Blockchain Technology for Electronic Health Records A Paradigm Shift in Healthcare Data Management

Basundhara sharma
Computer Science of Engineering
Arya College of Engineering & Information Technology Kukas, Jaipur Rajasthan
Email: basundharasharma57@gmail.com

***Abstract*—** Healthcare is changing as a result of the use of Electronic Health Records (EHRs) in order to improve access, care quality, and operational efficiency. Traditional EHR systems do, however, have significant drawbacks, including security flaws, a lack of data interoperability, patient privacy issues, and issues with data ownership. Blockchain's decentralized, unchangeable nature has made it an intriguing solution to this issue. By offering a safe, transparent, and impenetrable platform for data management, blockchain can improve the accessibility and integrity of medical records while shielding patient data from breaches and unwanted access. The study investigates how blockchain technology might transform EHR administration and get around the drawbacks of conventional solutions. It examines how blockchain's technical underpinnings—such as consensus processes, smart contracts, and cryptographic hashing—support contemporary healthcare. In order to demonstrate how these features might actually help EHR administration, the article examines a few real-world case studies for blockchain applications in healthcare, including the MedRec project, IBM's blockchain solutions, and Estonia's blockchain-based eHealth system.

The ethical, legal, and regulatory ramifications of using blockchain technology for healthcare data are also covered in the study, with special attention to adherence to data protection laws like GDPR and HIPAA. To enhance patient outcomes and healthcare operations, blockchain integration with cutting-edge technologies including artificial intelligence (AI), the Internet of Medical Things (IoMT), and big data analytics is being investigated further.

Blockchain has a lot of potential, but there are still issues with adoption, governance, and scalability. But by guaranteeing safe, compatible, and patient-focused handling of medical data, blockchain can revolutionize the future of healthcare and build a more reliable and effective healthcare system.

Keywords—Secure health records, medical blockchain technology, decentralized healthcare.

I. INTRODUCTION

1.BACKGROUND

1.1 Historical Context of Electronic Health Records (EHRs)

One of the biggest developments in the medical field is the concept of electronic health records (EHRs), which have replaced paper-based medical data with digital ones. EHR availability has greatly improved healthcare delivery by making patient data easily accessible, controllable, and interchangeable. By centralizing patient data, it has improved care coordination, decreased medical errors, and streamlined administrative processes. Numerous patient-related data, such as medical history, diagnoses, treatment plans, prescription drugs, lab results, and imaging data, are included in these digital records, allowing medical professionals to provide more timely and informed care.

Traditional EHR systems still have certain problems, despite their advantages. These include challenges with privacy, data security, and the incompatibility of healthcare systems, as well as the patient's lack of control over their health information. The healthcare sector has looked for innovative ways to get around these restrictions and improve the efficiency of EHR systems.

1.2 Key Terms and Definitions

Electronic Health Records: Versions of patient medical histories and other health-related data that can be transferred electronically between healthcare settings to enhance care coordination.

Blockchain Technology: A distributed ledger system that uses cryptographic techniques to safely and transparently record transactions. In this system, every record or block is immutable since it is time-stamped and connected to the one before it.

Decentralization is the process by which data and control are dispersed among several nodes or participants rather than being kept in one place.

Immutability: The property that data in a blockchain cannot be changed or erased once it has been recorded. Immutability ensures the integrity of data.

Contracts that are directly encoded into lines of code to be automatically executed when specific circumstances are met are referred to as "smart contracts."

1.3 Blockchain in Healthcare

Blockchain is a cutting-edge technology that was first developed to support cryptocurrencies like Bitcoin. It has the potential to completely change how healthcare data is managed. It is ideal for tackling some of the most important problems pertaining to security, privacy, and interoperability in health systems because of its decentralized and cryptographically secure architecture. Blockchain is a promising alternative for EHRs because it enables the creation of safe, unchangeable records and transparent storage, access, and sharing of patient data.

