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Framework for Enhancing Interoperability, Data Exchange, and Security in Healthcare through Blockchain Technology

Vimbai Alice Muderere[1], Belinda Ndlovu[2], Kudakwashe Maguraushe[3]
mudererev@gmail.com[1], belinda.ndlovu@nust.ac.zw[2], magark@unisa.ac.za[3]
[1,2] National University of Science and Technology, Ascot AC 939, Bulawayo
[3] School of Computing, College of Science, Engineering and Technology, Florida, Johannesburg, South Africa

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Abstract

The healthcare sector is changing, such as fragmentation issues, the sharing of data, and the security of protected health information. Traditional systems tend to work independently or in silos, resulting in disjointed patient records and system inefficiency. With more trusted healthcare providers, patients relying more on digital solutions than ever, the urgency for a consistent data management solution has never been greater. This systematic literature review (SLR) aims to investigate the existing framework, factors, opportunities and challenges of blockchain technology in healthcare systems. The integrative approach was done according to the PRISMA guidelines. A literature search was carried out on various electronic databases, including PubMed, IEE Xplore, and ACM Digital Library, which gave a total of 832 articles, to begin with. Based on set scale criteria, 18 studies were deemed relevant for analysis. The findings indicate that blockchain technology holds promise due to its ability to facilitate secure and easy data sharing through immutability, cryptographic methods, and the removal of centralized authorities. However, there is a challenge of interoperability, data exchange and security within the healthcare systems and other technologies. This study contributes to the body of knowledge by developing a conceptual framework that helps policymakers, researchers, and practitioners that act as guide to effectively implement blockchain technology in healthcare. The framework addresses key considerations of traditional systems, such as scalability, interoperability, security, and regulatory compliance, and offers a structured approach to resolving current challenges.

A. Introduction

The growing world of digitalization shows an increase in Electronic Health Records (EHRs), which results in the accumulation of vast patient records [1]. Traditional healthcare systems frequently encounter challenges in maintaining secure data storage, facilitating efficient data sharing, and ensuring smooth collaboration among healthcare providers [2]. To this extent, healthcare personnel and policymakers are sensing that, while EHRs are essential for effective care delivery and tele-healthcare, there is a need for interoperability, data exchange, and security[3], [4]. EHRs also need interoperability to effectively replace paper-based records and be trusted to store the user's entire medical history from childhood [5], [6], [7]. Further, patient data in EHRs is fragmented due to the various formats used by healthcare [8]. Addressing the significant variability in the types and contents of patient records requires attention to the need for interoperability and standardization of data types and contents. Efficient exchange of health information can also be hindered by using different EHR systems that use varying hardware and software systems [9].

In contrast to centralized EHRs, blockchain can be defined as a distributed ledger that is secure, decentralized, and immutable, and the impact on healthcare systems should be significant [10]. There are several classifications of blockchains, namely public (permissionless) and private or hybrid (permissioned) networks. Public blockchains, which are open to everyone, provide visibility as well as accommodate many different participants, while private blockchains limit the potential users, which allows better control over data privacy and security [11], [12]. Blockchain comprises a series of immutable data records, which are time-stamped and managed by a network of computers not owned by any single entity or institution [13]. Blockchain technology was introduced in 2008 through cryptocurrency technology, but in later years, it has been adopted in various industries and sectors [14]. It provides a distributed ledger technology meant to protect, secure, and open data sharing [15]. This essential structure allows the healthcare professional to share required information quickly and safely while protecting the patient's ability to maintain privacy and control over their medical records [16], [17].

Its integration in healthcare presents an opportunity to address interoperability, data exchange, and security challenges in EHRs [14]. In addition, Blockchain overcomes most limitations in traditional systems by introducing a patient-centred EHR that empowers the patient over their medical records to grant access to any stakeholder in healthcare except in emergencies [18], [19]. A study by [15] noted that the biggest issues confronted are protecting data, sharing that data, and making it interoperable with other systems when managing population health. Nevertheless, there is a possibility that the advent of blockchain can enhance the way EHR is handled, provide patients and providers with a safe and secure manner of sharing data, reduce the risk of changing information, and give patients a complete, up-to-date medical record [16], [17]. Blockchain also provides a secure environment for detecting fraudulent activities, which may arise from health insurance fraud and drug diversion [18]. Blockchain technology increases security and protects patient information from loss or hacking attempts, and allows patients to determine who has access to the medical record which enhances privacy and information protection [20], [21][19]. Moreover, blockchain technology can allow the benefit of smart contracts to simplify access permissions and control data availability for authorized user entities [22]. Blockchain technology aids in the automation of the medical insurance claims processing, thereby lowers administrative costs [20]. Blockchain promotes the adoption of healthcare portals, which ensure effective data management [23].

Despite the research on blockchain technology in the extant literature, gaps remain on how the integration of multiple systems, effective in data transfer and privacy and security concerns. It is on this premise that this study presents a comprehensive literature review to provide answers regarding the existing framework, factors, opportunities, and challenges through the following research questions

The literature review posed to answer the following research questions, what blockchain frameworks are currently used for interoperability, data exchange, and security in healthcare, which factors affect the adoption of blockchain in healthcare, what are the benefits or opportunities of adopting blockchain-based solutions in healthcare, what are the risks or challenges of adopting blockchain-based solutions in healthcare, and how has blockchain technology been applied in healthcare.

B. Methodology

In conducting this systematic literature review, we adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a standard means of doing and reporting systematic review.[24].

Search Strategy

Comprehensive literature searches were conducted across various electronic databases, including PubMed, IEEE Xplore, and ACM Digital Library. The search strategy was a mix of keywords and Boolean operators to ensure comprehensive topic coverage, using the following search string syntax(“Blockchain” AND “Interoperability” AND “Data exchange” AND “Security”). Additionally, the search syntax was applied to meet the search criteria for the specific database: ("Blockchain") AND ("Interoperability" OR "Data exchange") AND ("security" OR "privacy") AND ("healthcare") and ("Blockchain") AND ("Interoperability" AND "Data exchange") AND ("security" OR "privacy") AND ("healthcare").

The Inclusion and Exclusion Criteria

The inclusion criteria for the systematic literature review were limited to journal articles published between 2020 and 2025 that focus on the application of blockchain technology in healthcare systems. The articles addressed at least one of the aspects of interoperability, data exchange, or data security, and examined the factors, opportunities, and challenges of using blockchain technology in the healthcare system. Articles in which are written any language other than English were excluded. In addition, studies that do not specifically address the research questions of blockchain technology, interoperability, or data exchange and data security in the healthcare context, or have insufficient information and poor methodological quality, were excluded.

