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Blockchain Technology in Health Records Management Evaluating the Potential Benefits and Challenges

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Abstract

Background: The management of electronic health records (EHRs) is critical in modern healthcare, impacting clinical decision-making and patient care. However, traditional systems often suffer from privacy concerns, data silos, and inefficiencies. Nurses, as frontline providers, play a pivotal role in navigating these challenges, necessitating innovative solutions like blockchain technology.

Methods: This systematic review evaluates the integration of blockchain and artificial intelligence (AI) in EHR management. It analyzes existing literature on their potential benefits and challenges, focusing on security, data integrity, and patient empowerment. The study includes various pilot programs and applications within healthcare settings.

Results: Findings indicate that blockchain technology offers enhanced data security, decentralization, and transparency, which can mitigate risks associated with traditional EHR systems. AI complements blockchain by enabling advanced data analytics, improving patient monitoring, and facilitating personalized medicine. However, challenges persist, including the technical complexity of implementation, regulatory hurdles, and the need for standardized practices.

Conclusion: The integration of blockchain and AI presents a transformative opportunity for EHR management in healthcare. By enhancing data security and enabling patient-centered care, these technologies can improve overall health outcomes. Future research should focus on developing robust frameworks for implementation and addressing the barriers to widespread adoption, ensuring that nurses and healthcare providers can leverage these innovations effectively.

Keywords: Blockchain, electronic health records, artificial intelligence, nursing, data security.

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1. Introduction

Medical and healthcare researchers underscore the significance of their capacity to gather and analyze multi-source data to identify potential community health risks, offer case-specific treatments, and administer targeted medicine, thereby facilitating informed clinical decision-making and enhancing the quality of patient care. This information may enhance personal health information systems, including patient health records (PHR) and patient portals. Patients often lack convenient access to their past data, while professionals maintain primary ownership [1,2].

Integrating blockchain, artificial intelligence, and other accessible technology into a business's core is essential for success. To advance medical research and achieve patient-centricity, the industry must use technology to provide user- and customer-focused interfaces and data-driven choices for innovative data processing and enhanced results [2,3]. Artificial intelligence (AI) may facilitate the identification and prioritization of patients for medication monitoring and research, crucial for controlled drug manufacture and expedited timelines [3]. Clinical trial data was assessed using numerical drug design approaches and AI for the repurposing of commercial medications, examining the effectiveness of prescription compositions and dosage measurement [4].

Blockchain enables the creation and management of content blocks termed ledgers, integrating safe and automated data analysis. All health-related information will be securely documented and analyzed, enabling doctors, healthcare providers, and payers to obtain prompt updates. Storing extensive documents on the blockchain, such as comprehensive electronic medical records or genetic data, would be prohibitively wasteful owing to the substantial processing resources needed. This is a significant limitation of blockchain technology, since it complicates data searches inside a blockchain [5,6].

Integrating AI algorithms into the blockchain may mitigate this limitation. To understand health trends and patterns, artificial intelligence started learning and reasoning like to a doctor. It aggregates unstructured data from several sources, including the patient, the radiologist, and the images [7-10]. AI can do intricate computational tasks and rapidly analyze vast amounts of medical data. Nonetheless, several physicians are reluctant to use AI in healthcare, especially in roles that might impact patient health, owing to the substantial capabilities of AI, which has shown the ability to do various dynamic and cognitive tasks more rapidly than humans. The automotive industry has already shown its ability to use AI in the production of autonomous vehicles [11-15]. Nonetheless, several enterprises have already recognized machine learning techniques for fraud detection and financial risk identification, therefore illustrating the maturity of AI [16,17].

The term "Healthcare 1.0" designates this era. Due to insufficient financing, healthcare services were restricted and lacked integration with digital systems throughout this time. Conversely, biomedical equipment had not yet been constructed and lacked integration with networked technological devices. During this era, healthcare facilities mostly used paper-based prescriptions and reports, leading to heightened expenses and time expenditures [18].

