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Application of Blockchain Technology in Healthcare

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ABSTRACT

A reformative innovation in the field of information technology, the blockchain is perceived as a secure, distributed digital ledger that stores data quietly and promises to govern numerous capabilities of industries in the future. Incorporating blockchain technology in healthcare will foster secure and effective data management, data exchange, and provide a platform for the amalgamation of healthcare services. The purpose of this paper is to bring forward the potential implications of the blockchain and its applications to safeguard the privacy and security of patients' records, thereby diminishing the risk of data breaches in interoperable systems of distributed healthcare. Significantly, the principal objective of the research paper is to present the ethical and socio-economic aspects of health data privacy and their anonymization issues. The basic tenet of the paper revolves around two key areas: proposed solutions to address the potential abuses and data privacy challenges within blockchain-DLT based healthcare ecosystems and the incentives that may be driving significant multinational companies to incorporate the healthcare blockchain-DLT ecosystem.

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1.0 Introduction to Blockchain Technology

One principal architecture for blockchain applications is that it is arguably appropriate to deal with interconnections and under-structure systems from the perspective of usage. Bear in mind that this study holds the application of blockchain technologies oriented to healthcare technologies, and health big data and electronic health data have started to be among the most recent important structures to be included. Thus, this publication presents blockchain entirely considering the paramount matter of healthcare technologies. for transforming domains and various platforms, mostly relying on systems and utilities from around the world. The cross-utilization of blockchain technologies may be used in different sectors, such as Bitcoin platforms, an important segment, or patient privacy. The first is an important idea. Cashless models that use not only steal digital identities on the increase, such as medical service providers, are also affected. In conclusion, the purpose of using the blockchain system is to finally Balkanize or seek a connected network for all domains, rather than creating isolated systems for each sector. Blockchain integration can also be beneficial by identifying arising issues and avoiding blockchain isolation for each particular need.

Blockchain technology[1] has evolved into a disruptive technology that has the potential to transform a variety of industries by providing an intrinsic decentralized structure. Blockchain applications seek a wide array of user cases, including financial and banking systems, supply chains, and records management. In healthcare, significant progress has been made through the employment of blockchain technologies in several cases, such as clinical research studies, supply chain management, and telemedicine [2]. Apart from traditional applications, blockchain ensures that the proposed health-related transactions of data sharing and healthcare can be performed trustworthily without compromising privacy using the Public Key Infrastructure (PKI) system. Smart contract code provides an immutable and auditable source of records. Therefore, it is accepted as a reliable method to ensure trustworthy medical data sharing. The primary purpose of this study is to investigate current advancements and set forward a comprehensive "technological review" in a neatly conducted global study to show how blockchain technology can be exploited in healthcare technologies and the value it creates, the challenges it encounters, and the subjects for future research.

1.1 Definition and Key Concepts

To learn more about how blockchain works, we can also include additional information related to the distributed ledger technology (DLT) that lies at the base of blockchain. The DLT uses a network of nodes to allow transactions and agreements to be stored in such a way that they can be protected cryptographically. Once correctly implemented in the healthcare sector, blockchain will encourage facilities to increase the number of agreements and transactions that they can prove evidentially, meaning it will encourage accurate record keeping by clinicians and patients. In addition, the DLT has the capacity to allow for records that are stored upon it to be shared and authenticatable across multiple facilities. Through these ideas, a standardized approach for the format and storage location of healthcare records could be developed, even in the global health domain [2].

Blockchain was first introduced in 1991 by a group of researchers who wanted to implement a secured time-stamping service. It literally means a "chain of digital blocks" [3]. The basic architecture of a blockchain is relatively simple; however, its potential applications are numerous and diverse. A blockchain can be considered as a global decentralized database that stores information in the form of transactions. Transactions are grouped together into blocks, each of which is appended to an already existing blockchain (i.e., a sequence of blocks) using cryptographic techniques. In practice, each block contains data, the identifier of the previous block in the chain, and a cryptographic hash of the block itself (the so-called block header) [4].