Screening

The search yielded 837 articles from PubMed (n=76), IEEE Xplore (n=354), and ACM (n=407). 2 duplicates were removed. From the remaining 835 papers, 651 articles were further excluded because they were books and conference abstracts. After this process 127 articles were excluded by reading the title and were eliminated because the title did not focus on blockchain technology healthcare. From the remaining 40 papers, their abstracts were read and 20 papers were eliminated based on the set inclusion criteria. After abstract elimination 20 papers were read their full texts and 2 papers were eliminated because they could not answer the posed research questions of the study blockchain technology in healthcare.

Inclusion

After this exercise, 18 articles were included in the review. These articles are matched with research questions, providing a deeper insight into Blockchain technology, mainly to enhance interoperability, data exchange, and security.

C. Result

As suggested by [24], the PRISMA guidelines were applied. Figure 1 shows the PRISMA flow diagram for this investigation.

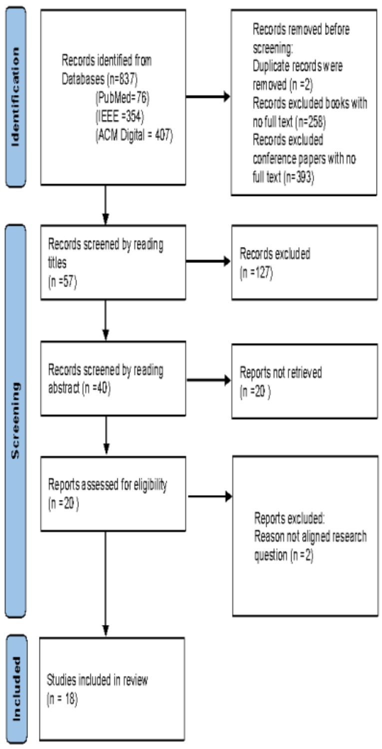

Figure 1. The flow diagram for this study using PRISMA is depicted

Results Table

Table 1. Papers that met the inclusion criteria

Author & Year	Country	Methodology	Blockchain Framework	Application area	Factors	Benefits/Opportunities	Risks/Challenges
[25]	Hong Kong	Mixed	Ethereum	• Internet of medical things devices (IoMT) • EHRs	• Interoperability • Security and privacy • Trust issues	• Improved data management • Increase in data transparency • Enhanced Privacy & security	• Scalability • High energy requirement
[26]	India	Mixed method	Ethereum Hyperledger fabric	• EHRs • Insurance claims • Pharmacy & supply chain management • Telemedicine & doctor consultation • Genomics • Neuroscience	• Scalability • Operational Cost	• Provide a decentralization system	• Data Access and Reliability • Security and Privacy concern • Regulatory& legal concern
[27]	Saudi Arabia	Mixed method	Ethereum Hyperledger fabric	• Clinical trials • Supply chain management • Health insurance	• Scalability • Cost undisclosed	• Integration with other system	• Interoperability issues • Security and privacy concern
[28]	Saudi Arabia	Qualitative	Ethereum Hyperledger fabric	• EHRs • Pharmacy & supply chain management • IoT devices	• Scalability • Regulations • Technical knowledge issues	• Enhanced Security and privacy	• Security & Privacy concern • Lack of technical knowledge

							• Scalability
[29]	Qatar	Qualitative		• Clinical Trials Management • Pharmaceutical Supply Chain • Medical insurance	• Scalability • Interoperability	• Patient identity management • Data sharing • Data monitoring	• High Energy Consumption • Lack of technical expertise
[30]	Pakistan	Qualitative	Ethereum Hyperledger fabric	• Pharmaceutical • EHRs • Neuroscience • Clinical research • Medical fraud detection	• Implementation cost • Standardization	• Improved data integrity	• Scalability issues • Uncertainty & Data Ownership • Rules& regulation concern • Security &privacy concern
[31]	India	Qualitative	Ethereum Hyperledger fabric	• Clinical trials • Telemedicine • Organ transplantation	• Regulations • Interoperability • Cost effectiveness	• Enhanced security • Increase in data transparency • Improved data Integrity • Improved data management • Efficiency& reduced cost • Drug traceability	• Data privacy concern • Data standardization • Legal& liability issues • Ethical concern • Scalability issues • Technological adoption hurdles
[32]	India	Qualitative		• EHRs • IoT	• Scalability	• Enhanced security&	• Regulatory&

				devices • Clinical trials		privacy protection • Improved data integrity& auditability • Improved data management • Empowerment of patients • Data sharing	Legal concern • Data Standardization • Scalability issues
[33]	India	Qualitative		• Supply chain management • Pharmaceuticals • Claims settlement	• Cost-effectiveness	• Provide a decentralization system • Data monitoring & access • Enhanced security & privacy	• Interoperability issues • Scalability issues • Legal issues
[34]	India	Mixed	Ethereum Hyperledger fabrics	• Health insurance • Clinical trials • Supply chain management		• Improved data management • Drug traceability • Clinical research benefits • Enhanced security	• Data privacy concern • Scalability issues
[35]	India	Qualitative		• Clinical trials • Supply chain management • Medical insurance	Cost effectiveness	• Improved data transparency • Efficiency &cost reduction • Enhanced security	
[36]	India	Qualitative			Implementation Cost	• Improved data transparency • Provide a decentralization system • Enhanced security	Security& privacy concern

[37]	Pakistan	Mixed method	Ethereum Hyperledger fabric	EHRs	Interoperability	• Improved security & privacy • Provide a decentralization system	
[38]	United Arab Emirates	Qualitative	Ethereum Hyperledger fabric	EHRs	Regulations	• Provide a decentralization system • Enhanced security • Improved data transparency • Speed & efficiency • Integration with other system	
[39]	USA	Qualitative		Pharmacy & supply management Organ transparent Clinical trial		• Accurate data management • Enhanced in security and privacy • Drug traceability • Clinical research benefits	Integration challenges Scalability issues Regulation
[40]	USA	Mixed method	Hyperledger fabrics		Interoperability	• Enhanced security &privacy • Provide a decentralization system	Scalability issues
[41]	Switzerland	Qualiattive			Regulations	•	Scalability issues Interoperability issues Privacy and security

[42]	USA	Qualitative	Ethereum Hyperledger Fabric	• EHRs • Remote patient monitoring • Pharmaceutical supply chain • Health insurance claims	Interoperability Scalability	• Provide a decentralization system	High energy requirements Privacy & security concern