The Healthcare 2.0 era was seen from 1991 to 2005. During this period, health and information technology converged to establish the underpinnings of contemporary healthcare systems. This technique included the use of automated monitoring, equipping physicians with imaging tools to evaluate patients' health. Concurrently, new user-driven innovations in the healthcare industry began to emerge with the rise of social media. Healthcare services initiated the establishment of online communities for the sharing of knowledge and expertise, the storage of data on cloud servers, and the provision of mobile access to paperwork and patient records, facilitating continuous access for both providers and patients. During this period, opponents expressed their discontent with the deceptive information and the violation of patients' privacy. Healthcare systems used interconnected electronic health management techniques with clinical imaging technology to provide physicians with more reliable, accurate, and rapid access to patient data [19, 20].

Healthcare 3.0 was introduced along with the Web, enabling users to personalize the distribution of patient healthcare data. User interfaces have evolved to be more streamlined and personalized, enabling enhanced and optimal experiences. Electronic Healthcare Records (EHRs) and wearable and implantable devices were launched, enabling real-time, pervasive monitoring of patients' health. Likewise, EHR systems [7] were developed those integrated independent non-networked systems, including social media networks, for the storage of patient data. The care period expanded, influenced by the concept of Industry 4.0, which incorporates high-tech and high-touch systems utilizing cloud computing, fog, and edge computing, big data analytics, artificial intelligence, and machine learning to establish blockchains that facilitate real-time access to patient's clinical data. The primary objective of this phase is to enhance virtualization, allowing real-time tailored healthcare. The focus is now on collaboration, coherence, and integration, using AI technologies to enhance the predictability and personalization of healthcare [22-25].

This research seeks to evaluate the potential of AI-blockchain in managing electronic health records (EHRs) while highlighting the associated problems and future prospects. This systematic review examines research that provides conceptual answers, experimental findings, prototypes, and blockchain applications for the management of electronic health records (EHRs).

2. Rationale for the Implementation of Blockchain Technology in Electronic Health Record Systems

Electronic Health Records (EHRs) often include data such as a patient's medical history, personal demographics (including age and weight), laboratory test results, and other relevant information [3,26]. Consequently, this data must be maintained in a safe and confidential manner. Additionally, hospitals in many nations, such as the United States, are under rigorous governmental oversight. The deployment and implementation of healthcare systems in practice also pose various challenges. As previously stated, centralized server models are susceptible to single-point attack vulnerabilities and malicious insider threats. Individuals, including as patients, who outsource or store their data in these EHR systems relinquish control of their information. They lack the capability to ascertain who is accessing it and for what objectives, constituting a breach of personal privacy. Such information may be susceptible to leakage by hostile insiders to another entity; for instance, an insurance company could deny coverage to a patient based on disclosed medical data [27-29].

Concurrently, data sharing is gaining significance, particularly as our society and people grow more mobile. Shared data may enhance medical service delivery by leveraging the interconnectivity of various healthcare institutions. Overcoming the "Information and Resource Island" (information silo) will be challenging, particularly owing to privacy concerns and limits. Moreover, the information silo fosters superfluous data duplication and bureaucratic inefficiencies [30].

3. Advantages of Implementing Blockchain and Artificial Intelligence

The coronavirus pandemic may be addressed via many methods using blockchain and artificial intelligence. Numerous practical uses of blockchain technology may be effectively used in combating the coronavirus pandemic. Blockchain technology may facilitate the global monitoring of coronavirus infection dissemination by the installation of blockchain network client software on users' mobile devices. A critical feature of blockchain is its capacity to safeguard user privacy, facilitating the early detection of epidemics while preventing the disclosure of user data [31]. It enhances outbreak and treatment management by increasing the efficiency and transparency of vaccination trials, while also monitoring all fundraising efforts and contributions. AI employs many strategies to attack the Coronavirus. Artificial intelligence may be used to detect viruses and predict their dissemination by examining the aggregated data on environmental variables, healthcare accessibility, and transmission mechanisms. By categorizing coronavirus inside specific localized epidemics, AI may ascertain its presence or absence [32].