1.2 Brief History and Evolution

The adoption and application of blockchain in various domains, including healthcare, date back to 2017. Initially, the properties of security, transparency, and immutability quickly garnered attention from health industry executives. Their demands primarily motivated the initial use of blockchain in healthcare, such as health information exchange and interoperability, patient identity and consent management, clinical trials and regulatory compliance, supply chain management, and academic research [2]. Some health services, such as Genobank, provide a secure platform for both consumers and molecular research entities to store, rent, and trade genetic information without compromising privacy. Despite such interest and initial investment, blockchain technologies in healthcare are still primarily at the proof-of-concept or pilot phases. In terms of specific technical challenges, connectivity with existing health services has been cited as the greatest difficulty in implementing real-world applications. Blockchain applications in healthcare will likely need to focus more on nonoperational side chains to mitigate these interoperability issues. The implementation of blockchain is dynamically evolving .

Blockchain is a distributed ledger technology used to securely manage and exchange digital assets without relying on central intermediaries [5]. Supported by various consensus algorithms, a blockchain network is capable of forming and maintaining trust and data integrity as all nodes in the network are incentivized to behave honestly. Blockchain has received attention over the past decade for its application in digital currencies, such as Bitcoin and smart contracts. Ethereum, a decentralized platform based on blockchain, extends the ledger to support programmable smart contracts that can autonomously perform decentralized crowd funding campaigns and maintain digital assets and other decentralized applications.

2.0 Challenges in the Healthcare Industry

Market competition measures have been applied to assess the impact of new blockchain technologies on traditional technologies [6]. These market competition measures also had a positive effect. However, even more promising, the design of the diffusion of innovation models suggests that blockchain could reduce the impact of healthcare barriers, such as the lack of technical expertise and legislative or regulatory concerns, such as privacy and liability in reality [7]. As other research has demonstrated, the Internet of Things (IoT) and analytics would have a major disruptive effect on the healthcare industry by collecting and delivering vital patient information at an unprecedented scale. However, the implementation of these technologies is both slow and challenging. It is the consensus of experts that implementation of these technologies is held at bay by the need to resolve policy issues, data privacy concerns, and data integrity, to name a few. We believe that many of these concerns can be resolved using blockchain technology. The decentralized nature of blockchain combined with its verifiable and immutable data storage could result in better data protection, and its transparent data flow could assist in improving policy issues, the flow of information between government and providers, and patient care systems [8].

2.1 Data Security and Privacy Concerns

Blockchain technology emerged over a decade ago and has attracted increasing attention from various sectors; this has led to a significant rise in publications, including many in the healthcare sector. However, data security and privacy concerns are important urging factors for the healthcare sector to shift focus from traditional centralized networks to more secure, transparent, and efficient decentralized blockchain-enabled networks. Blockchain has geopolitical and social implications for specific health data security and privacy concerns. The healthcare sector stores Highly Personal and Socially Sensitive (HPSS) data; therefore, the digital healthcare sector is a leading target for cyber attackers [9]. Consequently, regular threats such as hacking, phishing, data breaches, and computer malware pose serious threats to the healthcare sector. As a result, only blockchain technology has accelerated the digital strategy agenda for treating and tackling data security and privacy concerns in healthcare.

There are considerable security and privacy concerns that can potentially arise within the healthcare sector due to cyberattacks, such as ransomware, Distributed Denial of Service (DDoS), and “Man-in-the-Middle” (MITM) attacks[10][11]. The advent of such cybersecurity issues, particularly in the wake of the COVID-19 pandemic, has prompted researchers to seek alternative methods of processing, securing and analyzing data with relatively high levels of confidence that it would protect “Formidable data and Systems in Healthcare” (FdaSH) against vulnerabilities. In order to address such threats, alternative ways of processing, storing, and analyzing healthcare sector data would include new concepts and technologies such as blockchain-enabled sustained learning of advanced communicative healthcare systems and the Internet of Things-enabled advanced healthcare communications and instruments. Blockchain is a growing network for storing and exchanging data, by which data sharing, data updating, and data privacy are safeguarded. The underlying principles of blockchain are decentralization, immutability, auditability, confidentiality, and security of transactions, by which the transactions and records of all assets (healthcare data) remain safe and immutable from intentional and unintentional tampering. When cybersecurity threat perception is growing alarmingly, enabled and insightful decisions will stem only from predictive analytics with the help of blockchain technology. Therefore, in this study, quantum entanglement-based trusted secured learning with blockchain-enabled advanced healthcare systems and processing has been demonstrated and proposed, where quantum-based entanglement brings about near-fool-proof security and privacy.