Publication Per Year

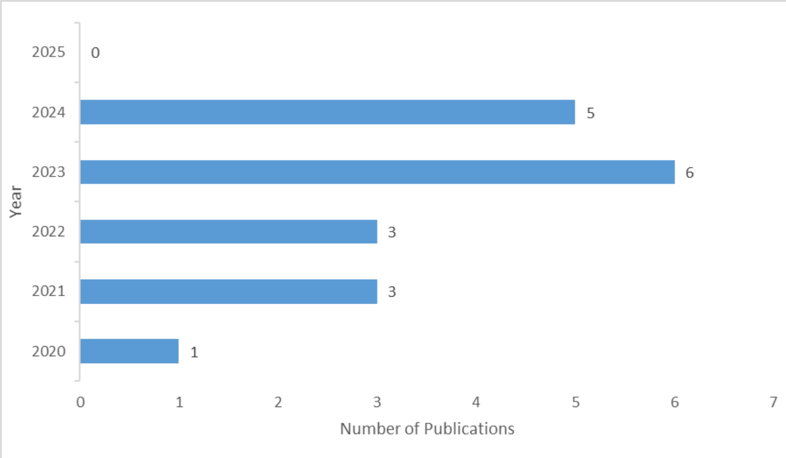

Figure 2. Publication by year

Figure 2 shows a trajectory reflection with the initial rise of curiosity in blockchain technology. The research was conducted from 2020 to February 2025; however, the slight decline in 2025 could simply be indicative of the early year status, as more research may still be forthcoming. The year with the most articles according to Figure 2 is 2024 & 2023 with 5 articles each, 2022& 2021 with 3 articles each, and lastly 2020 with 1 article.

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Publication Per Continent

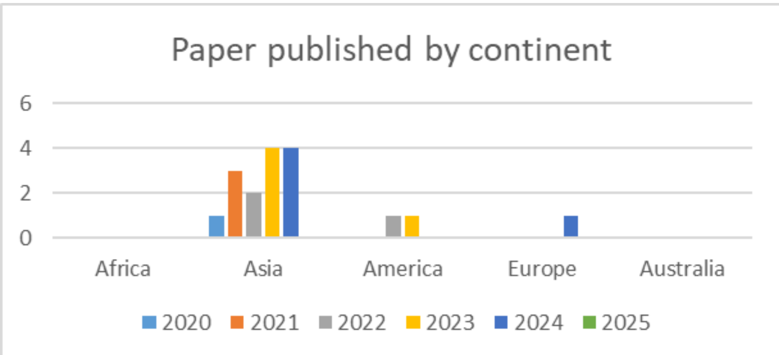

Figure 3. Number of papers per continent

Figure 3 shows Asia contributed to most of the publications with 14 articles, followed by America and Europe with 2 articles each, while other continents did not contribute any papers to this study. Indian researchers contributed most of the papers that qualified for the systematic review. The continent that contributes most due to factors includes strong research and development in blockchain technology and healthcare

Methodology used in the literature review

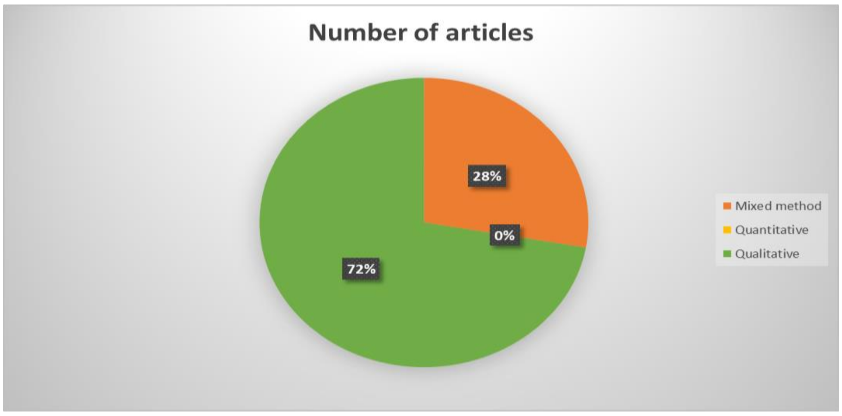

Figure 4. Methodology found in literature

Figure 4 shows the use of qualitative 12 with articles, mixed approaches with 5 articles and lastly, quantitative with no articles. The methodologies provide novel perspectives on the difficulties of healthcare data management systems. The insights gained through qualitative and mixed methodologies can be beneficial to healthcare practitioners and policymakers in understanding the impact of promising new technologies, thereby paving the way for successful implementation plans.

The blockchain frameworks in healthcare

Table 2 Existing framework

Framework	***References***
Ethereum	[25], [28], [26],[27],[34],[30],[31],[37],[38],[42]
Hyperledger fabric	[26],[27],[28],[34],[30],[37],[38],[42]

Table 2 shows the framework with the Ethereum framework with 10 articles and the Hyperledger framework with only 8 articles. Although several blockchain frameworks have been used in health care, but for the 18 articles reviewed, two (2) blockchain frameworks were identified.

Factors that affect the adoption of blockchain in healthcare

Table 3. Factors

Main Factor	**Sub factor**	**References**
Technical factor	Scalability	[26],[27],[28],[32],[29],[42]
	Interoperability	[25],[29],[31],[40],[37],[42]
	Security & privacy	[25],[26][41]
Regulatory factor	Regulations	[30],[31],[28],[38],[41]
	Standardization	[30]
Social factor	Trust issues	[25]

Economic factor	Technical knowledge issues	[28]
	Implementation, operational cost, cost effectiveness	[30],[26],[33],[35],[27],[36],[31]

The factors are grouped into four (4) main factors as illustrated in Table 3. The technical factors counted 13 articles, the economic factor counted 7 articles, the regulatory factor counted 6 articles and the social factor counted 2articles.

Benefits /Opportunities of adopting Blockchain technology in healthcare

Table 4. Benefits/Opportunities

Benefits/Opportunities	References
Improved data management	[32],[34],[39],[36],[25]
Provide a decentralization system	[26],[33],[36],[37],[38],[40]
Improved data integrity & transparency	[30],[31],[32], [25],[35],[36],[38]
Improved data sharing &Integration with other systems	[32],[35],[29],[38],[27]
Enhanced Security & privacy	[25],[31],[32],[34],[35],[36],[37],[38],[39],[40],[33]
Clinical research benefits	[34],[39]
Improved supply chain management & drug traceability	[34],[39],[31]
Efficiency & reduced cost	[31],[35]
Better patients result	[32],[29]

Table 4 shows 11 opportunities identified by literature which includes decentralization with 7 articles, increase in data transparency with 5 articles, enhanced security& privacy with 11 articles, clinical research benefits with 2 articles, improved data management with 5 articles, improved data integrity with 3 articles, efficiency &reduced cost with 2 articles, data sharing with 3 articles, drug traceability with 3 articles, better patients result with 2 articles and integration with other system with 2 articles.