Pneumonia, severe acute respiratory syndrome, and renal failure are potential consequences of coronavirus infections. A genome-based neural network, already developed for personalized care, can be instrumental in managing adverse events or symptoms induced by a coronavirus, especially given that the virus's impact varies according to individual immunity and genomic structure, and no singular treatment currently addresses all symptoms effectively. Artificial intelligence may expedite the development of new vaccinations for emerging coronaviruses [6]. As a concluding use of AI, it may be feasible to establish an automated model or connection between medical information and outcomes. Clinical strategies for coronavirus-like epidemics may benefit from the rapid discovery of diagnostic and treatment options provided by these models. A recent White House solicitation to use AI for aiding the US government in addressing the coronavirus epidemic is predicated on these potential benefits [33].

Disintermediation refers to the lack of a centralized authority responsible for the collection, processing, and validation of data and models that are created and disseminated. It facilitates a decrease in the time, errors, and costs associated with process performance for the development and enhancement of a predictive model that underpins clinical practice and risk management. Blockchain-certified transactions and their accompanying data are immutable, meaning they cannot be altered or deleted, hence preserving their authenticity and enhancing the security of the system in which these operations occur [9]. Moreover, the cryptographic framework, the permanence of the data sent throughout the network, and the absence of a centralized authority enhance trust in the system, as the need to maintain this confidence among the participating parties diminishes [10].

4. The Deficiencies of Healthcare Systems

Following the COVID-19 epidemic, existing healthcare systems have under examination. Some existing healthcare systems are now overwhelmed by the COVID-19 pandemic. Currently, there is no reliable data monitoring system available to provide essential healthcare institutions with real-time information about possible epidemics. Most current coronavirus information originates from disparate sources, including the public, hospitals, and clinical laboratories, often including significant inaccuracies due to insufficient oversight. The use of incorrect information complicates the detection of possible outbreaks and the implementation of quarantine measures. A further constraint is the existing laborious and imprecise coronavirus detection process, which often takes several hours to complete the virus testing. This is intolerable given the fast proliferation of the coronavirus. It is essential to rapidly and precisely detect coronaviruses. The processing of coronavirus data using human-dependent medical software is very challenging, particularly when managing intricate patterns and large datasets. Blockchain technology provides potential security solutions to combat pandemics [34-36].

The blockchain establishes immutable transaction ledgers for medical data exchange platforms. Furthermore, the integration of blockchain and smart contract technology obviates the need for central servers to guarantee equity among transaction participants. Traceability and decentralization are two fundamental attributes of blockchain that are absent in conventional security methods. Moreover, blockchain can provide dependable data analytics. The collecting of data is a crucial phase in disease analytics. Ensuring the trustworthiness of gathered data during data collection is crucial for maintaining the high quality of disease data analytics [37]. The use of erroneous data or unreliable database sources might result in biased analytical outcomes, potentially leading to severe repercussions, such as inaccurate diagnoses. Moreover, during an emergency outbreak, several sources of infectious illness data are gathered unprotected from hospitals, the public, or the media, potentially leading to data alterations. These flaws would unequivocally compromise the correctness of the acquired data, diminishing the dependability of the analytical process. Due to its security features, blockchain is highly sought after in these situations to guarantee the integrity of acquired data. Consensus mechanisms in blockchain guarantee the accurate sequencing of data records from sources to destinations (e.g., hospitals or clinical laboratories), hence assuring the integrity of data gathering. These blockchain attributes would guarantee precise data acquisition and hence dependable illness analysis [38].

Lastly, there are privacy concerns with the extensive surveillance of the population to track the coronavirus. Healthcare institutions may surveil users' mobile phones without a judicial warrant to mitigate the transmission of the COVID-19 coronavirus, for instance [4]. Nevertheless, human rights and privacy experts have opposed the proposal because to its potential to reveal persons' private information, which might result in significant violations of civil liberties. To mitigate the dissemination of the coronavirus, real-time monitoring solutions that safeguard user privacy are essential. As privacy concerns escalate, clandestine blockchain networks using Privacy by Blockchain Design (PbBD) technology to tailor privacy levels are increasingly attracting interest [39].

