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A Systematic Review of Artificial Intelligence and Blockchain Integration for Secure and Privacy-Preserving Electronic Health Records

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ABSTRACT

The growing use of Electronic Health Records (EHRs), Internet of Medical Things (IoMT), cloud computing, and Artificial Intelligence (AI) has hastened the digital transformation of healthcare systems. Although these technologies enhance clinical decision-making, healthcare accessibility, and patient management, traditional centralized EHR designs are still subject to cybersecurity threats, illegal access, interoperability difficulties, and privacy breaches. Blockchain technology has developed as a decentralized and tamper-proof platform capable of addressing these issues via immutable ledgers, cryptographic security, smart contracts, and distributed consensus. At the same time, AI approaches such as Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), and Explainable Artificial Intelligence (XAI) have shown great results in illness prediction, medical image analysis, clinical decision support, and personalized medicine. The combination of AI with blockchain offers the ability to create safe, intelligent, and patient-centered healthcare information systems.

This research offers a comprehensive evaluation of AI-blockchain integration for safe Electronic Health Record administration, examining current works released between 2022 and 2026, as well as crucial fundamental contributions. The study uses a systematic review process to evaluate AI algorithms, blockchain platforms, consensus mechanisms, smart contract technologies, and privacy-preserving methodologies utilized in healthcare applications. A comparative study identifies the strengths, limits, and implementation issues of current solutions. The evaluation names Hyperledger Fabric as one of the best blockchain systems for permissioned healthcare settings, and it mentions Federated Learning and Explainable AI as promising technologies for privacy-preserving collaborative healthcare analytics.

Based on the findings, the article provides a comprehensive conceptual framework for safe EHR administration that combines AI, blockchain, decentralized storage, smart contracts, and privacy-preserving approaches. The study also identifies open research challenges in scalability, interoperability, governance, regulatory compliance, and ethical AI, as well as a future research agenda focusing on Large Language Models, Digital Twins, Decentralized Identity, Zero-Knowledge Proofs, and quantum-resistant cryptography. The findings are useful for researchers, healthcare practitioners, politicians, and system developers working on trusted next-generation digital healthcare ecosystems.

Keywords: AI, Blockchain, EHRs, Healthcare Security, Machine Learning, Smart Contracts, and Federated Learning.

1. INTRODUCTION

Healthcare is undergoing a massive digital transformation due to significant advances in Artificial Intelligence (AI), cloud computing, the Internet of Medical Things (IoMT), big data analytics, and Electronic Health Records (EHRs). Governments and healthcare organizations throughout the world are investing heavily in digital health infrastructures to boost clinical efficiency, reduce medical errors, and enhance patient outcomes. The increasing volume of healthcare data generated by hospitals, diagnostic laboratories, wearable sensors, and telemedicine platforms has opened up new opportunities for intelligent healthcare analytics. At the same time, it has raised new concerns about cybersecurity, privacy protection, interoperability, and regulatory compliance [2, 4].

Electronic health records have become the cornerstone of current healthcare information systems. They provide for the efficient storing and transmission of patient demographics, laboratory data, prescriptions, diagnostic pictures, treatment histories, and clinical observations. When compared to traditional paper-based records, EHRs

improve healthcare accessibility, continuity of treatment, and evidence-based clinical decision-making. However, most current EHR systems rely on centralized databases, which are still subject to cyberattacks, ransomware events, illegal access, insider threats, and single points of failure [3], [6]. Furthermore, fragmented healthcare databases frequently impede smooth information interchange across hospitals, laboratories, insurance companies, and research institutions, restricting interoperability and collaborative healthcare delivery [7].

Artificial intelligence (AI) has emerged as a game-changing tool for evaluating complicated healthcare data and facilitating intelligent medical decisions. Machine Learning algorithms are widely used for disease prediction, patient risk stratification, and hospital resource optimization, whereas Deep Learning models excel at medical image analysis, cancer detection, electrocardiogram interpretation, and pathology classification [8], [12]. Natural Language Processing automates the extraction of useful information from clinical notes and EHRs, whereas Explainable Artificial Intelligence aims to increase transparency by giving interpretable therapeutic advice. Despite these advancements, AI systems require access to big, diverse, and reliable datasets, which raises serious issues about patient privacy, safe data exchange, and regulatory compliance [16], [18].