Risks /Challenges of adopting blockchain technology in healthcare

Table 5 Challenges

Challenges	References
Scalability issues	[30],[31],[33],[34],[39],[40],[41],[28],[25][32]
Security& privacy concern	[28],[31],[34],[36],[41],[30],[27],[26],[42]
Regulatory & legal concern	[31],[32],[33],[26],[30]
High energy consumption	[25],[29],[42],[30],[39]

and computing power limitations	
Lack of technical expertise &knowledge	[29],[28]
Interoperability issues	[33],[41],[27]
Adoption& implementation issues	[28],[25],[26],[31],[39],[27],[30]

Eight risks or challenges to implementing blockchain technology were noted in Table 5 of the literature review. Scalability counted for 10 articles, security & privacy counted for 8 articles, regulatory & legal concerns counted for 5 articles, High energy requirements counted for 2 articles, lack of technical expertise 1 article, lack of technical knowledge counted for 1 article, adoption & implementation issues counted for 7 articles, and computing power limitations counted for 2 articles.

Blockchain technology is applied in the healthcare system

Table 6: Application areas

Application area	References
Electronic Health Records (EHRs)	[25],[26],[30],[31],[37]
Telemedicine & Doctor consultation	[26][31]
Pharmacy &Supply Chain Management	[29] [26][31][33][27][34],[30],[28]
Clinical Trials and Medical Research	[27] [26][31][30][34]
Medical Fraud Detection Insurance and Claims	[26],[33],[34],[30],[27]
Organ Transplantation	[31]
Neuroscience	[26][30]
Genomics	[26]
Internet of Medical Things	[25]

Table 6 shows only identifies 8 application areas. Telemedicine counted for 2 articles, EHRs counted for 4 articles, Pharmacy & Supply chain management counted 5 articles, medical fraud detection or Insurance & Claims counted 3 articles, Clinical trial & medical research counted for 5 articles, Organ Transplantation, Neuroscience &Genomics counted 3 articles.

D. Discussion

This section answers the research question outlined in the literature review.

Existing blockchain framework

Numerous blockchain frameworks are presently used in healthcare which including Ethereum, Hyperledger, Quorum, and Corda [47]. Because Ethereum is a public blockchain, most articles have reviewed its use in interoperability, data exchange, and security.

Ethereum framework: A blockchain framework, allows integrating permissioned aspects into a decentralized and open-source blockchain framework. For example, the Ethereum framework can be used to develop and deploy decentralized software applications and executable self-enforcing contracts [49]. Ethereum makes use of the Bitcoin and is widely used in most healthcare applications. Ethereum was the pioneering blockchain to incorporate a smart contract system, operating in open (or permissionless) networks where anyone can participate [34]. The use of Ethereum in health applications includes securing patients' records, insurance management, and data sharing between health providers [6]. Most of the applications run on the Ethereum framework, such as Medrec and Ancile and also apply complex smart contracts [25]. A study by [28] highlighted that the Ethereum framework uses features of leveraging smart contracts to manage electronic health records for patient ownership and control. These smart contracts also help in patients' privacy and access control [26]. A study highlighted by [37] noted that to ensure secure medical records management, the smart contracts enable efficient and user-friendly interactions between components. A study by [27] also noted that one purpose of Ethereum is to provide patients with secure access to medical records. According to [30] the first global and open-source mutual insurance marketplace is using the blockchain associated with Ethereum. However, according to the study by [31] that blockchain networks, particularly public ones like Ethereum, may encounter scalability issues as healthcare data volume increases.

Hyperledger fabric framework: an open-source blockchain framework designed for enterprise solutions, including healthcare applications [20]. Hyperledger offers modularity and flexibility, allowing businesses to customize their blockchain solutions based on specific needs [48]. It is a framework that enables secure and scalability in data exchange [46]. According to the study by [27] that the application successfully transmitted mobile devices (smartphones) to a blockchain-based application on Hyperledger Fabric in a continuous remote application for patient monitoring. Unlike the Ethereum framework, the Hyperledger framework does not use Bitcoin, and it is a private blockchain [28]. According to [26] the first blockchain that allows access to health records developed with Hyperledger Fabric. [34] acknowledge that blockchain offers a distributed system with improved authenticity, privacy, and transparency; for smooth testing and vaccination, use the private blockchain Hyperledger Fabric. According to [30] the Hyperledger Fabric technology stores and maintains information, so it is very difficult, or even impossible, to manipulate, hack, or deceive the system.

Factors of adopting blockchain technology in healthcare

Several factors affect the blockchain technology adoption, whether negatively or positively. The main factors include technical, regulatory, social, and economic factors.

Technical factors: These are the technical aspects or considerations that affects the blockchain technology adoption in healthcare. The technical factors reviewed in the literature include scalability, security and privacy, and interoperability.

Scalability refers to the ability of a system to manage more data or transactions without sacrificing performance [27]. The healthcare providers (hospital and clinics) believe that there is a need for a system that can able to accommodate large volume of data transactions especially peak times [32]. These help in managing the records efficiently and processing medical insurance claims by both the hospital and medical insurers. However, scalability has become a growing concern for blockchain applications and adoption, however, because there is no limit to how many people can join the network. [28],[26] and [29]concurred that storage space and network challenges will affect effective use of the blockchain technology.

Interoperability is the extent to which EHRs systems interact with each other by sharing of patient's data. According to the study by [31] blockchain allows the facilitation of seamless data exchange between diverse EHRs and clinical trial platforms. The data sharing allows an effective way of patient care and disease management. According to the study by [25], that EHR interoperability consists of two aspects; the hardware and software differences, plus the design, function and implementation of the EHR software systems. Blockchain technology instead may be viewed as a too complex system and or impractical to be implemented by the stakeholders. [37] noted the healthcare providers effortlessly share and access patient information whenever necessary, irrespectively of the location where patient received treatment. The patient will see it as effective way of receiving diagnosis and early treatment. However, it was noted [29] regarding interoperability, a lack of trust within the healthcare sectors, and lack of IT professionals to implement blockchain technology were also present. Different system that are incompatible with the systems will affect the use of blockchain technology in healthcare, but an effective gateway can be implemented [40].

Security and privacy factor is important and needs to be addressed as indication on how the healthcare sector can adopt and how the patient can perceive on the technology to safeguards their medical records. Given how simple it is to exchange or steal digital data, data security and privacy are becoming more and more crucial [25]. Due to the sensitive health data security regulation that needs to be looked at before the adoption of the technology [41].

Regulatory factors: The laws, regulations, and standards that determine the use of blockchain technology in healthcare. The regulatory factors include compliance with regulations and the need for standardization from accredited standards, and global standardization organizations [30]. These laws and regulations are guided and aligned by the country and international laws (i.e., data protection law, health policy laws, cybersecurity laws, privacy laws, etc.) where blockchain technology is deployed. As it was highlighted by [28] regulations and standards may be overshadowed by privacy laws such as the EU General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA). It was concurred by [39] real data safety regulations, such as HIPAA and GDPR, are to be adhered to by healthcare organizations. But, limited understanding of the laws and practices specific to the healthcare industry can be confusing and complicated [41]. [31] also highlighted that this is especially concerning in regard to how rigid regulations demand data security and privacy be of utmost importance. Regulatory compliance is a legal necessity and a factor of stakeholder trust and the perceived usefulness of the blockchain in healthcare.