5. Distributed ledger technology

A blockchain may be defined as a decentralized public ledger available to all network participants, whereby all validated and finalized transactions are recorded in a sequential chain of blocks. The chain expands as new blocks are incessantly added to it. Blockchain technology utilizes a synthesis of asymmetric cryptography with peer-to-peer distributed consensus to ensure ledger integrity and user security. Consequently, these time-stamped blocks are linked using a cryptographic hash [11]. Each block generally has transaction records that have been validated by peers, sometimes referred to as miners. The chain is perpetually extended, with each subsequent block appended to the terminus. Each subsequent block includes a reference to the header of the previous block, which is fundamentally a cryptographic hash (e.g., SHA-256). The formation of each block has been characterized by pseudonymity, transparency, and immutability [12,13].

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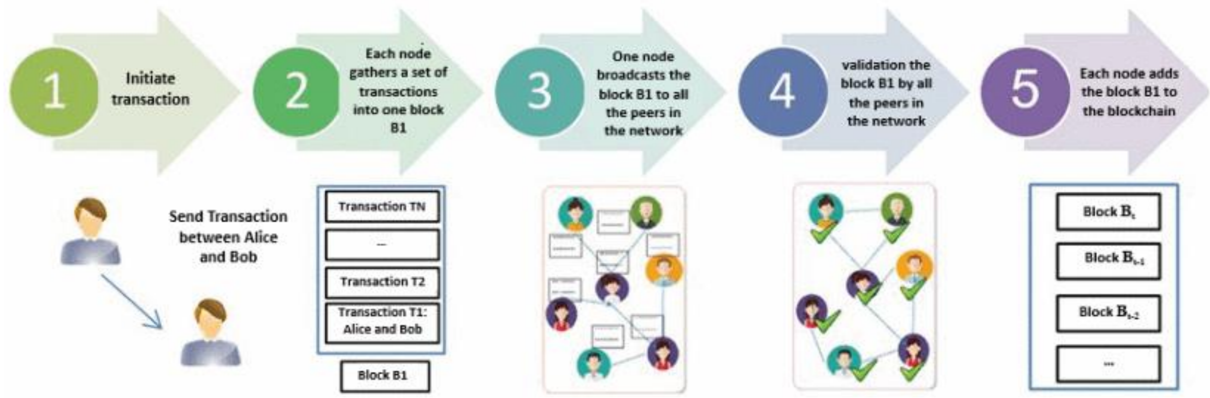

Figure 1. Illustration of the transaction flow inside the blockchain.

6. Algorithms for Achieving Consensus

The blockchain network lacks a one point of authority. The Byzantine Generals Problem [14] is a basic topic, a form of which was developed in the context of distributed networks in 1982. A coalition of Byzantine generals encircles the city, asserting that their likelihood of victory is minimal unless they coordinate a simultaneous assault. There is uncertainty on the presence of traitors in a scattered society. They must decide: to assault or to withdraw. The blockchain network faces a same difficulty.

Global pilot programs have started investigations into the use of blockchain technology inside hospitals, with many initiatives already in progress. Booz Allen Hamilton Consulting, after creating and implementing a blockchain-based pilot platform in the United States last year, was assigned to counsel the Food and Drug Administration’s Office of Translational Sciences on the use of this technology in healthcare data management (Figure 2). The Ethereum Foundation is now executing a pilot project at four major hospitals, using Ethereum to manage data access via virtual private networks. The project's use of IPFS enables encryption and reduces data duplication using off-chain cloud components and cryptographic methods to enhance user sharing [19].