Blockchain technology has gained popularity as a decentralized platform capable of overcoming these constraints. Unlike traditional centralized systems, blockchain uses an immutable distributed ledger in which every allowed transaction is cryptographically validated and permanently recorded. Smart contracts streamline patient consent management and provide safe access control, whilst decentralized identity techniques improve authentication and accountability [4], [9]. Permissioned blockchain technologies, such as Hyperledger Fabric, Quorum, and Corda, are ideal for healthcare settings because they offer customizable privacy regulations, efficient consensus processes, and institutional governance [9], [20].

The intersection of artificial intelligence and blockchain technology has lately emerged as a potential study area for safe healthcare information systems. Blockchain creates trust, transparency, and data integrity, whereas AI derives clinically relevant information from healthcare data. The combination allows for safe collaborative learning, intelligent clinical decision support, privacy-preserving healthcare analytics, and patient-centric Electronic Health Record administration [17, 19]. Emerging technologies like Federated Learning, Explainable AI, Large Language Models, and Decentralized Identity enhance the capabilities of integrated AI-blockchain healthcare ecosystems.

1.1 Research Gap

Although many research has looked at Artificial Intelligence or Blockchain on its own, few have looked at how they work together in safe Electronic Health Record systems. Existing studies frequently concentrate on a specific technology sector, such as blockchain-based healthcare security or AI-assisted diagnostics, without conducting a thorough comparison of AI algorithms, blockchain platforms, interoperability standards, and privacy-preserving measures. Furthermore, new concepts like Federated Learning, Explainable AI, Large Language Models, and Digital Twins have gotten less attention within integrated AI-blockchain healthcare systems. This study tackles these gaps by synthesizing recent material and proposing a coherent conceptual framework.

1.2 Research Contributions

The key contributions of this work include:

- A thorough study of AI-blockchain integration for safe electronic health records based on recent literature.
- A comparison of AI methodologies, blockchain platforms, consensus processes, and security strategies.
- Identifying critical research gaps, technological obstacles, and implementation impediments.
- A proposed conceptual AI-blockchain architecture for safe and intelligent healthcare information systems.
- A future research agenda that emphasizes new technology and potential research topics.

2. SYSTEMATIC LITERATURE REVIEW

The combination of artificial intelligence (AI) with blockchain technology has emerged as one of the most promising methods to creating safe, transparent, and intelligent healthcare information systems. A thorough evaluation of the literature produced between 2022 and 2026 was carried out to identify current trends, technical developments, implementation issues, and future research topics. The examined research were categorized into

four primary themes: (i) AI applications in healthcare, (ii) blockchain-enabled Electronic Health Records (EHRs), (iii) AI-blockchain integration, and (iv) security and privacy measures.

2.1 Artificial Intelligence in Healthcare.

Artificial intelligence has altered healthcare by allowing for data-driven diagnosis, prognosis, and tailored therapy planning. Machine Learning (ML) techniques including Support Vector Machines (SVM), Random Forest (RF), Decision Trees (DT), and Logistic Regression are widely utilized in illness prediction, patient risk assessment, and hospital resource management [8], [12]. Deep Learning (DL), namely Convolutional Neural Networks (CNNs) and Vision Transformers (ViTs), has demonstrated cutting-edge performance in medical image analysis, such as cancer identification, diabetic retinopathy screening, and neurological condition diagnosis [13].

Natural Language Processing (NLP) has helped to extract structured clinical information from physician notes, pathology reports, and discharge summaries, minimizing documentation mistakes and enhancing clinical procedures [14]. Recently, Large Language Models (LLMs) have shown great promise in clinical documentation, medical question answering, and decision assistance. However, its application in healthcare necessitates thorough validation due to concerns about hallucinations, explainability, and regulatory compliance.

Explainable Artificial Intelligence (XAI) has gained popularity for improving the transparency and interpretability of AI predictions. XAI approaches help physicians grasp the logic behind diagnostic suggestions, which boosts trust in AI-assisted healthcare systems [22].

2.2 Blockchain-Based Electronic Health Records.

Blockchain technology creates a decentralized framework for safe healthcare data management. Unlike centralized databases, blockchain uses an immutable distributed ledger in which each transaction is cryptographically confirmed and permanently stored. This design dramatically improves data integrity, traceability, and resistance to illegal alteration [2, 3].

Permissioned blockchain systems, such as Hyperledger Fabric, Quorum, and Corda, have emerged as the preferred choice for healthcare applications because to its flexible access control, identity management, and speedy consensus algorithms [9],[20]. Smart contracts automate important healthcare processes such as patient permission, medical record exchange, insurance claims processing, and access authorization, decreasing administrative complexity while increasing operational efficiency.

To overcome blockchain storage restrictions, several healthcare systems use hybrid architectures in which encrypted medical records are kept in cloud repositories or the InterPlanetary File System (IPFS), while blockchain maintains cryptographic hashes that validate data integrity [5], [21].