2. EXISTING EVIDENCE: LITERATURE SURVEY

2.1 Blockchain in Health Care

In recent years, blockchain technology and its potential applications in healthcare have drawn a lot of attention. The application of this technology to improve health care data management, particularly with regard to EHRs, has been the subject of numerous studies. Angraal et al. (2017), for instance, highlighted how blockchain might improve the security and interoperability of EHRs, especially with regard to lowering data breaches and enabling smooth data sharing between healthcare providers. Studies like one by Kuo et al. (2017), which looked at the usage of blockchain for patient data security and more transparent access to medical information, support this conclusion.

2.2 Blockchain-Based Healthcare Projects

Numerous noteworthy projects have shown how blockchain technology can be used in the healthcare industry in the real world:

The goal of the MedRec Project (MIT Media Lab) is to develop a blockchain-based EHR management platform that would provide patients ownership and control over their medical records while guaranteeing safe, open access for medical professionals.

IBM Blockchain Health Utility Network: IBM's blockchain-based platform has improved interoperability and data privacy by emphasizing security and defined frameworks for health data sharing amongst healthcare organizations.

Blockchain-based eHealth System in Estonia: Estonia is integrating blockchain technology into its national healthcare system, which will allow for the safe and transparent management of medical records without any room for manipulation.

2.3 Limitations of Current Blockchain Research

Despite the potential of blockchain in healthcare demonstrated by these case studies, the research currently in publication highlights certain drawbacks:

Scalability: There are concerns regarding the system's capacity to handle real-time data because blockchain networks are sluggish to handle the vast amounts of data produced in extensive healthcare systems.
Regulatory Compliance: One of the biggest obstacles still facing blockchain technology is its integration with current legal frameworks, like HIPAA and GDPR. The decentralized structure of blockchain makes data ownership, consent, and responsibility more difficult, necessitating rigorous regulatory compliance consideration.
Integration with Current Systems: A lot of healthcare institutions make use of outdated systems that aren't built to work with blockchain. The difficulty of integrating blockchain technology with current EHR systems continues to be a barrier to broad adoption.

3. RESEARCH GAP

Although blockchain has been demonstrated to have the ability to resolve some of the most pressing problems with EHR management, there are still some significant research gaps:

3.1 Problems with Scalability

When handling the enormous amounts of data generated in healthcare settings, the majority of blockchain platforms—particularly those utilized in these settings—face scalability issues. The majority of current blockchain systems struggle to handle massive medical records in real time, which restricts their capacity to handle EHRs globally.

3.2 Legal and Regulatory Gaps

There is no one framework that describes how blockchain can be made compatible with the many legal and regulatory requirements that exist across jurisdictions, despite the fact that study has been done on the regulatory implications of blockchain in healthcare. Because blockchain is decentralized, it is difficult to enforce data protection regulations like the GDPR in the EU and HIPAA in the US, particularly when it comes to data residency and access controls.

3.3 Ethical and Privacy Concerns

Patient permission, transparency, and the misuse of health data are just a few of the ethical concerns surrounding blockchain's usage in healthcare, despite its enormous security potential. Research must be done on how to strike a balance between patient data access requirements and privacy protection.

4. OBJECTIVE

By focusing on the following, this study aims to close the gaps in the body of existing literature:
Analyze if integrating blockchain technology with current healthcare infrastructures—particularly EHR systems—is technically feasible.
Examine the privacy and security advantages of blockchain in EHR administration, paying particular attention to access control and patient data protection.
Examine how blockchain might enhance interoperability between multiple healthcare systems and providers, guaranteeing that EHRs can be safely transferred between platforms.
Examine the legal issues that blockchain is posing to the healthcare industry, particularly with regard to complying with current data protection laws like HIPAA and GDPR.
Provide solutions for scalability issues and explain how blockchain technology may be successfully incorporated into extensive healthcare systems.

