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Could Blockchain Technology Empower Patients, Improve Education, and Boost Research in Radiology Departments? An Open Question for Future Applications

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Abstract
Blockchain can be considered as a digital database of cryptographically validated transactions stored as blocks of data. Copies of the database are distributed on a peer-to-peer network adhering to a consensus protocol for authentication of new blocks into the chain. While confined to financial applications in the past, this technology is quickly becoming a hot topic in healthcare and scientific research. Potential applications in radiology range from upgraded monitoring of training milestones achievement for residents to improved control of clinical imaging data and easier creation of secure shared databases.

Keywords Blockchain · Education · Big data

A Brief Overview of Blockchain

When Did It Start?

The concept of blockchain was first introduced in a white paper published in October 2008 by an Author or group of Authors, under the pseudonym Satoshi Nakamoto. The paper posed the mathematical basis for the Bitcoin cryptocurrency, introduced in 2009 [1]. Since then, blockchain technology has been mainly deployed in finance. More recently, it has gained considerable attention in the scientific community, with an increasing number of publications over the years, which have proposed its use as a novel method for valuable data management and recording [2–4]. Indeed, non-financial applications of blockchain technology are currently emerging in the fields of healthcare, education, and information sharing [2, 5].

What Is It?

Blockchain technology is a distributed transaction database in which interconnected computers—nodes of a peer-to-peer network—cooperate as a system to store a growing list of records encrypted as a single unit, or block, and then chained together. Blocks consist of data containing the details of transactions between users. A transaction is basically a string of data and it can contain any kind of information.

How Does It Work?

The core component is represented by the distributed ledger, a synchronized digital database that can be shared across a multiple sites, countries or institutions. All nodes have an identical copy and participate to transaction validation through a consensus mechanism, without the need for an intermediary or centralized authority. The widely utilized mechanism to achieve consensus is the proof-of-work algorithm, requiring computational effort to solve a challenging mathematical cryptographic problem. Once a transaction is validated, it is stored in a block, containing its details along with a timestamp (a unique identifier) and a cryptographic hash (a mathematically generated digital signature) of the immediately previous block. Thus, the cryptographic hashes establish the one-way order of the blocks and act as the chaining mechanism. Blockchain also relies on the concept of asymmetric cryptography, as each node in the network uses two keys: a public key, used for encryption, and a private one, for decryption and data access. Another key feature is immutability. Indeed, data can only be added to the blockchain in a sequential order which cannot be easily modified. Thus, once data is appended, it becomes a permanent and unchangeable segment of the blockchain.

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Blockchain and Healthcare

A blockchain can be employed as a digitalized, distributed cryptographic database where medical data could be stored and managed in a secure fashion [6]. Due to the high storage volume required, it could not be feasible to hold all information on a blockchain in this setting. Therefore, recent publications have proposed to store only index information and transaction records, mainly to allow patients to define access permissions and for sensitive data sharing traceability [7–10]. Indeed, the main field of healthcare research promoting blockchain implementation regards its use for electronic health records [11–14]. Among these, a project developed by the Massachusetts Institute of Technology Media Lab and Beth Israel Deaconess Medical Center has been successfully tested. It proposed a permissioned blockchain (only accessible by authorized users or institutions) in which electronic health records are stored in a local database whereas data authentication, access, and storage location are contained in the blockchain [15]. In a different experience, Yue et al. proposed a smartphone application that enables patient to manage and control the sharing of healthcare data on a blockchain platform [16]. Recent projects have also regarded storing and processing of different types of healthcare-related data, such as genomic, imaging, clinical trial, billing, and insurance claims, drug supply chain and biomarker data [17–21]. Specifically, in clinical settings, prototypes of blockchain have been proposed for data management of diabetic and oncological patients and for dermatologic image storage and distribution [22–24]. Moreover, mobile apps and wearable devices are providing an increasing amount of lifestyle-related data which may be integrated to electronical health records through blockchain solutions [25, 26]. Therefore, this technology could facilitate the secure collection of health-related big data ensuring their integrity and authenticity while enabling more efficient interoperability between patients, health care professionals, and researchers.

Blockchain and Radiology

Blockchain technology can offer radiology departments a platform to improve data management, ranging from clinical activities to educational and research purposes.

