pre-deployment of a patient care app called 'Streams', directed at patients suffering from acute kidney problems. The NHS granted DeepMind access to millions of records and confidential medical information, not limited to those directly related to the initial app that was created. Live data from real patients were used while testing the system, relying on 'implied consent' from patients. This partnership has suffered from a lack of transparency, and has hinged on issues of privacy (Powles and Hodson, 2017): "the failure on both sides to engage in any conversation with patients and citizens is inexcusable" (ibid).

Thousands of British patients had delayed treatment in May 2017 after A&E wards, GPs surgeries and other vital services across NHS were infected by malicious software with a virus based on hacking tools developed by US cyber-warfare agents (Bulman, 2017). All in all, thirty health service organizations were infiltrated by the malware, but many others had to

be shut down as a precautionary measure, which meant that the whole British healthcare system had to operate offline during the attack.

On 5 February 2016, the Presbyterian Medical Center in Hollywood paid a $17,000 ransom in Bitcoin to a hacker who had seized control of the computer systems. The malware infected the institution's computers by encrypting files and demanding ransom to obtain the decryption key, preventing hospital staff from being able to use these devices.

Electronic health record management and blockchain technology

In a globalized world characterized my mobility, patient data is scattered and fragmented along institutional and national lines, and circumscribed to data silos that are more easily accessible to the healthcare provider than to the patient. The maintenance and updating of EHRs does not always go without problems. This broad issue of data sharing and coordination is called interoperability (Office of the National Coordinator for Health Information Technology, 2015). It must be noted that write and read permissions still ought to be thoroughly managed, as not all health records can/should be made available to patients (U.S. Department of Health & Human Services, 2017). An important innovation in the blockchain-based management of EHRs is MedRec (Azaria et al., 2016) that "gives patients a comprehensive, immutable log and easy access to their medical information across providers and treatment sites". MedRec draws on blockchain technology to ensure authentication, confidentiality, accountability and data sharing (ibid.). The solution incentivizes the actors of the medical community to participate to the blockchain ecosystem. All in all, the advantages of blockchain adoption for health information exchange are substantial. MedRec enables faster access to medical data, improves systems operability, solves the issue of patient agency (i.e. full information to the patients about their medical history and any modifications to it), and finally improves the quality/quantity of data available for medical research purposes (ibid.). As McFarlane et al (2017, p.2), convincingly argue, there exists to date a trade-off in existing healthcare technological solutions between care and privacy, on the hand one, and economic fraud for patients on the other hand, an issue being exacerbated by the expanding mass of data being continuously generated by the healthcare system. Yet, "Blockchain's secure technology, properties, and distributed nature can help reduce the cost and efficiency of these operations as well as provide a viable security infrastructure".