Social factors: These are the societal aspects or human behaviors that affect the adoption of blockchain technology. The social factors include healthcare provider technical knowledge and trust issues. [25] acknowledges that the concerns and issues with trust for both patients and providers. While smart contracts make it possible for providers to track who requests data, patients and providers are still forced to be concerned about unauthorized access to and use of patient private information in the absence of a regulatory framework. Technical knowledge issues arise from familiarizing users with new technology. It was supported by [28] many individuals lack access to costly hardware and software, and a large number are not acquainted with the newest technologies. Social factor needs to be addressed to avoid technophobia.

Economic factors: These are the cost, the return on investment that affect the adoption of blockchain technology in healthcare. According to [26] the blockchain-based healthcare system requires resources to be constantly available for the purposes of reporting, upgrading, troubleshooting, and backing up. A study also by [31]also noted that blockchain solutions in the healthcare sector could have significant up-front costs for infrastructure, training, and development. [27] and [30] highlighted that the expenses associated with setting up and maintaining a healthcare blockchain remain uncertain. The transaction costs on the blockchain are influenced by various fundamentals, including network fluctuations, delays in transaction confirmation, and the volume of transactions. However, [33] and [36] suggested the introduction of blockchain technology would eliminate all third-party and mediator systems that we typically rely upon for data transfer and retrieval, resulting in cost savings. [35] also noted that by removing intermediaries from the payment chain, intelligent contracts will minimize costs.

Benefits or Opportunities of adopting blockchain technology in healthcare

Blockchain technology is a single ecosystem created by the platform's decentralized nature, which allows the secure and swift flow of patient data among doctors, hospitals, and pharmacists [33][50].

Improved data management: It is essential as it plays a pivotal role in healthcare by utilizing a distributed ledger to ensure that there is improvement in healthcare data management. As highlighted by [36] the system has distributed rights and control to all patient health information as well as any other relevant information. Improved data management will cause an effective real-time diagnosis and treatment of patients, and disease management in case of outbreaks. [34] also noted that blockchain technology has been extensively utilized for managing patient data, mainly to cost-effectiveness and security. According to the study by [32] the unique characteristics of blockchain, namely its, immutability and transparency, contribute significantly to data management. In contrast, [39]noted regulations, disjointed backend systems, and distributed shared medical data have hindered the progress of blockchain adoption in the area of data management. However, [25] noted that it is the nature of blockchain that improves interoperability in various healthcare settings, enabling effective data management.

Provide a decentralized system: Blockchain provides a block where patients records are securely kept and for easier accessibility in a decentralized system. There are no authority controls, and the potential for single points of failure is removed, as there can be no one central body to govern a decentralized network [38]. [26] also noted that in decentralized systems, the risk of a single point of failure is diminished. [40] also concurred that the distributed ledger structure removes the vulnerability of a single point of failure found in traditional systems like EHRs which depend on isolated databases. [33] also highlighted that the blockchain decentralized design makes it resistant to hacking and ensures that no single data is compromised. [37] highlighted decentralized systems ultimately allow patients access to their medical records directly, which can help to retain the completeness and certain accuracy of the data. [36] acknowledges also that the architecture allows a distribution and accessibility of the health data to various stakeholders. Decentralization in healthcare allows remote monitoring and early diagnosis of diseases by collecting data across multiple nodes and devices (wearable sensors and smart medical devices) [51].

Improved data integrity and transparency. The other crucial benefit of the technology is the improvement in the integrity and transparency of data as patients can be tracked and identified through unchangeable audit records [30]. As highlighted by [31] that blockchain's immutability guarantees that patient data cannot be changed or removed and remains unchanged over time. [32] concurred that blockchain technology's immutability and transparency keep the records of all transactions, hence, providing an auditable trail of data provenance, and therefore making the tracing of the origin and growth of patient records easier. Furthermore, [25] highlighted that the decentralized nature of blockchain technology means that each node can have a complete copy ledger, such that all data access is completely transparent to every node, making it impossible to tamper with data without knowledge of the other nodes. [35] noted that the data transparency feature allows for combating the distribution of counterfeit and misuse of drugs in health. Improved data integrity helps in achieving accurate, complete, and trustworthy clinical research or trials [36]. According to [33], smart contracts provide consistent rules that aid in the construction of a standardized rule-based approach to patient data access, thus allowing integrity and transparency in various healthcare organizations. Most importantly, data integrity and transparency are the catalysts for why blockchain technology is being adopted in healthcare.

Improved data sharing and integration with other systems: Traditional systems fall behind in data sharing as there are fragmented databases where patient data is stored separately on separate forms across the various healthcare providers. According to the study by [29], blockchains can provide a secure sharing of patient information between healthcare organizations. As [32] concurred that smart contracts using automated data-sharing agreements help in efficiently sharing and securing medical data, ensuring privacy and security.[35] highlighted that the development of diagnoses and therapies for several illnesses and epidemics is aided by effective data transmission and sharing among all the major network participants and healthcare professionals. Blockchain technology allows healthcare stakeholders to access and sharing of patient data from the system whilst maintaining privacy [52]. Integration of the system is noted by [31]as another prominent benefit, in that patients can access their medical records from different providers and ensuring patient care. [27] highlighted that the data linkage between healthcare providers will be developing through blockchain-based data management. The context of integrating blockchain technology, into health care systems enables real-time data exchange and facilitates teamwork [36]. This integration allows patient medical records to be effortlessly shared among hospitals, clinics, pharmacies, and laboratories. Data sharing improves clinical decision making and improves patient outcomes[53].

Enhanced security & privacy: Blockchain technology promotes security and privacy in healthcare by distributing data across a decentralized network rather centralized. Blockchain technology is resistant to cyberattacks because of its decentralized nature, which lowers the possibility of a single point of failure [31]. According to [25] and [39] privacy and security of blockchain means entails encrypting the data recorded in the block using cryptographic algorithms that protect the blockchain from cyberattacks. [28] and [40] concurred that blockchain employs encryption techniques, making it extremely difficult for authorization and to tamper with patient data. This will lessen the possibility of illegal access and data breaches. By preventing unwanted access to private information, data encryption protects patient confidentiality[38]. According to [34] that blockchain enhances the protection of sensitive information which is crucial for patients who are worried about breaches and identity theft. [36] highlighted that the data is safe and unchangeable due to the blockchain's non-editable structure, and the health records on its blocks are encrypted to ensure security. The use of encryption by the blockchain technology makes safe from data theft and also helps in identity theft [33]. The immutability feature of blockchain technology enhances the security of patients' electronic medical records (EMR) [35]. [37] concurred that the immutable nature of blockchain provides an unchangeable record of all transactions, making it easy to track and confirm the legitimacy of medical records. Additionally, the consensus techniques of blockchain, such as proof of stake or proof of work, also make a great contribution to security since there is no valid transaction until all participants in the network agree to it [32].