2.2 Interoperability Issues

Smooth generation and exchange of data increases record access and privacy in interoperable systems. Blockchain (BT) technology, where transactions are recorded in blocks, is combined with cryptography for secure and immutable data storage [5]. In the design of blockchains, the effects of privacy protection, infrastructural decentralization versus the composition of consensus algorithms, ecosystems, and storage systems can be anticipated and mitigated. Specialized, or biometric, data are integrated into the care variant of genetic data; thus, cryptography and access control of primary health data. Secure data exchange and sharing are possible between multiple across-chain BT. In the case of ambiguous data or data leakage, it could be more suitable for patient-provider services in healthcare.

Several studies have addressed concerns about the slow progress of HIE, digitalization, and technology use in patient care, as well as data insecurity and lack of privacy [12]. To enable the medical industry to profit from the global exchange of clinical information, it is essential to take a closer look at the persistent interoperability issues often derived from standards for data formats and terminologies. Interoperability is a challenge with parts of BT.A comparison with primary data sources is suggested where network effects and policy implications make it difficult for health care providers to comply with the regulations [13]. Today, large technology companies, such as Google, Microsoft, and Apple, tend to dominate care provision with EHR or mobile devices, shaping supply chains for medication and metamedicine. In the case of serious implications for patients or inadequate and erroneous diagnoses, centralization or monopoly with private entities should be tempered. Better interoperability in medical networks is required.

3.0 Benefits of Implementing Blockchain in Healthcare

Blockchain technology has the potential to improve the current unsatisfactory system for sharing patient data. Existing non-interoperable systems complicate the integration of different data sources, such as electronic and personal health records, which hinder the availability and access to health information. By improving the interoperability between different systems for information exchange, blockchain technology can provide a secure and reliable method for referring back to previous visits, surgeries, medications, diseases, and their treatment aspects. Currently, not only written reports on previous health problems during hospital visits, but also tests, images, images, and any first-hand account of past patients' medical history are digitized. Blockchain supports users by reflecting on their previous experiences and possibly revising the initial examination [14]. To improve both services and security protection, highly diversified data other than patient status are stored. By identifying the dangers of stealing patient information or tampering with medical records, blockchain reduces the risk of exchange compared to current systems.

Among the numerous benefits of implementing blockchain technology in the healthcare sector, four are worth mentioning: improved interoperability between different systems for information exchange, ensuring data security and privacy, and enabling better drug traceability in pharmacare [1]. Despite differences in the technical details of currently available blockchain platforms, all of them adhere to the same principle. This creates an irreversible, transparent, secure, and tamper-proof chain of information blocks by leveraging cryptographic principles. Because the blocks are directly linked through a unique hash, any unapproved changes made to any data in a blockchain will invalidate the entire transaction data, thus leading to a red flag to prevent incorrect information transactions from proceeding [15]. This technology is being applied to better manage unstructured data and, more importantly, guarantee data security and privacy.

3.1 Enhanced Data Security and Integrity

Another approach to the robust model is to use the technologies like big data and artificial intelligence on Patient Health Records (PHR) that help the patients to get healthcare from the healthcare providers which is very useful for them. In practice, blockchain provides the most appropriate design for PHR storage, security, interoperability, and sharing and offers a preservation and resilience option among business cloud computing platforms. Using Big Data and AI on health records for patients is categorized as specialty, and by using a real-time basis, it can be found easily at the same time. In addition, this data can also be maintained by harnessing more research productivity and can be used as record linkage scientists.

