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Blockchain Adoption in Healthcare: Enhancing Interoperability, Security and Data Exchange

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Abstract

Fragmented data across the healthcare industry increasingly impedes interoperability, compromises data security, and ultimately interferes with safe and quality patient care delivery. This research introduces a framework that uses blockchain technology to enhance interoperability and data exchange in healthcare environments. Leveraging qualitative methods, semi-structured interviews were held with fifteen health care practitioners at various facilities who gave their insights and perceptions of data sharing and blockchain technology. The findings were thematic and conceptualized through the Technology Acceptance Model, focusing on perceived ease of use and perceived usefulness, and the Technology-Organization-Environment framework that examined organizational support and regulatory compliance. Thematic analysis identified four main themes, including (i) factors influencing adoption: ease of use with four participants, usefulness with three participants, organizational support with two participants, regulatory compliance with two participants, and technical infrastructure with two participants. (ii)Application areas included patient data management, billing and payment, and remote patient monitoring; (iii) benefits such as a more effective decentralized system, safer storage of data, and patient empowerment. (iv)Challenges included privacy concerns, the costs of implementation and system failure, and patients' knowledge and stakeholders' digital literacy. The findings suggested that stakeholders knew the potential disruption to any blockchain system. However, major issues needed to be addressed before implementation. This research expands the conversation about innovative solutions to health care interoperability. It exposes potential ways to address the challenges to adoption. Recommendations for future research include examining the scalability and integration of blockchain technology across different healthcare environments and addressing the pressing need for empirical evidence regarding its real-world applications and impacts.

Keywords: Blockchain Technology, Healthcare Interoperability, Data Exchange, Privacy and Security.

1. INTRODUCTION

Data security, interoperability, and exchanging data when siloed systems are in use are major challenges faced by the health sector [1]. In the past, healthcare data has been largely restricted to the siloed organization of traditional health systems,

impacting patient care and inhibiting research [2]. The only thing that can hinder a patient's care progress is limiting their care; challenging care methods and organizational processes. These limit the flow of information and our ability to provide holistic care, especially based on the best available evidence (evidence-informed practice). Blockchain can advance some of these issues by providing embedded security on immutability, decentralization, and security processes when developed [3]. Blockchain is recognized as an entirely new digital record management system that can change, improve, and facilitate health care management and delivery in light of the increasing complexity of health care data in a digital world [4]. For example, the blockchain-based health record, MedRec, designed by MIT Media Lab, illustrates how a blockchain health record system can improve patient control over data use while protecting sensitive data and facilitating data sharing from the patient to the care provider[5]. MedRec has also demonstrated improved interoperability, enhanced patient access to their own records, and increased patient engagement. These are emerging areas of new solutions aiming to take autonomy and control back from the providers to the patient, based on patient-driven interoperability, while acknowledging this progression[6],[7].

A blockchain structure supports trust enhancement and data integrity. It encourages seamless access and sharing of health data among stakeholders, including their health care providers, patients, and other members of the health ecosystem [8]. The isolative nature of Electronic Health Records (EHRs) delivers a disconnected perspective on information, which diminishes opportunities for effective communication and care coordination [9]. Unfortunately, different systems are combined in a disconnected manner, therefore stymying the need for communication and cross- collaboration of the information required to realize desired endpoints [10],[11],[12]. Without the availability of comprehensive data, providers will further complicate timely treatment and decision-making, relying on eHealth information.

Furthermore, combining all available data increases the incidence of mishaps and theft. It therefore questions the safety of sensitive patient data [13][14]. Data breaches involve patient privacy violations, undermine trust in healthcare systems, and if patients cannot trust the everyday EHR system, which frequently lacks strong protection for critical health information[15]. Patients frequently hesitate to provide sensitive data due to fear of inadvertent exposure[16]. The ambiguity of reluctant compliance with regulatory legislation makes compliance proclivity exasperating for the healthcare industry. Medical data policies can stimulate innovation and enhance EHR interoperability. However, they ultimately must consider patient safety and reporting information security in the provision and delivery of healthcare [17], [18]. Although the potential of blockchain to solve many problems in healthcare is emphasized in the current literature, empirical

studies focused on the implementation of blockchain, especially in low- and middle-income countries like Zimbabwe, are lacking[19]. While many articles present uses for blockchain in healthcare systems within developed countries, there are challenges for developing countries that are understudied. Unique healthcare challenges exist in Zimbabwe, such as limited resources, dilapidated infrastructure, insufficient healthcare personnel, and regulatory challenges compared to developed countries, [13],[20]. This lack of focus requires a study that examines the opportunities for integrating blockchain to meet the healthcare necessities of providers and patients in Zimbabwe.