Clinical research benefits: Blockchain can enable clinical trials by ensuring the data accurate, and authenticity [39]. Blockchain technology used in further researches of the diseases, patients and improved clinical trials from makes use of real time and remote monitoring [54]. Immutability allows the records to be kept for future research and diseases management without any alteration. Blockchain technology allows for long-term medical data preservation technology which is important in tracking disease progression or outbreaks, treatment and future research [55]. Clinical research also allows personalized medicines for patients from securing genomics and clinical data.

Improved supply chain management and drug traceability: Blockchain technology improves on pharmaceutical supply management and drug management in healthcare. According to the study by [39] in conjunction with tools like point-to-point tracing of drugs as well as authenticity verification, blockchain technology, when utilized for medicine traceability, helps to address the issue of medicine counterfeiting by ensuring that drugs are authentic. [31] also noted that blockchain technology significantly reduces errors in record-keeping and authentication, ultimately bolstering consumer and stakeholder trust in the pharmaceutical industry. [34] noted that by eliminating instances of fraud and fake medical supplies, the medicine traceability capability of blockchain technology opens up the possibility for enhanced supply chain efficiency.

Better patients result: It is achieved through monitoring and tracking of patient medical records, which grants patients control of their medical records. According to [29] blockchain technology can provide patients with authority over their health data. [32] noted that, interoperability, in turn, increases patient care management and improves patient outcomes, decreases administrative burdens to providers, and lowers costs to health care. The incorporation of blockchain to EHR improves patients' power over their personal health information, ultimately leads to better care for the patient. Data monitoring in blockchain technology allows, according to the study by [33], doctors can monitor patients and patients can have access control over their medical records for improved outcomes for patient.

Efficiency & reduced cost: Blockchain technology reduces cost in terms of streamlined processes and reduced intermediaries can lead to cost savings in healthcare administration. [31] acknowledges that smart contracts automate tasks such as processing insurance claims and payments, reducing administrative costs that require manual intervention in traditional systems. This will speed up workflows (billing and payments), reduce human error, and fraud in the healthcare sector. [35] noted that managerial work is reduced since blockchain is precise and uncomplicated, saving time, effort, and money. The feature immutability reduces repeated data validation between the healthcare sector and leads to time and effort savings. The study by [51] also shows that integrating blockchain with "*Robotic Process Automation (RPA)*" and *"AI-driven*" tools can further streamline operations.

Challenges of adopting blockchain-based solutions

With the advent of IoT/IoMT, AI, and cloud computing, the amount of healthcare data continues to increase, resulting in large data sets (big data) [41]. Blockchain technology has faced major challenges in healthcare that includes security and privacy, scalability issues, regulatory & legal concern, adoption & implementation issues.

Scalability issues: Blockchain technology may struggle to manage a large number of transactions in healthcare, and the slow network, as highlighted by [28]. There is a need for storage space and full coverage on the network [40]. [30] noted that given the vast amount of data involved, a significant issue for blockchain-based healthcare systems is scalability. [25] and [41] also concurred that adding patients and healthcare providers can cause system congestion, which is brought on by the heavy computing load, which may result in query inefficiencies. This can cause performance to decline due to processing delays when the data load increases. [32]and [39] further noted that the inevitable pattern of blockchain technology, where every node of the network individually verifies and stores each transaction, sets constraints regarding scalability as the network grows. [33] analyzed that the limitations on data size for blockchain-based systems lead to scalability problems due to the abundance of clinical data. [31] noted also, blockchain frameworks, particularly public ones like Ethereum, can encounter scalability issues as the volume of healthcare data grows. [34] highlighted also that the volume of the transaction involved is vast, leading to increased transaction processing rates and the communication latency.

Security and privacy concerns: Safeguarding of data and its ownership is a challenge in blockchain adoption. Although blockchain technology has been proven to be effective in security and privacy. However, according[42] Cyber threats to patient data, that is, 51% attacks, or smart contracts that make blockchain not immune. [28] highlighted the concern of privacy being violated by blockchain applications distributing personally identifiable information in a publicly-accessible database. A study by [27] highlighted the possible threat of privacy violations resulting from deliberate attacks on the blockchain for healthcare by criminal organizations or even government agencies, that may violate individual patient privacy. [30]concurred that there are still the possibility of breaching security and attacks by criminals or government entities on health care blockchains and breaches to the security of patient data will occur. [26] acknowledge that healthcare data will be created through different stakeholders and can impact the accidental breach of protection, privacy, and security safeguards.[34] also highlighted that hat data privacy is a concern in blockchain, but more so for health care data specifically, which contains sensitive personal data that needs protection. Users may find the encryption or decryption key pair necessary to authorize access to their medical data to be a bit overwhelming [56]. Overlooking these privacy issues would not only be a violation of regulations but also damage trust, a crucial factor in the healthcare sector [41]. Managing patient consent on the blockchain requires well-defined smart contracts and user-friendly interfaces to ensure compliance with con- sent preferences [31]. Patients must fully understand the implications of granting or revoking consent.

Regulatory and legal concern: Vulnerabilities related to regulatory compliance on data and security can complicate the adoption. [28] highlighted that blockchain encourages disintermediation, thus no one will be responsible for breaking the laws and regulations in a country. [26] noted that effective operation of a blockchain-based healthcare system requires interoperability between the public and private sectors in the absence of legal norms. [30]highlighted that one of the main problems is associated with blockchain technology’s integration with EHR systems since this sphere deals with regulatory and legal aspects. [57] highlighted that creating appropriate guidelines for a blockchain-based healthcare system's worldwide regulation of ownership rights in medical transactions is difficult. Achieving data standardization across the healthcare industry is challenging due to legacy systems and varying data formats [16]. [32] concurred that, because standardized protocols and data formats are lacking in the context of blockchain-based EHR systems, interoperability may end up being the most difficult aspect to tackle. According to the study by [34] written records could still be altered, and the blockchain could be reconstructed if a majority of participants agree. However, it is extremely challenging for regulatory authorities to examine blockchain and confirm if transactions and data have been altered.