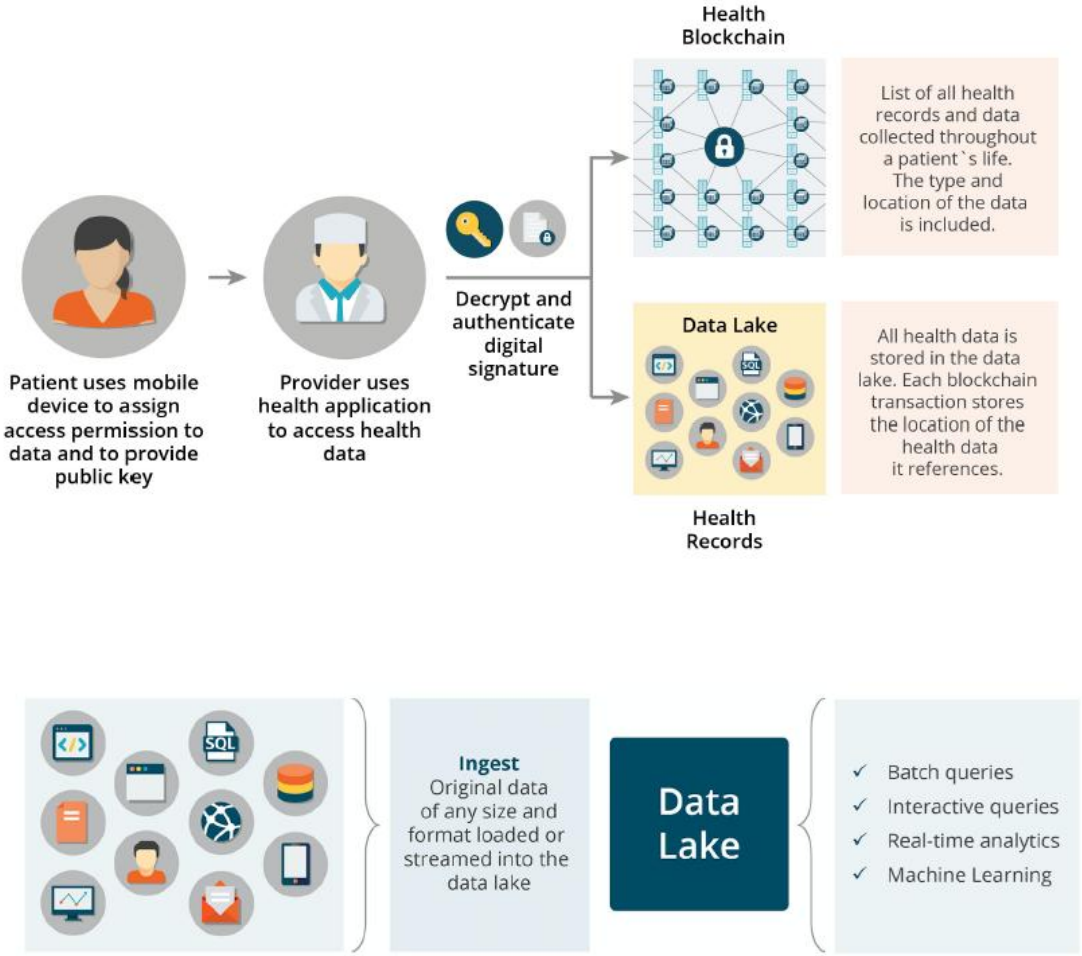
In the case of MedRec, the major breakthrough is that it is not EHRs that are stored on the blockchain, but the digital signature thereof, grouped in an index akin to a card catalog in

a library. For the patient, the benefits are invaluable. She is constantly informed about the read- and write-permissions concerning the EHRs, and where the latter can be sent to (Halmanka et al. , 2017).

Linn and Koo (2016) propose a similar blockchain-based solution, focusing on the importance of offline and off-chain data container, so-called datalakes:

> the health blockchain would contain a complete indexed history of all medical data, including formal medical records as well as health data from mobile applications and wearable sensors, and would follow an individual user throughout his life. All medical data would be stored off blockchain in a data repository called a data lake. Data lakes are highly scalable and can store a wide variety of data, from images to documents to keyvalue stores.

These data lakes will be able to store huge quantity and wide variety of encrypted and digitally signed medical data, thereby ensuring privacy and authenticity of the healthcare information. Combined with machine learning tools, these data lakes would greatly simplify interactive queries and real-time big data analytics (ibid.)



Source: Linn & Koo (2016, pp.4-5)

Linn and Koo (2016) stress the role of open APIs used to integrate and exchange data with the blockchain. They also emphasize the great variety of information sources that may be used by the new ecosystem (blockchain + offline data lakes), such as mobile applications and consumer medical electrics (Internet of Medical Things) discussed in the next section.

The Mayo Clinic (Peterson et al., 2016) investigates the issue of data sharing and interoperability in healthcare by designing a new algorithm. The authors also address the issue of security with the help of network-wide keys and smart contracts,

The CEO of Humana, Bruce Broussard (2016) thinks that blockchain technology and smart contracts will become pivotal in the healthcare industry through the automatic verification and authorization of information related to payments and payer contracts, which will be conducive to efficiency gains.

Gem, a blockchain company that develops enterprise blockchain solutions launched Gem Health in 2016, aimed at developing blockchain applications and shared infrastructure for healthcare. These blockchain healthcare solutions solve important issues of digital identity and interoperability: "[w]e need a modern infrastructure that unlocks new channels for services to connect, while balancing the need for strong data privacy and security. Blockchain technology is that infrastructure. (Vergel de Dios, 2016)"

Another interesting initiative comes from Deloitte Netherlands, in collaboration with SNS Bank and Radbou, who have developed Prescrypt, a proof-of-concept that helps verify the patient's digital identity, genetics data or prescription history, by giving patients full ownership of their medical records, allowing them to grant and revoke provider access to their data (Deloitte, 2016, p.3)

Blockchain: a decentralized solution for healthcare management?

Blockchain technology increasingly appears as a novel decentralized solution for enhanced healthcare information management. Deloitte (2016) has listed in a report the blockchain opportunities in the healthcare sector: from disintermediation of trust, reduced transaction costs, digital identity management, shared data to secured access to patient longitudinal health data and smart contract for accessing patient health data, blockchain technology hold the promise the transform the landscape in health care system management.