This study explores the potential of using a blockchain technology framework to address data security, interoperability, and data exchange issues that are significant challenges in the healthcare industry[14]. With the following objectives, this study will explore how blockchain could provide greater patient data control, improve care coordination, and improve stakeholder trustworthiness.

1) To identify the factors that affect the implication or adoption of blockchain technology in Zimbabwean healthcare.
2) To explore the potential or benefits of blockchain technology in Zimbabwe's healthcare
3) To examine the challenges and barriers that may be faced in Zimbabwe's healthcare environment.
4) To identify the application areas of blockchain technology in healthcare.

The integration of the Technology Acceptance Model (TAM) with a Technology-Organization-Environment (TOE) framework is especially appropriate for this study of blockchain technologies in healthcare[21],[22]. The TAM model allows for depth in understanding individual perceptions of blockchain technology and considers perceptions of relevance, perceived usefulness, and perceived ease of use for healthcare workers and IT professionals, among others[23],[24]. The TAM model also enables this research to account for healthcare workers' and IT professionals' characteristics, attitudes, and behaviors towards technology. The TOE framework complements the TAM model by expanding the analysis of perceptions to consider macro-system variables related to technological, organizational, and environmental contexts related to blockchain technology adoption. The TOE model also accounts for institutional policies, regulatory frameworks, and prevailing external pressures[25]. As such, combining the TAM and TOE frameworks provides a holistic understanding of the variables, conditions, challenges, barriers, and facilitators that lead to, or obstruct, acceptance and implementation of blockchain technology. This study will contribute to understanding practical ways to connect technology acceptance models with existing policy to ensure blockchain technologies are effectively integrated into healthcare organizations

2. METHODS

The study methodology uses the research flow chart as shown in Figure 1. The research flow shows the study design used, how participants were sampled and recruited, data collection, data analysis, results, and discussion.

Figure 1. Research flow chart

2.1. Study design

The study uses qualitative analysis to investigate what healthcare workers know about blockchain and how it can help manage data, improve security, and enhance patient outcomes[26][27]. Qualitative research design allows for a thorough understanding of participants' experiences, perceptions, and motivations. In-depth interviews were used to collect data, and open-ended conversations allowed participants to share their thoughts and stories effectively. The study was conducted in both private and public healthcare facilities in Zimbabwe (Harare and Mutare) to assess technological adoption levels.

2.2. Sampling and Participant recruitment

When selecting participants for this study, purposive sampling was used to identify participants with specific characteristics of interest to the study so that we could collect rich, detailed data. This selection process was thoughtfully designed to engage participants working in different capacities of the health care environment so that the perspectives gathered would reflect the complexities of the multifaceted health care context. Participants were required to have at least one year of experience in their role for meaningful opinions based on their understanding. Healthcare professionals above 18 years old and able to communicate in English from the Zimbabwe health sector, including Doctors, Nurses, IT Administrators, Pharmacists, Lab technicians, and public health officers, were recruited, hence showing an inclusion criterion of diversity in healthcare. A sample size of 15 healthcare professionals, with nine females and six males, was included in the study, as shown in Table 1, which is appropriate given the qualitative approach that values depth over statistical generalizability[28]. The sample size allows for deep engagement with the lived experience of stakeholders, which is important when undertaking research into the complexities of implementing blockchain technology in healthcare.