High energy consumption and computing power limitations: It is widely accepted that blockchain technology requires high computational power for transaction processing [39]. According to [42] that public blockchains utilize a mining technique whereby a lot of energy is used to keep the blockchain running. [25] and [29] concurred that in a proof-of-work (POW) blockchain environment, the nodes (miners) are continuously guessing a random number in order to gain the rights to create the next block. This process consumes high amounts of energy and has negative impacts. According to [25], reliance on fossil fuels as the source of electric power created with the substantial amounts of computational energy used in blockchain systems contributes to global greenhouse gas emissions and climate change. In these blockchain systems, data gets collected through IoMT devices, which regularly have low computational and power capabilities [30]

Lack of technical expertise and knowledge: [29]insufficient technical skills and capabilities during blockchain implementation can have disastrous outcomes. [28] noted that lot of users are not conversant with the latest technology, and not all users have access to expensive hardware and software resources.

Interoperability issues: [33] also noted, interoperability issues are due to the lack of standards across different blockchain-based systems. It was further supported by [41] the absence of standardization across healthcare platforms, which results in incompatibility. [27] also, emphasized interoperability indicates that different healthcare applications may not be able to connect, because there is not yet a blockchain standard for the industry.

Adoption& implementation issues: The ability to use or implement blockchain technology in the healthcare system. According to [28] many hospitals are owned by the government, meaning implementing systems requires government engagement. Governments are hesitant to adopt new technologies, complicating the implementation of blockchain technology in government-owned hospitals. The cost of investing, maintaining, and funding of blockchain technology may be a major obstacle and the cost of implementation. Since the patient records are stored in different EHR systems (disparate systems) integration can pose a challenge. [25]also indicated integration is primarily a technical issue that requires specialist attention. However, according to [27], blockchain technology can integrate with EHR systems it can also be integrated into the terminology technology of AI and Cloud computing systems. [26]noted that it is difficult working in blockchain frameworks as they are composed of multiple complex technology. [30]noted that healthcare uses blockchain technology, it requires adequate infrastructure, inter-infrastructural support, technicians, experts, for proper implementation However,[31] healthcare providers may be resistant to adopting new technologies, necessitating comprehensive training and transition plans.

Application areas of blockchain technology in healthcare

Blockchain technology has been used in various industries, and the healthcare sector has not been spared by the technology.[30] noted that blockchain can be utilized in telemedicine, e-health, genomics, medicine, telemonitoring, neuroscience, personalized healthcare access, and clinical research by creating secure datasets for users and facilitating various transactions.

Electronic health records: Blockchain technology ensure for secure, distributed storage of patient data thus ensuring integrity and empowering of patient. It has become a viable way to get around the drawbacks of conventional health record systems [37]. The study by [25]shows that blockchain is employed to secure the storage of health records, manage and share EHRs. It was also supported by [26] that blockchain technology makes EHRs more secure, manage, and able to retrieve patients' data. The study by [31] acknowledges that EHRs, blockchain technology offer a secure and efficient solution for the management of patient health records, effectively addressing the limitations of traditional systems. [30] noted that EHRs facilitate the sharing of healthcare data among various entities, allowing for access, monitoring, and information exchange. [38] concurred the decentralizing infrastructure and utilizing cryptographic techniques can increase EHR security, immutability, and traceability.

Telemedicine: The main purpose of telemedicine is the sharing of patient data, secure & efficient communication between health providers & patients. According to [26] telemedicine improves the flow of health data by enabling doctors to provide real-time medical care. As noted by [31], telemedicine signifies a significant advancement aimed at enhancing productivity, improving security and privacy about data sharing and remote medical consultations. Blockchain is a good way to enable supply chain identification, access point data, and prescription traceability [28].

Pharmacy & Supply chain management: Facilitates the monitoring & administration of medical supplies in health care. Tracking drugs helps prevent counterfeit drugs [37]. According to [29] the traceability feature of blockchains plays a crucial role in managing the pharmaceutical supply chain. [31] Also, acknowledge that blockchain technology allows for enhancements in drug traceability, providing a robust framework to monitor the lifecycle of pharmaceuticals with a focus on bolstering transparency and security within the supply chain. It was highlighted by [26] that the distribution of fake or inadequate prescriptions can have severe consequences for patients. However, [33] blockchain's immutability in healthcare can address multiple issues simultaneously. [27] noted that several current methods apply blockchain's cryptographic features to develop a decentralized, verifiable track and trace functionality for pharmaceutical products. [34] noted that blockchain based medicine traceability enhances the efficiency of the supply chain to manage and deliver those items instead of a more traditional approach to supply chain management, since it limits fraud and fake products. [30] highlighted that the processes of introducing of new medicines and quality checks may be take years to completion and, may be expedited by using blockchain technology throughout the pharmaceutical process.

Clinical trials & Medical research: It is facilitated by a partnership among researchers and provides accountability for clinical trials [30]. According to [32] the existence of blockchain technology, patients can safely put forth and share their medical records, keep track of their health metrics in real time, and participate in decentralized clinical trials. The study by [26] that blockchain can help prevent the misrepresentation of information and the concealment or rejection of negative outcomes in medical research. Blockchain enhances healthcare research practices by supporting the anonymization of patient data through advanced cryptographic methods. According to a study by [27], the use of blockchain in clinical trials will eliminate data falsification and the omission of undesirable findings. A study by [31] clinical trials enhanced by blockchain technology represents a transformative approach to optimizing the management, transparency, and integrity of clinical trial operations. blockchain based medicine traceability enhances the efficiency of the supply chain to manage and deliver those items instead of a more traditional approach to supply chain management, since it limits fraud and fake products. [34].

Organ Transplantation, Neuroscience, Genomics:

Organ Transplantation: According to [31] it serves as a secure and tamper-proof repository for organ-related data, thereby preserving the integrity of records containing information about donors and recipients. Blockchain technology is used for organ transparency and restricting organ trafficking as it will be stored in a database [58].

Neuroscience: According to [30], neuroscience research detects the current mental state and brain activities. And [26] concurred that blockchain innovation has been developed as a data technology in several neuroscience applications, such as brain augmentation, brain simulation, and brain reasoning.

Genomics: It is study of genomes which are the structure, function and evolution. According to [26] blockchain technology has established an answer of storing and trading genomic information with security.

Remote patient monitoring, IoT: Remote monitoring of patients and use of multiple wearable devices or sensors that collect patient health data, record it, and then encrypt that data [25]. According to [28] noted that blockchain technology can be used to safeguard IoT devices and stop tampering and unauthorized access. Further concurred by [32] that the use of secure devices that record and transfer health data to blockchain records as electronic health records (EHRs), healthcare providers can view patient behavior, track chronic conditions, and provide personalized care.

Medical fraud detection and Health Insurance & Claims: This is the identification and prevention of fraudulent activities in healthcare [59]. According to [27] blockchain technology's transparency, decentralization, immutability, and verification capabilities can significantly improve the handling of health insurance claims. [33] noted that an issue in the healthcare industry regarding claims processing is the length of time it takes to process claims. According to [30], Blockchain is immutable, so it facilitates authenticity in medical fraud detection. [26] concurred that blockchain technology transparency, decentralization, unchanging nature, and auditability help in insurance and claims handling.[34]

noted that in health insurance provides financial protection and helps cover healthcare costs during medical emergencies, alleviating the fear of incurring debt.