Could It Empower Patients?

Currently, imaging studies are stored in centralized networks such as medical institutions or third party service databases, while printed records and physical copies (e.g., CDs or DVDs) are often employed to transport them between hospitals or healthcare providers. This exposes patients to potential delays in their care pathway as errors may lead to incomplete study transcription on a physical copy, or these can be damaged over time. Furthermore, medical imaging data are vulnerable to harmful tampering. Patel described a blockchain framework that enables the patients to own their imaging data and control healthcare provider access privileges, without the need for an intermediary [27]. In his proposal, there would be no medical image storage on the blockchain as transactions would represent a list of users with permission to access each study. In a final note, it is possible to hypothesize that a future implementation could be the creation of more accessible records of radiation exposure for both patients and healthcare providers.

Could It Improve Education in Radiology?

In the recent literature, proposals for blockchain applications to medical education can be found. The aim is to record and verify curricula data while making it more easily accessible to students, teachers, and institutions [28, 29]. In this light, we believe that the introduction of blockchain technology in the academic radiology setting could be also valuable to monitor resident progress through the years. Reports and procedures performed during the different rotations, as well as test results, congress and course attendance could be easily archived and also serve as digital proof of acquired competences. Such a tool could also optimize the use of administrative resources by reducing bureaucratic workload, with the added benefit of increased transparency, as records stored via blockchain can be automatically verified. These data could even be logged after the end of residency programs, assisting the current systems for monitoring continuing medical education. Finally, a blockchain implementation in the educational system could be in the assessment of faculty member competencies and academic performance in a secure and unalterable fashion.

Could It Boost Research in Radiology?

One of the issues currently limiting research in radiology is represented by the challenge of sharing patient data and create large imaging databases. This is especially true for the development of radiomics and artificial intelligence applications, of great interest in recent years as shown by the many published studies across different fields in medical imaging [30–33]. Creation and access to such databases could greatly boost validation of these techniques and development of more data hungry algorithms (i.e., deep learning) [34]. Blockchain could be used to solve some of these challenges. Firstly, this technology could provide a reliable method for management of patient consent to image sharing between institutions and a way to guarantee the possibility of retraction of such consent at any time. This knowledge, in turn, may aid in obtaining patient acceptance as they would rightly empowered in the management of personal data. A second application could regard the control of access to the databases, providing a secure means of tracking and storing this information. In fact, it could grant permission to individual users (i.e., physicians) or institutions (i.e., hospitals, imaging centers) to view image studies through transactions.

Potential Limitations and Possible Solutions

Security and privacy are the major strengths of blockchain, but they could turn into weaknesses in a multidata-driven healthcare distributed system. Specific implementations and appropriate solutions have been proposed to mitigate these challenges [6].

In a public blockchain network, user identity is protected with the use of the public key, but through a deeper analysis of the publicly shared transaction data associated with that public key, the user may be identified. This issue is critical especially for healthcare applications, for whom it has been proposed to adopt permissioned (or private) blockchain that enable only authorized users or institutions to participate. Moreover, in permissioned blockchain, only restricted members can have permissions to append data but permissions to read data can still be public or restricted to some or all participants of the network [13]. In this scenario, a blockchain-based framework could be adopted by healthcare organizations, in order to fulfill privacy regulations and to achieve high standards of security.

Another problem related to privacy and security could be found in patients' key management. Indeed, it could be difficult for patients to access or give permissions on different blockchain medical institutions if several passwords are needed. Moreover, they might be unable to recover keys in case of emergency conditions, dementia, or accidental loss of public/private key. A proposed solution involves a trusted agency or a special government organ in quality of administrator and authority management system [23]. This strategy could enhance blockchain's use of public-key infrastructure (PKI) providing a secure identification method across different medical institutions and assuring instituted measures for a secure key management [34].

Conclusion

Although blockchain is in its infancy, we should become aware of this ground-breaking technology and of its many potential applications in healthcare, including medical data storage, distribution, and protection. It could drive innovations acting as a vehicle to increase imaging data value for patient care as well as educational and research aims. Nevertheless, evidences of factual applications of blockchain in the field of radiology are still limited, but further investigation of this technology would definitively be worth the effort.

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