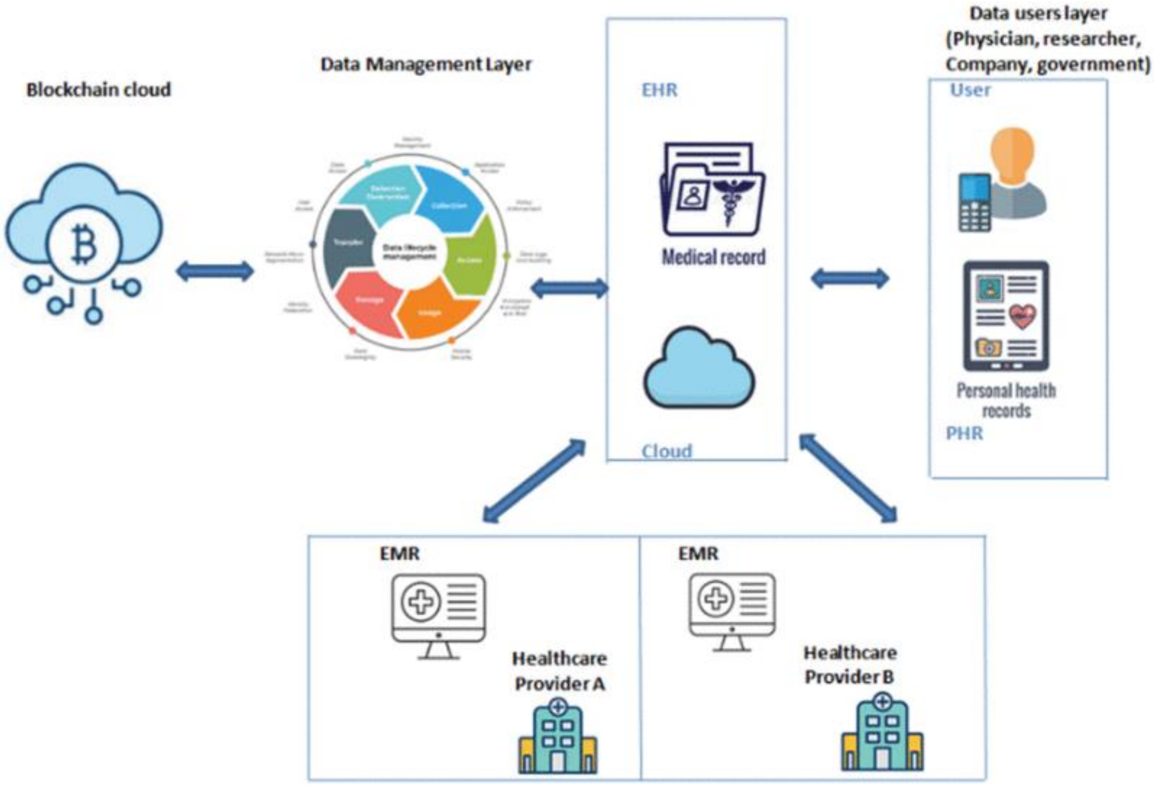

Figure 2. The framework of blockchain technology for healthcare institutions.

7. Blockchain and Data Security in Healthcare

A relationship exists between blockchain technology and the General Data Protection Regulation (GDPR) enacted in the European Union. The GDPR emphasizes the need of using blockchain technology for data portability, traceability, and legal access audits. According to the previously presented information, many concerns may arise, as the real control may be compromised during the technical execution of the smart contract over data. Dynamic consent management [20] is a system that fully complies with the GDPR consent provision. In addition to "private blockchains," Enterprise Blockchains are considered particularly adept at adhering to GDPR regulations, as transactions involving digital records can be modified or erased by individuals or authorities who own and manage the network, utilizing a specific consensus algorithm [21]. Private blockchains are managed by a single firm or organization, with access limited to persons, often corporations, who fulfill specified pre-established criteria or constraints [22].

A firm's management of its private web applications will parallel its management of public web applications. Government agencies, owners of public health data, and healthcare reimbursement organizations exemplify use cases that their technology may solve. These private blockchains are anticipated to have the most substantial influence on the future of healthcare policy and administration. The European Commission's Research & Innovation Program IMI (Innovative Medicine Initiative) Pilot project "Blockchain-Enabled Healthcare," led by Novartis, is exploring the potential of blockchains. It aims to use known standards such as Ethereum while also formulating additional standards as required. The focus is on those capable of implementing initiatives that will directly benefit patients [23].

8. Management of Personal Health Record (PHR) Data on the Blockchain

Personal health records (PHR) have recently started to be developed using data from sensors, including wearable and medical Internet of Things devices. Multiple stakeholders, such as patients, physicians, pharmaceutical experts, and insurers, will gain advantages from real-time AI-driven healthcare analytics [24,25].