2.3 AI/Blockchain Integration

The marriage of AI with blockchain brings together intelligent data analytics and decentralized trust. AI derives clinically relevant insights from healthcare data, while blockchain assures data security, transparency, and accountability throughout its lifespan.

Several recent research have developed blockchain-enabled Federated Learning frameworks that allow numerous healthcare institutions to collaborate on training AI models without disclosing sensitive patient data [15], [23]. Blockchain tracks model modifications, authenticates participant institutions, and keeps immutable audit logs, increasing confidence in distributed machine learning settings.

Researchers have also investigated blockchain-supported Explainable AI systems that retain model provenance and assure the traceability of AI choices [18]. These integrated solutions promote regulatory compliance and confidence in AI-assisted diagnosis by establishing visible and verifiable decision-making procedures.

Although integrated AI-blockchain systems show great potential, their general adoption is limited due to computational expense, interoperability issues, governance complexity, and a lack of defined implementation frameworks [19], [24].

2.4 Security and Privacy Measures

Healthcare data is extremely sensitive and requires strong security measures during collection, storage, transfer, and analysis. The examined literature finds numerous complimentary technologies that improve privacy and cybersecurity.

The most often used mechanisms are:

Attribute-Based Encryption (ABE) enables fine-grained access control based on user characteristics.

Zero-Knowledge Proofs (ZKP): Enable information verification without disclosing private data.
Differential Privacy (DP) safeguards patient data during AI model training by reducing disclosure risks.
Secure Multi-Party Computation (SMPC) enables collaborative analytics without disclosing raw datasets.
Decentralized Identity (DID): Allows patients to control their digital identities and ensures safe authentication.
Multi-Factor Authentication (MFA) improves user verification for healthcare applications.
The integration of these technologies with blockchain improves confidentiality, integrity, availability, and accountability in current healthcare ecosystems.

Table 1. Summary of Representative Studies on AI–Blockchain Healthcare Systems

Ref.	Year	Focus Area	AI Technique	Blockchain Platform	Key Contribution
[3]	2022	Healthcare Security	ML	Ethereum	Secure healthcare data sharing
[4]	2023	Electronic Health Records	Smart Contracts	Hyperledger Fabric	Decentralized EHR management
[5]	2023	Medical Data Storage	DL	IPFS + Blockchain	Hybrid storage architecture
[15]	2024	Federated Learning	Federated AI	Hyperledger	Privacy-preserving collaborative learning
[18]	2024	Explainable AI	XAI	Blockchain	Transparent AI decision support
[20]	2025	Healthcare Interoperability	ML	Corda	Secure institutional collaboration
[21]	2025	Blockchain EHR	AI Analytics	Hyperledger Fabric	Intelligent EHR management
[23]	2026	Trusted AI	Federated Learning	Consortium Blockchain	Secure distributed healthcare analytics

3. COMPARATIVE ANALYSIS AND PROPOSED FRAMEWORK

The systematic study shows that artificial intelligence (AI) and blockchain technologies work together to solve the security, privacy, interoperability, and intelligence needs of contemporary electronic health record (EHR) systems. However, AI approaches, blockchain platforms, and consensus mechanisms differ significantly in terms of scalability, computing efficiency, explainability, and practical application. This section evaluates these technologies and presents an AI-blockchain architecture for safe healthcare information management.

3.1 Comparative Analysis of AI Techniques

AI approaches vary in computing complexity, interpretability, and healthcare applications. Traditional Machine Learning (ML) methods including Decision Trees, Random Forests, Support Vector Machines (SVM), and Logistic Regression work well for structured healthcare datasets, illness prediction, and patient risk assessment. Their minimal computing needs make them ideal for everyday clinical applications.
Deep Learning (DL) models, such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Vision Transformers (ViTs), are highly accurate in medical image analysis, cancer detection, EKG interpretation, and radiological image categorization. However, these models need big annotated datasets and significant computing resources.
Federated Learning (FL) solves privacy issues by allowing several healthcare organizations to train AI models together without sharing raw patient data. Explainable Artificial Intelligence (XAI) boosts clinician trust by offering clear explanations for AI-generated suggestions. FL and XAI are potential solutions for reliable AI-assisted healthcare systems.

3.2 Comparison of Blockchain Platforms

Blockchain technologies provide different levels of security, scalability, transaction throughput, and governance. Public blockchains like Ethereum have advanced smart contract capabilities but have limits in terms of scalability, transaction costs, and privacy. As a result, permissioned blockchain systems have become the preferred option for healthcare applications.