Table 1. Sample Size and Demographics

Participant ID	Role	Age
P1	IT Tech/Support	31-40
P2	IT Tech/Support	41-50
P3	Nurse	18-30
P4	IT Administrator	31-40
P5	IT Administrator	18-30
P6	Nurse	31-40
P7	Nurse	41-50
P8	Doctor	31-40
P9	Pharmacist	18-30
P10	Public Health Officers	31-40
P11	Doctor	41-50
P12	Public Health Officers	41-50
P13	Lab Scientist/Technician	41-50
P14	Pharmacist	31-40
P15	Lab Scientist	18-30

2.3. Data Collection

The interviews took place at different sites, such as hospital conference rooms, office spaces, and locations. They were conducted at a convenient time for the participant. Each interview lasted around 30 to 45 minutes, but the shared dialogue suggested that it was time well spent. Interviews were chosen as the central way of gathering data because they allow exploratory, nuanced discussion. Their qualitative nature allows participants to describe their feelings about and thoughts regarding blockchain technology. An expert review was sought to ensure the rigour and credibility of the interview questions. This ensured alignment of interview questions with the established theoretical perspectives and constructs, such as the TAM and the TOE frameworks. This systematic process ensured that the interview and question process would effectively facilitate data collection that would be comprehensive and informative about the evaluation of blockchain technology in health care. The semi-structured interview guide included open-ended questions focusing on experiences with data exchange and perceptions of blockchain technology. A sample of the interview question includes: Which technologies are you familiar with, given the digital systems and innovations in healthcare? What are your thoughts about a patient-controlled digital system that grants or restricts access to their health documents? What do you think about technologies enabling the secure sharing of medical information between healthcare organizations without the risk of data breaches? In your opinion, what would you consider the possible advantages of such a healthcare system? What difficulties or problems do you see arising from this patient-controlled health record system? What is your opinion on a database that securely stores and tracks

all contributions made during clinical trials and medical research while ensuring permanent verification? In what ways do you think such a system could enable data sharing across different institutions without alteration?

2.4. Data Analysis

The thematic analysis for the study on blockchain adoption in health care in Zimbabwe was done using the NVivo software to support a systematic identification of themes and patterns within the collected data.NVivo also provided an organized method for coding qualitative data; its structure allowed researchers to break down the data into themes, sub-categories and overarching categories to support the systematic examination of thought patterns in response to themes, thereby building trustworthiness in the findings.

The analysis began with some necessary data cleaning to note any missing responses, build consistency, and check the data formatting, such as spacing and capitalization. The data analysis was guided by the established framework outlined by Braun and Clarke, which requires first becoming acquainted and familiar with the data before coding [27][29]. After reading and using NVivo, in this case, the initial coding occurred within NVivo through classifying the responses based on recurring themes, which were then merged into themes with broader categories that encapsulated the main aspects of blockchain adoption. The themes underwent a thorough review to respond to the data, leading to clear definitions and naming of the themes. The analysis identified key themes, including factors, benefits and challenges to adoption, and application area. In this study, saturation was reached, and researchers also noticed that participants' responses started to become repetitive and that no new themes were unveiled.

2.5. Ethical Considerations

Informed consent was sought for in writing to make sure each individual understood their participation in the study. Efforts were made to protect the identity of the participants, and rules were in place to ensure that data collected would be safeguarded and only accessible to the researchers. Each individual was allowed to voluntarily participate, and each individual could change their minds about participation at any time without penalty.The study received ethical clearance from the Institutional Review Board (IRB) of the National University of Science and Technology (NUST/IRB/2025/138).

3. RESULTS AND DISCUSSION

Applying blockchain technology in healthcare presents numerous potential benefits, challenges, and implications for patient care. data privacy and

security[30],[31]. This section summarizes the themes and sub-themes identified in Zimbabwe healthcare practitioners' comments regarding the use of blockchain in the healthcare sector as shown by the Table 2.

Table 2 Theme and subthemes

Themes	Subthemes
The factors that affect the adoption of blockchain technology	Organizational support Regulatory compliance The ease of use Perceived usefulness Technical infrastructure
The benefits of adopting blockchain technology	Decentralization Patient Records Management Secure Storage of Data Facilitating Research and Data Sharing
Challenges of adopting blockchain technology	Security and Privacy Concerns Cost and System Failures Regulatory and Legal Concerns
The Application Area of Blockchain Technology in Healthcare	Patient Data Management Supply Chain Management Clinical Trials and Research Telemedicine and Remote Patient Monitoring Health Information Exchange Billing and Payments

3.1. The factors that affect the adoption of blockchain technology

The analysis with five subthemes included organizational support, regulatory compliance, ease of use, perceived usefulness, and technical infrastructure.