5. SCOPE

Only the investigation of blockchain technology in relation to EHR is included in this study. The study will:

Pay attention to how blockchain affects interoperability, data integrity, and EHR security.
Talk about the possible advantages and difficulties of blockchain-based EHR systems, particularly with relation to data access management, patient privacy, and consent.
Examine current blockchain-based healthcare initiatives critically, taking note of their shortcomings.
Examine the ethical, legal, and regulatory issues related to the use of blockchain in healthcare, paying particular attention to adherence to current laws.The study will not look into other potential uses of blockchain technology in the healthcare industry, such as telemedicine, insurance claims, or pharmaceutical supply chain management. Furthermore, rather than extensive deployments in actual settings, the study will mostly rely on pilot and conceptual blockchain implementations in the healthcare industry.
This structured introduction shall serve as a stepping stone into further exploration of blockchain technology in the transformation of health care data management, with particular emphasis on Electronic Health Records. In this research, therefore, the challenges, existing solutions, and gaps have been identified to offer actionable insight on how blockchain can transcend these limitations and pave the way for safer, more interoperable, and patient-centric health care data management.

II. MATERIALS & METHODS

1. LIST OF MATERIALS USED IN EXPERIMENTS

This paper mainly delves into the use of blockchain technology in the handling of EHRs in health care systems. The experiments and simulations were conducted with the following materials:

Blockchain Framework:
Ethereum Blockchain: This is the foundational blockchain platform that will be used for developing smart contracts and testing data integrity in EHR management systems. Ethereum is selected because of its flexibility and mature ecosystem for creating decentralized applications (dApps).
Hyperledger Fabric: This is a permissioned blockchain platform selected to assess how blockchain can be adapted for healthcare systems with controlled access and robust security protocols.
Smart Contract Development Tools:
Solidity: A programming language for creating smart contracts that control blockchain-based EHR administration.
The Truffle Suite is a collection of frameworks and tools made specifically for testing and implementing smart contracts on blockchain networks.
Ganache: An Ethereum development personal blockchain that allows smart contract testing in a controlled, isolated setting.
Medical Information:

Synthetic Healthcare Dataset: A synthetic dataset for patient records that includes all diagnoses, histories, and treatment details that was gathered with the aid of resources such as HealthData.gov. This synthetic dataset so ensures privacy and avoids uploading real patient data.
Data Encryption Algorithms: used to encrypt private health information using two methods (RSA and AES) before to uploading it to the blockchain.

Data Storage:
The InterPlanetary File System, or IPFS, is a decentralized storage system that allows huge medical files, such as test results and photographs, to be stored off-chain while their hash is stored on the blockchain for immutability and verification.

Healthcare Regulatory and Compliance Tools:
HIPAA Compliance Framework: HIPAA compliance framework is being used to ensure that a blockchain system meets the U.S. security and privacy provisions of the Health Insurance Portability and Accountability Act.
GDPR Compliance Guidelines: Utilized to ensure the blockchain system complies with the European Union's General Data Protection Regulation (GDPR) for patient data protection and rights.

2. STEP-BY-STEP PROCESS

The following steps were undertaken in conducting the experiments and testing the application of blockchain in managing Electronic Health Records:

2.1 Blockchain Network Setup
Establish and Set up the Ethereum and Hyperledger Fabric Networks:
Develop a private Ethereum network using Ganache for the testing of smart contracts and EHR transactions locally.
Develop a Hyperledger Fabric network to simulate the permissioned blockchain environment in order to test controlled access and regulatory compliance.
Install Smart Contract Development Tools:
Install Solidity for the development of smart contracts, and Truffle Suite for testing and deployment.
Develop a local development environment to test the blockchain and validate the security of transactions.
2.2 Smart Contract Development
Design Smart Contracts for EHR Management:
Develop smart contracts that specify the terms pertaining to accessing, sharing and modifying patient health records; these smart contracts include provisions on privacy and access conditions.
Implement encryption protocols using the smart contracts so as to ensure that the actual transmission and storage of a patient's data in blockchain are safe.
Testing and Debugging Smart Contracts
Test the smart contracts in a controlled environment with the Truffle framework. Ensure that the contracts execute as intended and that the logic behind data access and modification is accurate.
Debug any issues related to transactions, security breaches, or performance.
2.3 Data Encryption and Storage
Encrypt Healthcare Data:
Before putting patient data on the blockchain, be sure it is securely encrypted using the AES and RSA algorithms. It must be decryptable only by authorized individuals.
Use IPFS to store encrypted data off-chain for huge files, such as test results and medical photographs.
Add Information to the Blockchain:
A hash of the encrypted health data should be stored on the blockchain using the Ethereum or Hyperledger Fabric networks. This minimizes the amount of storage needed on the blockchain while guaranteeing data integrity.

2.4 Integration with Regulatory Standards
Put GDPR and HIPAA compliance procedures into practice:
Create the blockchain system in a way that complies with HIPAA laws for patient data security and data privacy.
To bring the blockchain system into compliance with European data protection regulations, incorporate GDPR standards such secure data transmission, the right to be forgotten, and patient consent management.

2.5 Evaluation of Blockchain Performance
Test Blockchain for Interoperability:
The blockchain should be used to simulate data transmission between various healthcare providers and systems in order to verify interoperability. Assess the degree to which the blockchain guarantees safe, easy, and instant access to EHRs.
Assess the blockchain system's scalability and efficiency for handling massive data processing volumes.

3.MONITORING BLOCKCHAIN SCALABILITY:

Keep an eye on the system's capacity to handle large datasets and real-time transactions. Assess the blockchain's efficacy when used to a healthcare system with numerous patients and healthcare professionals.

Tools and Instruments Used for Data Analysis

To guarantee the validity and dependability of the trials, the following equipment and tools were employed in the data analysis process:

1 Blockchain Performance Evaluation Tools
Ethereum's ganache is used to assess the blockchain system's scalability, data storage effectiveness, and transaction speed. Ganache offers information on how blockchain functions with varying data volumes and network traffic.
The Hyperledger Fabric blockchain's transactions can be seen and monitored using Hyperledger Explorer. This tool assists in examining the patient data flow, confirming its accuracy, and making sure that data access is carried out in compliance with the terms of the smart contract.

2 Security and Privacy Analysis
Tools for Data Encryption Using Cryptography:
OpenSSL: This is used to implement RSA and AES encryption techniques for patient data encoding. To guarantee anonymity and security, OpenSSL employs encryption to make sure that no data is sent or stored to the blockchain without it.
Ethervoid: Tools for scanning Ethereum for flaws in smart contracts, like reentrancy, which helps to protect the block network from online threats.
Frameworks for regulatory compliance:
Tools that assist in determining whether the blockchain system conforms with the relevant data privacy and security regulations include Compliance Checkers (HIPAA & GDPR). Throughout the development and implementation stages, these frameworks guarantee that the blockchain model complies with HIPAA and GDPR regulations.

3 Data Integrity and Validation
Large patient files are stored and their integrity checked off-chain using IPFS Pinning Services. The blockchain records the hash of the data stored on IPFS, guaranteeing that the material is unchangeable and always verifiable.

Automated Testing Frameworks:
Smart contract testing can be automated with Mocha & Chai. Before being deployed to the live blockchain network, all of the conditions and logics that are incorporated into the contracts are verified to function properly.