Hyperledger Fabric offers flexible access control, modular consensus techniques, private communication channels, and rapid transaction processing, making it ideal for Electronic Health Record applications. Quorum enhances Ethereum with enterprise-level privacy capabilities, whilst Corda enables safe information sharing between trusted entities without broadcasting transactions to the whole network.

3.3 Comparative Analysis of Consensus Mechanisms.

Consensus algorithms control how blockchain members validate transactions. Healthcare systems demand low-latency transaction confirmation while ensuring high security and fault tolerance.

Proof of Work (PoW), while extremely secure, requires large computing resources and is inappropriate for healthcare contexts that require fast transaction processing. Proof of Stake (PoS) increases energy efficiency while being more suitable for public blockchain environments.

Permissioned consensus systems, like Practical Byzantine Fault Tolerance (PBFT), Raft, and Proof of Authority (PoA), offer fast throughput, predictable transaction confirmation, and little computational overhead. These properties make them ideal for healthcare consortium networks that include hospitals, labs, insurance providers, and regulatory organizations.

Table 2. Comparative Analysis of AI and Blockchain Technologies

Technology	Major Advantages	Limitations	Healthcare Suitability
Machine Learning	Fast, interpretable, efficient for structured data	Limited capability for complex datasets	High
Deep Learning	High diagnostic accuracy and automated feature extraction	High computational cost	Very High
Federated Learning	Privacy-preserving collaborative learning	Communication overhead	Excellent
Explainable AI	Improves transparency and clinician trust	Additional computational complexity	Excellent
Ethereum	Mature ecosystem and smart contracts	Scalability and privacy limitations	Moderate
Hyperledger Fabric	Permissioned access, modular architecture, scalability	Requires consortium governance	Excellent
Quorum	Enterprise privacy and Ethereum compatibility	Smaller ecosystem	Very Good
Corda	Secure institutional collaboration	Limited healthcare adoption	Very Good

3.4 Proposed AI–Blockchain Framework

Based on the comparative research, a conceptual AI-blockchain architecture is presented to facilitate secure Electronic Health Record maintenance. The framework combines AI, blockchain technology, smart contracts, decentralized storage, and privacy-preserving techniques into a single architecture.

The suggested framework has six functional layers:

1. Data Acquisition Layer.

Healthcare data is gathered from hospitals, diagnostic laboratories, pharmacies, wearable medical devices, and Internet of Medical Things (IoMT) sensors.

2. Artificial Intelligence Layer

Machine Learning, Deep Learning, Natural Language Processing, Explainable AI, and Federated Learning are used for illness prediction, medical imaging analysis, predictive analytics, and clinical decision support.

3. Smart Contract Layer.

Smart contracts handle patient permission, access authorization, insurance verification, healthcare workflows, and regulatory compliance.

4. Blockchain Layer.

A permissioned blockchain network uses cryptographic hashing and consensus techniques to keep immutable transaction records, verify participant identities, and ensure data integrity.

5. Secure Storage Layer.

Encrypted Electronic Health Records are stored in cloud repositories or the InterPlanetary File System (IPFS), whereas blockchain keeps just cryptographic hashes and metadata for scalability.

6. Application Layer

Patients, physicians, hospitals, insurance providers, researchers, and regulatory agencies may securely access healthcare information based on preset authorization policies.