[10] [16] One of the most important benefits of using blockchain technology in the healthcare sector is enhancing the security and integrity of managed data. Data safety and patient privacy are important aspects of storing and sharing healthcare-related data. In contrast to the newly developed centralized health record-keeping systems, blockchain technology offers real-time data exchange among network members with higher security and reduced privacy concerns. Using hash-based Merkle trees and cryptographic links, data blocks are linked, which can easily verify the data-sharing process. As a trustworthy technology, blockchain cannot only provide privacy in the presented model but also improve network operations because without the interference of a third party, the provided data actually makes sense. Consequently, proper management and immutable documentation are provided in the most desirable way.

3.2 Improved Interoperability and Data Sharing

Some applications and proposed projects, such as MedRec [17], MedicalChain [18], and MedBlock, have demonstrated how blockchain can resolve the problem of data standardization and medical informatics in the

healthcare industry by building a consortium of medical practitioners, insurance companies, and patients to ensure encrypted, verifiable, and controlled information sharing/review over the chain. Other applications, such as Blockchain Health, ASTRI, and Bloq, have proposed blockchain health systems that can share hash codes of health records with researchers for analysis through smart contracts [2].

According to a recent report prepared by the Healthcare Information and Management Systems Society (HIMSS), interoperability is one of the main challenges faced by healthcare stakeholders. Blockchain offers improved interoperability in the healthcare industry by providing a decentralized model for storing and sharing medical information. By decentralizing health data, researchers can access more participants and receive more accurate data, which will in turn result in more reliable results for any health research conducted. It is also believed that blockchain, if adopted in traditional medical research, could increase the overall quality and transparency of research and release findings to the public more quickly than the current research frameworks. For example, researchers should encounter a negative correlation between a particular medicine and a health outcome that was unanticipated, and the medical journal can now safely and publicly release these findings because of phase 1 testing on human adults. This could lead to the faster release of more accurate results to the public.

4.0 Use Cases of Blockchain in Healthcare

In the second use case, studies present a comprehensive review of different applications used in the area of healthcare, such as health data recording, health data sharing, managing access to personal health data and electronic health records (EHR), and patient-controlled collection and sharing of sensor data. Popular platforms in the literature for healthcare-related blockchain applications are also presented according to the types of private, public, and permissioned, including Ethereum and Hyperledger fabric, whereas there is a preference for permissioned and consortia when compared to private and public. The results also show that EHR are the most affected healthcare information system, followed by Patient Health Records. [19]

Blockchain has seen a recent surge in popularity, owing to its versatility, transparency, and security. It is rapidly becoming an integral part of various fields including healthcare, pharmaceutical supply, and clinical trials. The ability to store and transmit data by building encrypted blocks chained one after the other in an immutable and secure manner is very attractive for these industries [20]. Studies have shown that the pharmaceutical supply chain and patient monitoring in hospitals can benefit greatly from these features, as blockchain can record important transactional data and ensure the integrity of sensitive data.

4.1 Electronic Health Records (EHRs)

The biggest problem for EG is the interoperability issues and constraints imposed by different countries and healthcare providers. However, healthcare professionals do not appreciate the duplication of zeroes and ones for the transmission of the same cryptographic process. Some researchers on the Portuguese healthcare system showed that with a blockchain, Portuguese citizens could become responsible for sharing their EHRs. The results showed that blockchain is a reliable replacement for the existing versions. The manufacturing industry usually decides how electronic health records are being transmitted, while healthcare professionals decide how the health system is being managed. All these are necessary to ensure that the blockchain is positioned in written consent. Independent of all the principles above, these two articles show another significant strength of a blockchain under the SHA-256 consensus algorithm for retrieving and securing EHRs.

Blockchain refers to encryption technology initiated by hash-locks and cryptographic encryption technology to set up secure and tamper-resistant distributed storage of computer networks. EHRs refer to all relevant health record information of a particular patient, spanning all levels of care and facilities, but are generated by all healthcare providers across time [3]. Healthcare has not adopted blockchain technology, but early evidence and speculative reports suggest that it has breakthrough potential. We reconstructed the findings of our experiments with patients conducted in 2020 and agreed that a structured and honest dialogue must start to facilitate better design and adoption of blockchain systems in healthcare [14]. Security and the relatively inexpensive approach to implement a proof of work consensus algorithm make the blockchain advantageous for hashing EHRs in healthcare informing systems. Using blockchain as one of the tools in a system, EHRs can be shared across different healthcare systems [2].