Organizational support is critical in adopting blockchain technology in the Zimbabwean healthcare sector. Participants stated that if senior leadership at the hospital provides support and resources, they are more willing to use new technologies. For example, P4, IT Administrator, said, "*When management provides support and devotes time for training on new technology, it creates an atmosphere of growth.*" This indicates that leadership is important to create conditions and an atmosphere for new technologies. A similar rationale was provided by P3, Nurse, who stated that some initiatives have been ignored after starting because, without help from the organization, they seem unlikely to succeed. "*If we do not have senior leadership support, then the best technology in the world will not save us*," she stated. Findings indicate that strong organizational support is essential when adopting a blockchain strategy because it provides training and resources. Lastly, it fosters the organizational attitude to engage with technological change.

Regulatory compliance is a significant consideration for the use of blockchain in healthcare. Participants were concerned about using blockchain because of the potential legal implications of data privacy and security. For example, P8, a Doctor, stated, "*We need to ensure any new system complies with healthcare regulations because if it does not comply, we can get sued.*" This example demonstrates the uncertainty regarding legal regulation when considering innovative technology. In another example, so P2, an IT Technician, explained that there were ways to work with blockchain, but he felt explanations on regulation were important, explaining that "*if there are no regulations, no one can effectively do anything. Regulations also have to allow for innovation and protect the patient.*" With so much uncertainty surrounding regulatory matters, it is clear that regulations need to be addressed to build confidence in using blockchain technology in healthcare.

The ease of use was an important consideration for adopting blockchain applications in Zimbabwean hospitals' healthcare professionals' minds. Participants indicated that if the interface were easy to use, they would be more open to using a shared system. P3, a nurse suggested, "*If the shared or distributed system is easy to use and does not need much training, I might use it in my normal nursing practice.*" This indicates that ease of use can help users, especially those who identify as hesitant users, to adopt the application willingly. P4 stated that ease of use positively impacts new users in their onboarding process and will make support staff's job easier too, stating, "*When it is easy to use, we get fewer help requests, and we can focus on other IT problems.*" These comments indicate that any efforts to decrease the perceived ease of use of a potential blockchain application would enhance the chances of its use in the Zimbabwe health service environment, especially in technological literacy and remote areas. However, participants were adamant in their belief that if the complexity of blockchain is addressed incorrectly, it can be disastrous for implementation. As noted by P15, a Lab scientist said, "If the technology is so complicated that *the employees can't understand it, they won't use it.*". Overall, participants viewed intuitive and user-friendly design as one of the most important aspects of building acceptance of a technology. Pharmacist P14 shared similar views: "Training after the system was implemented should be easy. If not, *we could lose time and resources by losing pharmacists in launching this new technology*". This shows the importance of training programs and support for healthcare workers to understand blockchain technology.

Perceived usefulness is another significant factor in healthcare professionals' adoption of blockchain technology. Participants seemed to consistently see the usefulness of blockchain in improving operations and patient outcomes. For instance, P8, a Doctor, stated, "*If a shared system can get me access to patient records instantaneously and securely, it would fundamentally change how I conduct patient care.*" This illustrates that they believe blockchain could help tremendously to streamline processes, as information can be retrieved quickly and with more reliability. P11, a

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Doctor explained data integrity as, "*Knowing that patient data is secure and immutable is confidence, especially when making clinical decisions.*" Such views suggest that perceived usefulness, including improved security and data accuracy, can be instrumental in prompting healthcare professionals to engage with blockchain technology. Participant P15, Lab Scientist, said, "The technology could help us develop improved processes and easily enact secure patient data transfers." Overall, the data suggests that to catalyse the acceptance of blockchain, authorities could provide evidence of the advantages of using blockchain to support healthcare practitioners in their work. As noted by P14, a pharmacist, *"If we could ultimately prove that we could create medication records that are time-sensitive and irreversible, it would phenomenally impact our workflow and workplace safety."*

As participants declared in all interviews, **technical infrastructure** is a factor in blockchain adoption, specifically the existing technical infrastructure. Participants discussed that poor infrastructure can be a barrier to implementing blockchain solutions. For example, P4, an IT Administrator, indicated this when sharing, "*Our IT system is going to have to upgrade for blockchain, or it is going to be a real struggle.*" So, not only will the existing systems have to support blockchain, but there will also have to be compatible systems to integrate blockchain-based solutions successfully. The healthcare professionals were concerned about how reliable the internet would be in rural community contexts. P6, nurse, shared, "*I cannot really count on internet access, so that could be something that really disrupts my ability to use blockchain mechanisms effectively, especially in emergencies.*" These comments indicate the significance of investing in the proper and existing technical infrastructure. That will enable blockchain adoption initiatives so that partners will use the implementation as designed without performance interruptions to assist their patients.