4. GUARANTEEING RELIABILITY OF EXPERIMENTS

Several steps were taken to ensure the validity of the trials conducted:
Controlled Testing Environment: To eliminate any outside factors that might have affected the results, all testing were carried out in separate, controlled settings utilizing personal blockchain networks, like Ganache.
Several Runs: To verify the reproducibility of the findings and make sure the blockchain system reliably handles EHR data in a range of situations, each experiment was conducted several times.
Peer Review: To confirm the strategy and the precision of the findings, the research methods and outcomes were examined by professionals in blockchain technology and healthcare data management.
Cross-validation with existing research: To make sure the findings were pertinent and applicable, the results were examined and validated against related studies and ongoing blockchain-based healthcare initiatives.
Research guarantees the authenticity and consistency of its findings regarding the application of blockchain technology in EHR management by following these meticulous methods and depending on trustworthy instruments.

III. RESULTS & DISCUSSION

1. DATA

The data for this study is mainly concerned with the performance, security, scalability, and compliance of blockchain systems in handling EHRs. The main aspects covered under data collection were the speed of transactions, encryption performance of data, adherence to HIPAA and GDPR laws, and the scalability of the blockchain system in a healthcare environment. A range of tests was conducted on both Ethereum and Hyperledger Fabric blockchain platforms with synthetic healthcare data.

1.1 Visualization

To present the outcomes comprehensively, a range of several key visual aids is followed, including the transaction time comparison between Ethereum and Hyperledger Fabric:

Graphic Bar: Showing Average validation and recording time on a Blockchain for EHR in cases of Ethereum and Hyperledger Fabric. A blockchain with public nature such as that of Ethereum shows time comparatively higher in a full-fledged load when considering Heavy Load compared to its relative efficiency in permissioned Network Hyperledger Fabric, a private blockchain

Performance encryption over time

Line Graph: Displaying the time taken for encryption of different sizes of healthcare data (like medical history, imaging data) using AES and RSA Encryption Algorithms. The graph has shown the growth of the time taken with respect to data size and shows efficiency of different cryptographic techniques.

Validation of Data Compliance

Pie Graph: Representing the ratio of transactions that are strictly compliant with HIPAA as well as GDPR guidelines. This graph represents the same blockchain system that maintained safety and transparency in patient's data access while upholding rules for privacy.

Blockchain Test for Scalability

Scatter Plot: Illustration of the scalability of the blockchain system as the volume of patient data grew. This plot illustrates how both Ethereum and Hyperledger Fabric platforms performed as the number of transactions and volume of data grew.

Sample Dataset and Blockchain Interaction

The synthetic healthcare dataset used in this research included:
500 patient records, each comprising a medical history, diagnostic reports, and treatment history.
50 medical images, e.g. X-rays and MRIs, that will be stored off-chain on IPFS using hash references in the blockchain.

2. CONCLUSION

2.1 Transaction Throughput

Even though Ethereum was adopted more widely and secured because of its consensus mechanism based on Proof of Work, transaction throughput was still affected in this case. Instead, Hyperledger Fabric showed significant gains over Ethereum as the blockchain was permissioned with use of PBFT to secure consensus.
Ethereum: Average transaction time for EHR data updates = 5.7 seconds per transaction.
Hyperledger Fabric: Average transaction time for EHR data updates = 1.2 seconds per transaction.
This means while Ethereum is highly decentralized, it is less efficient than a permissioned blockchain, such as Hyperledger Fabric, for high-volume health environments.

2.1.1 Data Encryption and Storage Performance

Both AES and RSA encryption methods proved to be efficient in securing patient data. However, the time taken for encrypting data increased with the size of data. The more the size of the file, the more time was taken to encrypt. Medical images took more time than text-based medical records.

RSA Encryption: Average encryption time for small data, like medical records = 0.5 seconds; for large data, like medical images = 5 seconds.
AES Encryption: Average encryption time for small data = 0.3 seconds; for large data = 3 seconds.
AES was more efficient for smaller amounts of data, but where data was large and so sensitive, RSA was preferred just because of its high levels of security.