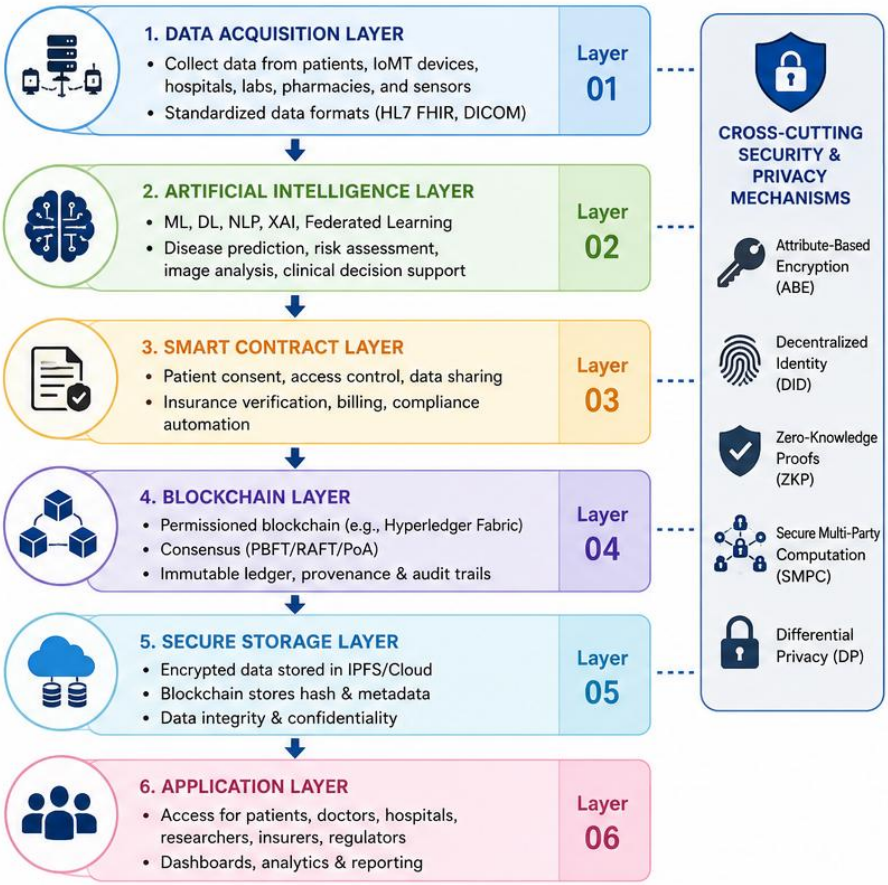

Figure 1. Proposed integrated AI–blockchain framework for secure Electronic Health Record management.

3.5 Research Gap Matrix

The systematic review highlights several research gaps that require further investigation.

Research Area	Current Status	Research Gap	Future Direction
AI Diagnosis	Mature	Limited explainability	Explainable AI
Blockchain EHR	Mature	Scalability challenges	Layer-2 and lightweight blockchain
Federated Learning	Emerging	Trust management	Blockchain-enabled FL
Smart Contracts	Moderate	Regulatory compliance	Policy-aware contracts
Healthcare Interoperability	Moderate	Standardization	HL7 FHIR integration
Privacy Protection	Mature	Computational overhead	Hybrid cryptographic frameworks

According to the report, future healthcare systems should prioritize combining trustworthy AI, permissioned blockchain networks, decentralized identification, and privacy-preserving machine learning in order to create scalable and safe healthcare ecosystems.

The comparative research shows that no single technology can independently meet all of the functional requirements of secure Electronic Health Record systems. Artificial intelligence offers sophisticated healthcare insights, whereas blockchain delivers transparency, trust, and safe data management. The proposed conceptual framework combines various complimentary technologies to provide a single architecture capable of enabling safe, scalable, interoperable, and patient-centered healthcare services.

4. CONCLUSION

The fast digital revolution of healthcare has expedited the use of Artificial Intelligence (AI) and blockchain technology to enhance the security, efficiency, and intelligence of Electronic Health Record (EHR) systems. This systematic study looked at current breakthroughs in AI-enabled healthcare analytics, blockchain-based EHR administration, and their integration to solve long-standing issues such as data privacy, interoperability, trust, and security. The reviewed studies show that AI improves disease diagnosis, predictive analytics, personalized treatment planning, and clinical decision support, whereas blockchain strengthens data integrity, decentralized trust, secure access control, and auditability via distributed ledgers and smart contracts.

The comparative research shows that permissioned blockchain systems, notably Hyperledger Fabric, provide a suitable basis for healthcare applications due to their scalability, adjustable privacy measures, and efficient governance mechanisms. Similarly, new AI paradigms like Federated Learning and Explainable Artificial Intelligence (XAI) enhance collaborative healthcare analytics while protecting patient privacy and boosting clinician confidence in AI-assisted decision-making.

To overcome the constraints noted in the literature, this study proposes an integrated AI-blockchain framework that incorporates intelligent analytics, permissioned blockchain, smart contracts, decentralized storage, and privacy-preserving technologies into a unified healthcare architecture. The framework aims to improve Electronic Health Record security, promote trusted information exchange, and increase interoperability among healthcare stakeholders.

Although tremendous progress has been made, various problems still exist, including scalability, interoperability, governance, regulatory compliance, ethical AI, and computing efficiency. Future study should look into how Large Language Models (LLMs), Digital Twins, Zero-Knowledge Proofs (ZKPs), Decentralized Identity (DID), post-quantum cryptography, and Edge AI may be combined to improve the security of healthcare information systems. This review's conclusions give significant information for researchers, healthcare organizations, governments, and technology developers looking to create intelligent, secure, and patient-centered digital healthcare ecosystems.

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