3.2. The benefits of adopting blockchain technology

Adopting blockchain technology sub-themes can benefit the system by decentralizing it, managing patient records, securing data, facilitating research, and sharing data.

Decentralization of the system emerged as a value proposition in terms of using a distributed database that would potentially enhance interoperability between EHRs. Participant P1, IT Technicians indicated "*that a major benefit was building a database that interconnected all major hospitals and clinics*". Thus, decentralization enables data management to be done securely and easily. This is an example of how centralization is broken down within a disaggregated healthcare system in Zimbabwe. P4, IT Administrator echoed that, "*If we can decentralize the data, you are assured that the data is not trapped in one facility and is accessible at any time.*" In this regard, decentralization emerged as a fundamental principle of blockchain technology when exploring sustainability and networked governance principles. The

participant also discussed the value of a distributed database with no central point of control. Participant P6, nurse, noted about "*several systems, including electronic health records and digital health systems, that were potentially interconnected with a decentralized distributed ledger system to improve data availability and usability*". Participant also expressed their support for decentralized access and the respective benefits. Participant, P3, nurse stated, "*If I can see the patient's record at different hospitals, it allows me to understand the patient's data and make a decision quickly.*" The decentralized patient data can improve care coordination among healthcare practitioners. Participant P7, a nurse, expressed decentralized access and confidence about care, as it builds a level of trust with the patient: "Patients feel safer knowing their information is being shared responsibly and not stuck with one organization." The benefits of decentralization would also remove risks of data breaches and manipulation. IT Administrator, P5 stated, "*In a centralised system, when one database is compromised, the entire network is at risk. A Distributed network helps that problem*". Doctor, P8 shared an experience-based clinical perspective on the benefits and stated, "By accessing comprehensive patient histories from multiple data sources, *you can better diagnose patient cases and proceed with more informed treatment plans*". This illustrates the possibilities of better patient outcomes through collaborative care made possible by decentralized data sharing.

Patient Records Management is another advantage. Standardized data formats make patient records more consistent and more accurate. Participant P9, Pharmacist, mentioned that "*if standards were established, interoperability could be improved, resulting in more timely treatment and diagnosis.*" The immutability of blockchain promotes trust, as it enhances transparency and accountability, which helps to establish trust with the patient and the provider. For example, an IT Administrator, P4, highlighted, "*blockchain guarantees accuracy and the patient record will never change, which is important for safe healthcare delivery*". This suggests that the secured transactional nature of blockchain evokes trust for decisions made on data for patient treatment that can prevent many of the previous undocumented, unauthorized changes to records. A nurse, in particular, P6, emphasized that having record information improves their ability to provide care quickly, while being safe and with the necessary patient information. P6 stated that, "*When I know about a patient's history using their medical record information across multiple facilities in real-time, it allows me to provide care on my own timeline to make informed decisions.*" This level of care timing is simply important for nursing interventions, especially in an emergent care situation where timeliness can reactively affect patient outcomes. Participant P11, a doctor, indicated that blockchain technology could effectively facilitate information sharing among healthcare providers. P11 noted, "With a decentralized system, I can work with specialists without waiting; it allows me to manage the whole patient." It is important to collaborate with other health care providers to provide holistic care, and this technology would enhance that collaboration. A public health officer, P10, also mentioned, "*Effective management of*

patient records is also important in terms of public health. If patient records were accurate and easily accessible, we could improve on public health events (a.k.a. outbreaks)." This demonstrates the potential for effective data management systems to promote healthcare delivery and public health efforts.