	HIE pain points	Blockchain opportunities
	Establishing a trust network depends on the HIE as an intermediary to establish point-to-point sharing and "book-keeping" of what data was exchanged.	**Disintermediation of trust** likely would not require an HIE operator because all participants would have access to the distributed ledger to maintain a secure exchange without complex brokered trust.
	Cost per transaction, given low transaction volumes, reduces the business case for central systems or new edge networks for participating groups.	**Reduced transaction costs** due to disintermediation, as well as near-real time processing, would make the system more efficient.
	Master Patient Index (MPI) challenges arise from the need to synchronize multiple patient identifiers between systems while securing patient privacy.	**Distributed framework for patient digital identities**, which uses private and public identifiers secured through cryptography, creates a singular, more secure method of protecting patient identity.
	Varying data standards reduce interoperability because records are not compatible between systems.	**Shared data** enables near real-time updates across the network to all parties.
	Limited access to population health data, as HIE is one of the few sources of integrated records.	**Distributed, secure access** to patient longitudinal health data across the distributed ledger.
	Inconsistent rules and permissions inhibit the right health organization from accessing the right patient data at the right time.	**Smart contracts** create a consistent, rule-based method for accessing patient data that can be permissioned to selected health organizations.

Source: Deloitte (2016)

https://www.healthit.gov/sites/default/files/4-37-hhs_blockchain_challenge_deloitte_consulting_llp.pdf

Blockchain health strategies and public private partnerships

In many countries, healthcare systems are managed by public agencies. Blockchain strategies have been more easily deployed in the USA thanks to a recent piece of legislation (del Castillo, 2017), known as the America Competes Reauthorization Act, which places *"a high priority on designing and administering pilot programs for scientific breakthrough prizes, in conjunction with private entities, for technological breakthroughs of strategic importance to the United States that have the capacity to spur new economic growth."* , and makes it easier for US government agencies to *"enter into a grant, contract, cooperative agreement, or other agreement with a private sector for-profit as well as a nonprofit entity […]to administer a prize competition"* (US Congress, 2015-2016)

Consumer medical electronics and wearables

A revolution started at the onset of the present decade in patient care driven by the growth in wearables and consumer medical electronics. Whereas consumer medical electronics is a high-growth segment at the intersection between medical electronics (see figure below) and consumer electronics, wearables are defined more precisely and rigorously as follows: "devices that can be worn or mated with human skin to continuously and closely monitor an individual's activities, without interrupting or limiting the user's motions" (Gao et al, 2016)

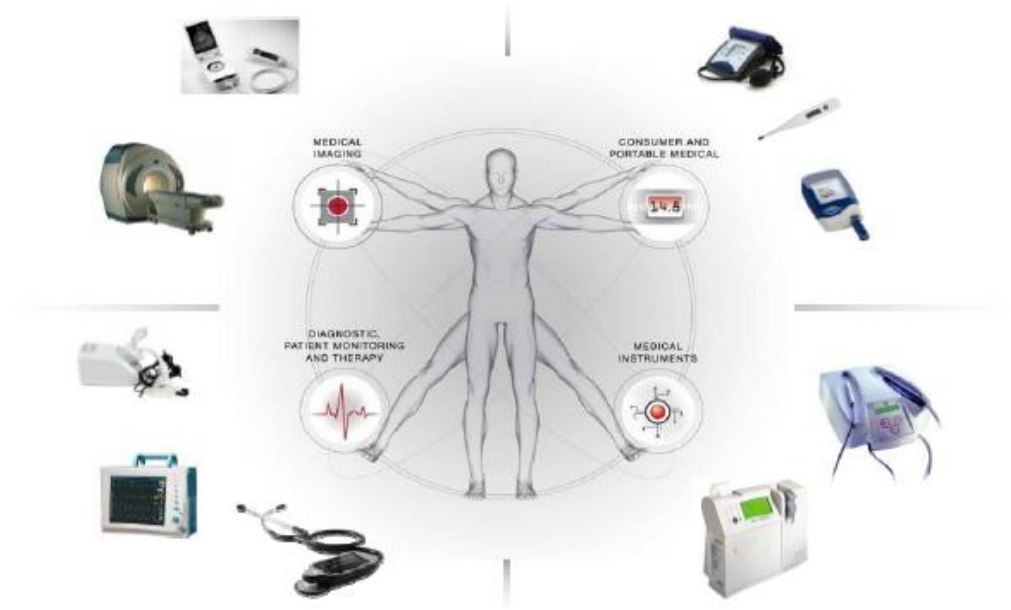


Figure 1 An early Classification of the Medical Electronics Industry

Source: Texas Instrument, Inc (Srinivasa, 2011)

The main idea is that healthcare services are shifting from a centralized, hospital-oriented model towards a distributed patient-centric model. It is this distributed nature that makes it all the more relevant for future blockchain applications.