9. Conclusion

Blockchain software is garnering significant attention from individuals and organizations of many types and sizes. Its properties, including decentralization, anonymity, permanence, and auditability, have the potential to transform the traditional sector. Blockchain applications are anticipated to use Artificial Intelligence methodologies to transform the healthcare landscape. The process will be both transparent and secure, while enhancing healthcare quality at a reduced cost. We examined many blockchain technologies within the healthcare sector in the suggested framework, identifying significant research initiatives and prospective research opportunities. We specifically examined a suggested framework for health data management and how blockchain technology will empower individuals and facilitate the health data sharing process. Researchers agree that blockchain technology would enable patients to really own and control their data. The blockchain enables the timestamping of health records, ensuring that once they are included in the distributed ledger, they cannot be altered. Patients possess the authority to dictate who may access their data and the rationale for such access.

Healthcare systems in the 21st century will include various technologies that link patients with their providers, such as remote healthcare facilities and wearable gadgets. These systems consistently generate data and are vulnerable to malicious assaults during transmission across many tiers of the underlying communication network. This study examines many research projects proposing tamper-resistant solutions to guarantee the integrity of health data with blockchain technology and artificial intelligence technologies.

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تقنية البلوكشين في إدارة السجلات الصحية: تقييم الفوائد والتحديات المحتملة

الملخص

الخلفية :تُعد إدارة السجلات الصحية الإلكترونية (EHRs) عنصرًا حيويًا في الرعاية الصحية الحديثة، حيث تؤثر على اتخاذ القرارات السريرية وجودة رعاية المرضى. ومع ذلك، تعاني الأنظمة التقليدية من مشكلات تتعلق بالخصوصية، وعزلة البيانات، وعدم الكفاءة. يلعب الممرضون، كمقدمي رعاية في الخطوط الأمامية، دورًا محوريًا في التعامل مع هذه التحديات، مما يستلزم حلولًا مبتكرة مثل تقنية البلوكشين.
الطرق :تقوم هذه المراجعة المنهجية بتقييم دمج تقنية البلوكشين والذكاء الاصطناعي (AI) في إدارة السجلات الصحية الإلكترونية. تحلل الدراسة الأدبيات الحالية حول الفوائد والتحديات المحتملة لهذه التقنيات، مع التركيز على الأمن، سلامة البيانات، وتمكين المرضى. وتشمل الدراسة برامج تجريبية وتطبيقات ضمن بيئات الرعاية الصحية.

النتائج :أشارت النتائج إلى أن تقنية البلوكشين تقدم تحسينات كبيرة في أمان البيانات، اللامركزية، والشفافية، مما يمكنه من تقليل المخاطر المرتبطة بأنظمة السجلات الصحية التقليدية. يُكمل الذكاء الاصطناعي تقنية البلوكشين من خلال تمكين التحليلات المتقدمة للبيانات، وتحسين مراقبة المرضى، وتسهيل الطب الشخصي. ومع ذلك، لا تزال هناك تحديات قائمة، بما في ذلك التعقيد التقني للتنفيذ، العوائق التنظيمية، والحاجة إلى ممارسات موحدة.

الخلاصة :يمثل دمج تقنية البلوكشين والذكاء الاصطناعي فرصة تحولية لإدارة السجلات الصحية الإلكترونية في مجال الرعاية الصحية. من خلال تحسين أمان البيانات وتمكين الرعاية المتمحورة حول المرضى، يمكن لهذه التقنيات تحسين النتائج الصحية بشكل عام. ينبغي أن تركز الأبحاث المستقبلية على تطوير أطر عمل قوية للتنفيذ ومعالجة العوائق أمام الاعتماد الواسع، لضمان أن يتمكن الممرضون ومقدمو الرعاية الصحية من الاستفادة الفعالة من هذه الابتكارات.

الكلمات المفتاحية :البلوكشين، السجلات الصحية الإلكترونية، الذكاء الاصطناعي، التمريض، أمان البيانات.