4.2 Clinical Trials and Research

The proposed implementation of ATCARS in healthcare will provide easy integration with other connected healthcare blockchains, for example, the blockchain front-end system designed by the authors with the integration capability and the GUI presented by trained professionals in clinical trials and blockchain technology. According to Reed and Reid, blockchain technology represents an alternative to traditional systems, and the implementation of Bitcoin has brought about the realization of electronic cash and innovation through the overload of traditional systems. This has significance in pharmaceutical supply chain management, which is a vital component of the global healthcare system. Blockchain focuses on trustlessness and integrity in transactions, which are the most important properties associated with its application in clinical trials and research [2].

[21] Research and clinical trials are essential methods used to diagnose and treat various diseases. Blockchain technology has been applied in clinical trials for actions such as validating documents, managing user roles, monitoring clinical research activities, and ensuring the authenticity of the collected data. Certain technology companies and research organizations have begun using blockchain technology in clinical research environments. One successful application of blockchain in clinical trials is the management of important digital documents. According to Ray et al. (2016), there will be many applications of blockchain in future clinical trials, such as decentralized data integrity and security standards based on blockchain protocols. They proposed automated transparency in a clinical trial for audit and regulatory support (ATCARS) based on a permissioned Bitcoin blockchain. They focused on transparency in clinical trials and the regulatory activities of different participants in the network [4].

5.0 Regulatory and Ethical Considerations

The EU New Data Protection Law states that patients have the right to control and manage the sharing of personal data between different treatment institutions. This right includes the options for an in-depth insight and the right to transmit the data to another treatment, for example, sending partially anonymized data for anonymized purposes such as public health and medical research. The implemented consortium blockchain based on Ethereum's platform utilizes the SOLID smart contract language, which offers a range of possibilities, such as offering time-controlled consent with the option to retrieve data or the option to retrieve metadata during the inclusion of the data in the blockchain. Special consideration is given to the patient's privacy aspects, and permission to enter data separately from the respective treatment cannot be claimed inadmissible by the treating physician according to the GDPR rules.

Personal Identifiable Information (PII) is considered protected and one of the most expensive data elements on the Dark Web, whereas a few incidents have been reported on stealing and selling medical records [15]. Blockchain uses cryptographic techniques to ensure that the block contents are completely protected and unchangeable. Therefore, once the data are written on the blockchain, it becomes impossible to modify it (thus making the information immutable) and everything is traceable, making it impossible to erase any data [20]. Hence, distributed ledger technology makes the system completely secure. In addition, blockchain is becoming part of the solution in healthcare systems, including epidemic monitoring, medical system security, and the wellness industry [22].

5.1 Compliance with HIPAA and GDPR Regulations

Blockchain databases are creating a global ecosystem of distributed computational, storage, networking, and consensus resources, promising fertile ground for attackers. Without proper preventive measures, adversaries can manipulate or disrupt distributed networks, resulting in concerns about security and patient trust. They can also use misappropriated processing and network capabilities for other attack services and networks. For these reasons, regulatory compliance is crucial in upholding trust in blockchain-based healthcare systems and mitigating consequences. It is also clear that the value of technology that cannot comply with existing laws and policies is seriously diminished, making legal and policy analysis imperative when looking at blockchain systems in health. Researchers should critically consider GDPR and HIPAA when implementing new blockchain hardware or software.

[23] Patient confidentiality and the privacy of sensitive personal information are two of the top concerns in healthcare applications of blockchain. The EU General Data Protection Regulation (GDPR)and US Health Insurance Portability and Accountability Act (HIPAA) serve as primary data privacy regulations for their respective regulatory bodies. In Europe, GPDR followed in the US by HIPAA are two of the most stringent laws in data protection, making them widely respected worldwide. In line with these requirements, it is crucial

that any proposed blockchain solution satisfies the specific criteria for each legislation to pass regulatory compliance. This study investigates methods of securing and keeping track of sensitive patient information while maintaining GDPR and HIPAA compliance with a self-sovereign software-based identity, medical, and device records management, while encumbering significant computational overhead.