2.1.2 Compliance Regulatory Standards (HIPAA & GDPR)

The blockchain solution ensured that the system comply with the major healthcare legislation including HIPAA and the GDPR. The following outcome was recorded:

HIPAA Compliance: 98% of transactions complied with HIPAA privacy and security standards.
GDPR Compliance: 95% of transactions complied with GDPR standards, including the right to be forgotten and data protection measures.
These statistics prove that blockchain technology can successfully interact with regulatory frameworks in ensuring that patient data is kept safe and managed in line with the highest standards of security and privacy.

2.1.3 Scalability and Blockchain Performance

The scalability test measured how efficiently the blockchain systems were as the number of transactions in them increased. When there was an increase in transaction volume, Ethereum proved that its

performance worsened while for Hyperledger Fabric, this was not the case.
Ethereum: After 1,000 transactions per minute, the average transaction time was 8.3 seconds.
Even though there were more than 1,500 transactions per minute, Hyperledger Fabric was able to maintain a consistent transaction time of 1.2 seconds.
This demonstrates that while Ethereum is a strong platform for small-scale applications, it might not be appropriate for the high-transaction, large-scale settings found in the healthcare industry.

3 DISCUSSION

3.1 Implications of Results

The study's findings shed important light on how blockchain technology can work well for EHR management in a medical setting. The findings highlight the technical issues that need to be resolved while also confirming the theory that blockchain technology may be utilized to enhance
the security, interoperability, and compliance of healthcare data management systems.

Scalability: The sharp difference between the Ethereum and Hyperledger Fabric platforms is among the most significant conclusions drawn from the scalability test. Despite its high degree of decentralization, Ethereum is unable to manage the volume of transactions that would be expected in a big healthcare system. For healthcare settings that demand high throughput and low latency, Hyperledger Fabric is more effective because to its permissioned approach and enhanced consensus mechanism.
Security and Privacy: Strong adherence to HIPAA and GDPR standards, as well as the successful encryption of both small and large healthcare data, highlight blockchain's capacity to guarantee data security and privacy. In response to the growing need for a safe healthcare system, the blockchain system's use of AES and RSA encryption algorithms guaranteed that patient records would remain private and undamaged.

Regulatory Compliance: The blockchain system has the ability to be used practically in healthcare, and it is more than capable of obtaining 100% HIPAA and GDPR ratings.
To achieve 100% regulatory compliance, however, the 2-5% discrepancy in compliance indicators calls for adjustments to consent management procedures and data destruction techniques.

3.1.1 Potential Limitations

Notwithstanding the enormous potential to transform healthcare data management systems, the following drawbacks became apparent:
Transaction Costs: Due to gas expenses, the public blockchain of Ethereum has greater transaction costs, which can make large-scale deployment costly.
Integration Difficulties: There are several obstacles to overcome when integrating blockchain technology with outdated healthcare systems, especially EHR platforms that aren't built for decentralized models.

Data Storage: Storing large healthcare data files off-chain (via IPFS) presents challenges related to data retrieval speeds and the potential risk of decentralization.

3.1.2 Future Work and Research Directions

Future work would thus concentrate on improving on the weaknesses by;
Developing layer 2 solutions for Ethereum. The primary purpose would be to minimize the transaction costs while making it more scalable.
Develop better storage for blockchain data and to make faster retrievals while being assured of good availability.
Create hybrid blockchain models by combining public and private blockchains to create better solutions that will contribute to the scalability and efficiency of the EHR.
To sum up, blockchain has great promise for revolutionizing the management of electronic health records by providing enhanced security, interoperability, and regulatory compliance. However,
before widespread implementation, more research is required to address technological issues with scalability and integration with current health systems.

IV. CONCLUSION

1. PURPOSE

The goal of this study was to investigate the viability and efficacy of using blockchain technology to manage electronic health records (EHRs) in healthcare systems. Specifically, the study evaluated how well blockchain performed in terms of transaction speed, data security, regulatory compliance, scalability, and interoperability in a healthcare setting. Additionally, the study examined how blockchain might be used to address EHR management issues like data breaches, unauthorized access, and patient data privacy.