We distinguish hereafter between four broad categories of medical electronics, namely medical imaging (1), consumer and portable medical (2), medical instruments (3), and diagnostic, patient monitoring and therapy (4). We focus more particularly in this section on the first category that now intersects with the IoMT (Internet of Medical Things)

Figure 2 Examples of Personal Health Devices (Source: Srinivasa, 2011)

Personal health devices are characterized by miniaturization, portability, wireless functionality, customization and personalization. The ingredients of success are ultra-low power consumption, battery life, reduced size and cost, and the existence of microcontrollers (ibid.). Market drivers[1] are aging population, rising healthcare costs, new lifestyle diseases (e.g. obesity), growing awareness amongst consumers (e.g. preventive health and wellness management), shortage of trained medical staff (Srinivasa, 2011; Frost & Sullivan, 2012).

The Internet of Things (IoT), often presented as a revolution (Evans, 2011), consists of a network-based concept that functions with the help of sensors, electronics, and software applications. It enables so-called connected objects, also called IoT devices to gather and exchange data. In the medical arena, wearables and sensors that keep track of changes in pressure, temperature, motion, light, and sound, are particularly adapted to the present needs of the healthcare industry. What is needed is a system-wide solution through the interplay of the IoT market, in order to support "seamless mobility, load balancing, efficient scalability, low-latency response, and developing applications utilizing services offered by multiple sensors and gateways" (Rahmani et al. 2018, pp.643-4). The IoT market is a truly global one, and emerging economies (the BRICs) are pushing the market forward, and increasing competiveness levels.

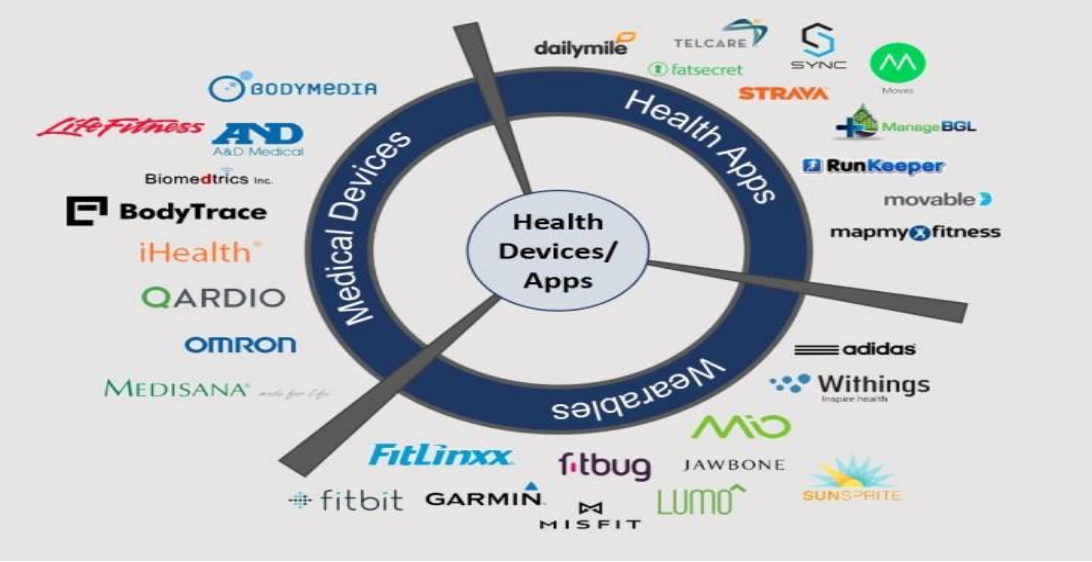


Figure 3 Major players in the health devices/apps marketSource: Bodenheimer (2017)

[1] Key players in the market include Devices, Inc., Cypress Semiconductor Corporation, Fairchild Semiconductor International, Inc., GE Healthcare Pvt. Ltd, Maxim Integrated Products, Inc., NXP Semiconductors N.V., On Semiconductor Corporation, Philips Healthcare Pvt. Ltd., Renesas Electronics Corporation, Siemens Ag, STMicroelectronics N.V., Tekscan, Inc. and Texas Instruments, Inc. A.