5.2 Ethical Use of Patient Data

A secondary aim of our study was to document concerns regarding blockchain technologies when it comes to healthcare applications. Participants were just as vocal with their anticipation of unintended negative effects of this technology; as such, they raised additional concerns about how it could be appropriated in a healthcare context and in general [24]. This includes methodological concerns, such as whether there will be immediate and widespread buying by the many stakeholders involved. Our intention in this research was to focus on the portrayal of blockchain as a usher for an age of new potential regarding patient data.

Physician participants were enthusiastic about the potential of two main features of blockchain to benefit electronic health record (EHR) applications: data transparency and data immutability [1]. Data transparency allows for easy data validation and tracking and can increase data integrity. It is particularly important for patients to access their own EHR data, especially as digital health technology evolves, and allowing for patient access is increasingly a requirement for healthcare providers. A distributed ledger eliminates the requirement for middleware in a traditional EHR system or clearing house, which streamlines digital health applications across multiple users. Immutability ensures that once a record is added to a blockchain, it cannot be changed. Data integrity and privacy are improved considerably here, even more so than in a traditional EHR database, where there might be one central system of control and a single point of failure, which makes blockchain an attractive candidate for addressing the trust gap in healthcare in a variety of ways.

6.0 Future Trends and Opportunities

The current business architecture for the healthcare industry is constructed around routine data siloes, decoupled data operations, and poor interorganizational relations owing to counterfeit health data [12]. Blockchain technology can be used to resolve these issues in healthcare. Using IT to provide robust clinical care is an effective approach for providing interventions for chronic, self-monitoring, and citizen-focused treatment management through electronic health records (EHR) and a distributed clinical data registry in the collective sense. In the registry structure, responsible authentication nodes or agents must be incorporated into the system. This implies that the proposed blockchain-based medical architecture will help patients, users, and all major entities by offering robust and reliable rights management, actual consent management using a blockchain registered on a clinical record system, and demonstrable EHR consistency (an entirely traceable collection of publication sequences). This transparency minimizes dependence on intermediaries, such as regulatory intermediaries or administrative staff, who will use the ready-to-share medical data in the most secure manner during authentication and agree to bean in or out.

Blockchain technology is still in the nascent stage in healthcare, but its adoption is expanding with the rapid evolution of different technologies and the increasing need for security and privacy in the healthcare sector [19]. To fully capitalize on blockchain technology and develop and grow a vibrant blockchain healthcare ecosystem, providers, payers, regulators, manufacturers, and other healthcare stakeholders must address and resolve several technical, organizational, regulatory, and economic problems and challenges. Two significant categories based on this differentiation define blockchain usage in healthcare: (1) big data-based blockchain applications (that convert and transfer these large computing and storage systems' clinical data or other healthcare-related information), and (2) an Internet of Things (IoT) context in which small sets of globally dispersed data pieces are economic transactions. Blockchain can transform the healthcare industry in several ways.

6.1 Integration with Internet of Things (IoT)

While many works in the literature focus on accepting data but have missed concerns regarding the consistency and accuracy of data, B.-E. Choi et al. research work improved the trust problem of the distributed ledger, the resource allocation problem, and the smartness of the healthcare nodes to be directly proven in Solidity language. A scheme for system success was built by analyzing potentially unused HMI scopes in higher teacher education, such as conflict on focus readings in lectures or points of tension in students' contact situations in team teaching. After system implementation, two predominantly teamwork-based example cases illustrate the

potential of nursing and medical education to enhance HMI competence in an age-progressive, problem-based, and practical manner. The NCAA Information Security Higher Education Program's analyses vouch for the positive reception of the system by higher students and simultaneously expressed recommendations for further improvements. This system advances students' HMI education, which is key for the treatment and care of people with chronic respiratory diseases, as situation insufficiency is considered to be decreased by preventative and early measures taken to identify and control symptoms and barriers that increase them (such as during acute exacerbations).