E. The proposed Conceptual framework

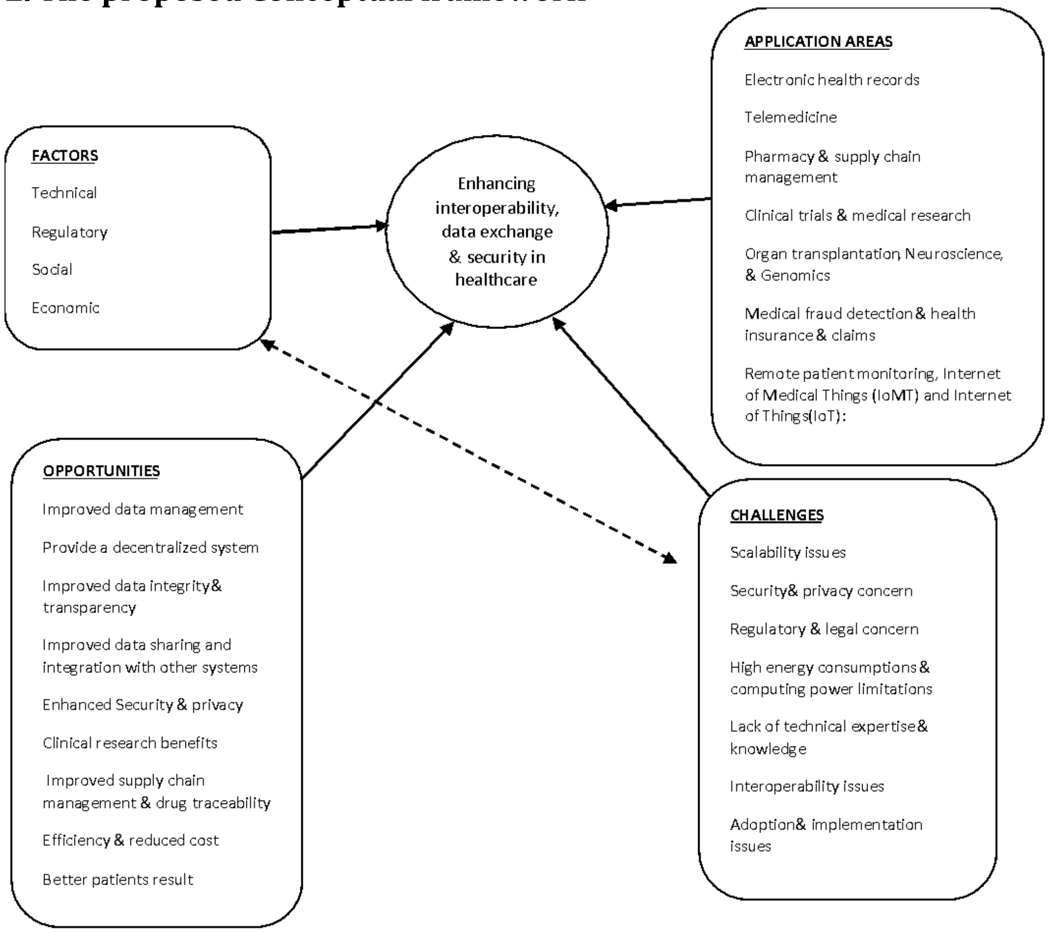

Figure 4. The proposed conceptual framework

The proposed conceptual framework is depicted in Figure 4. It shows the factors, opportunities, challenges, and application areas. The conceptual framework can be used by the researcher and policy makers in healthcare in the implementation of blockchain technology.

F. Implications of Research Findings

The health sector is evolving as with technology, so the adoption of the blockchain framework that addresses the challenges and factors in all aspects will be viable. Although the research has identified several factors and challenges that need to be considered when adopting. The literature reviews only centered on the Asia, America and Europe continent, with Africa and Australia continents lagging. These continents have invested more in blockchain technology through research and development.

Practical implications: The implications of the research conducted on blockchain technology and its impact on healthcare are very critical. The results suggest that blockchain improves not only interoperability but also sharing of information which in turn enhances patient care and makes the healthcare operations more efficient. With regard to policy makers, they can use the developed conceptual model as a framework to aid the deployment of blockchains while concentrating on overcoming scalability, security, and compliance issues with laws and regulations for governance. Furthermore, blockchain provides better control over data by safeguarding electronic health records (EHRs), thus improving data management and promoting better EHRs automation processes like insurance claims through smart contracts will lead to significant savings in administrative costs while enhancing security and reducing risks associated with data breaches. This enhances trust on digital health services provided.

Theoretical implications: On a theoretical level, the study contributes to the understanding of blockchain's role in tackling interoperability and security challenges within healthcare systems. The knowledge that this study has determined includes important research gaps, in particular those related to the integration of blockchain into existing systems & use cases in genomics or organ transplantation. The recommendations indicate that what we learnt offers a theoretical framework for interoperability standards, and possibilities for further research. While specific blockchain technology impeded interoperability were discussed, the respondents' attention to awareness of socio-technical aspects (eg. trust issues, knowledge of technology), opens up the theoretical discussion of technology acceptance in healthcare, to also include socio-technical advertising. In summary, this study highlighted how blockchain technology has the potential to unlock new models of patient-centered care. Overall, the theoretical implications of this study signal a significant and needed change in healthcare data management, to promote the privacy of patients.

G. Conclusion, Research Gap and Future Recommendations

Blockchain technology has the potential to revolutionize the healthcare sector by boosting security, data exchange, and interoperability. The knowledge gained from research may influence government and policymakers in adopting blockchain technology in healthcare. By using the conceptual framework that highlighted the factors, opportunities, and challenges reviewed by the literature, the adoption or implementation of blockchain technology may take place. Further research based on research gap may be done on data protection and integration with legacy systems (ie, traditional paper-based and electronic health records). The need for a deeper understanding of how blockchain can be integrated with legacy systems and need for empirical evidence about the real-world application. Further research on a need for deeper investigations of blockchain applicability in specific service delivery areas like neuroscience, genomics, and organ transplant. Literature review identified a research on theoretical framework lacks on the most article. Another research gap on the socio-technical aspects of blockchain technology which require in-depth understanding on how healthcare providers will adopt of blockchain technology, experiences in locally. It is important for future studies to be conducted to gain a better understanding of its impact and barriers for implementation of blockchain in real-world settings.

Limitations of our study

The research reviewed articles that were written only in English and resulted in a tilted perception of the global healthcare scene. It concentrated on 3 databases and was restricted to a particular period; thus, it may leave out databases with more viable information. The search criteria used also limited the articles.

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