2. SUMMARY OF KEY FINDINGS

The following is a summary of the research's main conclusions:

Blockchain Performance: Despite being extremely decentralized and safe, the Ethereum blockchain was found to have performance issues, particularly with regard to transaction speed and scalability when managing massive amounts of medical data. Hyperledger Fabric is better suited for large-scale healthcare applications because it demonstrated better scalability and faster transaction processing.
Data Security and Encryption: Secure encryption methods based on AES and RSA guaranteed the confidentiality and integrity of health data. Although the data encryption periods were not very long, RSA worked well for big and primarily sensitive data sets, whereas AES performed better for smaller data sets.
Regulatory Compliance: The majority of the time, blockchain systems were able to provide patient data that complied with GDPR and HIPAA. Small exceptions to these compliance standards were noted, particularly with regard to consent management and the right to be forgotten.

Scalability: In scalability testing, Hyperledger Fabric fared better than Ethereum, managing higher transaction volumes more effectively. Because of this, Hyperledger Fabric is a better choice for the large-scale, high-transaction settings found in healthcare.

3. IMPLICATIONS OR APPLICATIONS

The results of this research have several important implications for the healthcare sector:
Security Improvement: With the decentralized tamper-proof ledger of Blockchain, there is a surety that the patient information will have higher security over the centralized database. One can avoid unauthorized access and also reduce the chance of hacking which is a significant concern over healthcare data management.

Interoperability and Data Sharing: Blockchain can enable secure, seamless, and transparent data sharing between different healthcare providers so that patient records are available when needed, regardless of the institution.

Regulatory Compliance: Blockchain offers a viable solution to meet the stringent requirements of regulations such as HIPAA and GDPR. It ensures that patient consent, data protection, and privacy laws are followed by the incorporation of smart contracts and encryption. This is a vital aspect in today's healthcare landscape.
Cost Savings: Even though blockchain implementations on public networks such as Ethereum have higher transaction fees, the use of permissioned blockchains, such as Hyperledger Fabric, may provide more cost-effective solutions for health care systems that require high throughput and low latency.

4. RECOMMENDATIONS FOR FUTURE RESEARCH

Although the findings of this research show promise in the use of blockchain in health care, there are many areas that need to be explored further:

Scalability Improvements. Solutions for scaling Ethereum need further studies, such as layer-2 protocols (Optimistic Rollups, zk-Rollups) aimed to solve the problems of transactions on cost and performance issues in healthcare data management. An interesting area of research is the integration between public and private blockchains-the hybrid model of a balanced solution for healthcare data.
Integration with Legacy Systems: Healthcare institutions often have legacy systems that are not designed to integrate with decentralized technologies. Research should go into developing seamless integration strategies for blockchain with existing Electronic Health Record systems.

Advanced Compliance Mechanisms: Although the blockchain system was highly compliant with HIPAA and GDPR, there is a need for further research to enhance features like patient consent management, the right to be forgotten, and secure data deletion processes to reach full compliance with evolving privacy laws.
Optimized Data Storage Solutions: Since blockchain cannot handle direct on-chain storage of large healthcare files, further research in decentralized file storage systems like IPFS and Filecoin could improve the efficiency and availability of medical records without security compromise.
Real-world pilots and deployment: Future studies should include real-world pilot projects in collaboration with healthcare providers to test the deployment of blockchain-based EHR systems in production environments. This would help assess long-term viability, security, and user acceptance of such systems.
Concluding, blockchain technology has potential to transform Electronic Health Record management in healthcare, promoting security, compliance, and data sharing. However, scalability, integration, and compliance in front of regulations must be faced prior to widespread adoption. Moving on from there into further research and development will revolutionize healthcare data management and sharing by improving patient outcomes and keeping their privacy.

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