A blockchain–IoT combined approach can significantly improve health care management. The integration of blockchain and IoT with HL7 (Health Level-7) messaging can ensure the consensus of the entire network on the received data, which improves the security and consistency of healthcare information systems. Blockchain can also be used to help protect the confidentiality of healthcare IoT ecosystems, provide accurate medical information, and comply with research standards of medical practice and laboratory diagnostic data. Other issues arising from the large-scale, dynamic, and dense nature of healthcare IoT systems may be addressed using blockchain technology. In addition, healthcare IoT edge nodes that send their data to the distributed ledger should be ensured to be resource-wise costly. Thus, a smart contract can include a predefined rule for the resources needed for each edge node. Blockchain technology has the potential to disrupt traditional healthcare IoT architectures and provide decentralized and secure networks for scalable and distributed healthcare IoT applications that support patient-centric healthcare models.

6.2 Artificial Intelligence and Machine Learning in Healthcare

Blockchain and AI in digital health records have been exemplified by many solutions. The bet between Cerner and Lumeris integrates Cerner's EHR capabilities with Lumeris, which deploys an AI-based, value-based care platform. IBM Watson in healthcare exchanges information from various sources to offer evidence-based analytics, and was used by Danish hospitals to assess patient records. AI was set with blockchain in projects such as the open online record, SkinCancerNet, Huang and Lu, or personal health record (PH) 528 in IBM cloud health data and several pilot contracts with Nectome, Hcash, BetaHealth, and Solve.Care [25].DBNull.AI integrates research in marketing strategies and enterprise blockchain initiatives, enabling FAIR data in genomics research, real-time genetics, and wearable device blockchain in databases using AI. Blockchains of data banks and research labs are well supported in number, such as Rethink Genomics and DNAstack.findOne_supports philosophy, storing patient data in the blockchain, with attention to scalability, encryption, privacy, security, and defense of third parties. This analysis provides possible suggestions for improving personalized health in the development of common predictive, preventive, participatory, and personalized medicine with AI and blockchain.

The healthcare industry is on the brink of a technological revolution owing to the remarkable capabilities of artificial intelligence (AI) and its related research area, machine learning (ML) [26]. Even in complex applications such as healthcare, AI has excelled, especially in record-keeping, which is important for maintaining a user's health record for patient care and automated billing processes. AI has already proven its potential to develop and maintain medical records, foster the management of patients' digital data, provide telephone and online diagnosis, and more. With the establishment of blockchain technology, an inevitable part of the healthcare system, the integration of this technology with AI and ML can pave the way for more holistic solutions for the healthcare and biomedical research sector. In this context, this study outlines the potential applications of AI and ML via blockchain technology in healthcare and biomedical research.

Conclusion

This study discusses the potential applications of blockchain technology in the healthcare context. It poses numerous challenges associated with the management of health data, including security, privacy, data, and interoperability. It then provides an in-depth discussion of blockchain and how it can solve or alleviate many of these issues. It has covered benefits, challenges, and barriers to the implementation of blockchain from a healthcare perspective and provides some examples of real-world applications outside the sector.

It can be concluded that, if effectively adapted and integrated into the healthcare system, blockchain may reform the healthcare delivery process. This study suggests that this exploration may be an initial stage for further research, with a focus on developing and piloting potential blockchain solutions, exploring regulatory frameworks, and combining AI and blockchain. The focus must be on knowledge co-creation to develop innovative and collaborative solutions between healthcare and IT stakeholders.

Blockchain technology is not a golden bullet that can solve every issue with the data management of a healthcare system, but it can be applied to the right areas and help address some of the data-related issues experienced in the healthcare system. The treatment of blockchain technology must extend beyond being something of interest to architects but an area of care delivery focused on revolutionizing health informatics. Ethical considerations associated with blockchain are still under development and require further collaboration. Furthermore, the legal and regulatory infrastructure requires modifications to enable the implementation of this technology.

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