The IoT ecosystem is forecasted to reach $3.04 trillion and 30 billion connected "Things" by the year 2020 (Business Wire, 2014) while the total healthcare IT market is projected to reach $50 billion by 2020 (IHS, 2015). Wearables today have become deeply interlinked with the rise of the Internet of Medical Things (IoMT), a fast growing sub-segment of the IoT market:

> Wearable devices are currently at the heart of just about every discussion related to the Internet of Things. The requirement for self-health monitoring and preventive medicine is increasing due to the projected dramatic increase in the number of elderly people until 2020. Developed technologies are truly able to reduce the overall costs for prevention and monitoring (Haghi et al., 2017).

The IoMT facilitates the measurement of critical elements such as vital signs (Peng et al., 2012), electrocardiogram (ECG) and electroencephalogram (EEG) measurement, skin temperature etc. Bodenheimer (2017) explains that the IoMT allows people to monitor health parameters, such as body weight, heart rates, burned calories, sleep patterns, blood sugar levels, and a variety of fitness-related metrics as well as monitoring of nutrition and medication intake. He sees numerous opportunities in the use of blockchain technology applied to healthcare, such as "more collaborative patient engagement, reconciliation of data across different silos, health information sharing, and quality data reporting". He envisions a health care system wherein patients "create and manage their different providers and family members, and "caregivers can view, edit, and share an integrated and centralized personal health record". In spite of the revolutionary or foundational nature of blockchain technology in the healthcare sector, he recognizes we are still in the early phase of testing.

Likewise, for Rahmani et al. (2018, p.642),

> [I]t is no longer sufficient enough to design just standalone wearable devices, instead it becomes vital to create a complete ecosystem in which sensors in a body area network seamlessly synchronize data to cloud services through the IoT infrastructure.

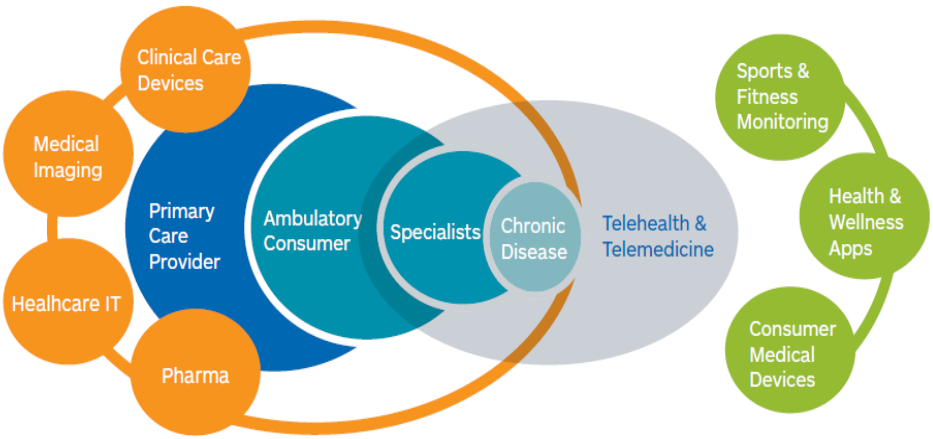


Figure 4 Health IT ecosystem in 2040 (Source: IHS, 2015)

The above figure forecasts the Health IT ecosystem in 2040. However, to be fully complete, key areas, such as genomics, DNA sequencing, and health blockchain apps are arguably missing (Brennan, 2017; Stanganelli, 2016; Lin 2017). As Stanganelli (2016) argues "[t]he inherent provenance benefits of blockchain are allowing the healthcare and life-science industries to indelibly record medicinal and genomic data that will effectively combat counterfeit pharmaceuticals and protect intellectual property".

Conclusion

As a foundational technology, blockchain technology has the tremendous potential to open doors for enhanced interoperability, and allow for more performant, better managed, and easily transferable electronic health records across data silos, institutional boundaries and national jurisdictions. The booming market for consumer medical electronics and the advent of the Internet of Medical Things, are a testimony of the transformation of the healthcare system toward more self managed and patient-centric models, and form a new experimental field for emerging blockchain health applications. By 2020, the global healthcare landscape will likely have been profoundly redesigned since the beginning of the millennium.

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