Secure Storage of Data is the number one advantage. Blockchain utilizes smart contracts and cryptographic hashes to protect medical records digitally. Participant P3, a nurse, discussed that *"security is essential to protect patient identity and adhere to healthcare privacy policies".* An IT technician, P1, stated, "One *of the features of Blockchain is its secure databases using encryption, which keeps patient records safe from unauthorized viewing; you don't get that level of security with databases.*" This emphasizes the security features stacked around blockchain and reduces the risks of data breaches. Nurses, P7, established that secure data features mattered for secure data, stating, "*I concentrated more on my care and not whether data was leaking when I knew I was storing patient records in secure data.*" This indicates secure data storage means more than secured patient data; the mental load health care providers carry when confidently storing patient information translates into their patient focus. A public health officer, P10, exclaimed that secure storage helps adhere to legislative requirements, suggesting "*the blockchain allows us to comply with rigorous data protection regulations while ensuring the confidentiality of patient information."* Thus, secure data storage has the dual benefit of supporting ethical and legal practice in health care. Participant, P8, a doctor, indicated that having secure data storage builds trust in the clinician. As P8 noted, "*I can trust the data when making treatment decisions, if I know patient information is securely stored."* Trust is critical to caring for patients, as a clinician needs the right information to diagnose and plan treatment.

Facilitating research and data sharing is another benefit of implementing blockchain into Zimbabwe's healthcare system. By securely and efficiently granting access to anonymized patient data, blockchain can support medical research and public health initiatives. A public health officer, P10, explained, "*Distributed ledger allows for secure data sharing, which is important when tracking trends or doing significant research. This way, we will know we are not compromising patient data.*" This is extremely important for enhancing public health initiatives and improving population health outcomes. Various participants believed there would be a benefit to securely sharing patient data to impact medical research. A lab scientist, P13, noted, "If we could access high-quality anonymized data, it could fast-track *our understanding of disease and the data gathered on successful treatment to share for the benefit of everyone.*" This also reiterated the possibility of enhancing collaborative opportunities for research with blockchain, so health institutions can collaborate to share data and knowledge. In addition, a doctor, P8, suggested that blockchain can speed up the checking of necessary data for clinical studies. "*By allowing us access to secure records, we can get information for the trials and studies quicker, which leads to faster innovations in treatment,*" P8

stated. This improvement in research duration is crucial for timely addressing health matters, especially in Zimbabwe.

In addition, an IT administrator P4 mentioned the importance of compliance in data sharing. *"Distributed or shared allows us to share data under strict regulatory jurisdiction without breaching any legal obligations to secure patients' confidential information."* Having compliant information builds trust for both researchers and patients. Lab scientist, P15 articulated this viewpoint: "*By using this new technology, we know that our research data is secure and is only disclosed to authorized entities; this could enhance our data tremendously."* This indicates that blockchain can secure sensitive data while also fostering a collaborative culture. Another participant, P12, a Public health officer, stated*, "When using a decentralized method, researchers now have the ability to share their data without wondering if there is any manipulation of data or being deceived by collaborators."* This highlighted that blockchain technology can remove mental roadblocks to data sharing, allowing researchers to do so, and this could potentially foster even broader and more impactful research.

3.3. Challenges of adopting blockchain technology

Blockchain technology adoption in healthcare is determined by eliminating challenges and risks. Continuous research and engagement with various partners or stakeholders help eliminate challenges. While blockchain presents opportunities for healthcare professionals, obstacles must be overcome before widespread utilization can occur.

Security and Privacy concerns are substantial, as noted by participants who discussed the implications of protecting against data breaches and ensuring privacy. For example, Participant P3, a nurse, cautioned "*that with poor controls, the data leaks could damage the reputation of the health care facilities*". Protecting sensitive data is important in order to maintain trust with patients. Although blockchain technology can increase data security, the decentralized aspect of the technology raises doubts about how it wants to handle its patients and their information. For example, IT Technicians P1 noted that *"...even though the system has the benefits of security in terms of inward going able to lend access to patient information...will the patient be worried in terms of who is accessing their data and how!?"* This indicates the need for clear policy, data access, and data sharing. A nurse P6, explained, "*Patients have to feel comfortable sharing their sensitive medical and health care information without it potentially being exploited. Suppose patients believe that their privacy is being jeopardized. In that case, they might not even want to share some important medical information, leading to the effective care of patients and their health results". A public health officer, P10, observed that regulatory frameworks for data privacy are still evolving. "The legal aspects of data protection are too complicated. The technology has to comply with laws while respecting patients' ownership of rights"*. Dealing with regulations is extremely complicated for healthcare providers wanting to utilize

blockchain solutions. In addition, a doctor, P8, expressed a concern related to data permanence: "*Once you have data on the shared ledger, it cannot be changed or removed. This also presents an issue when dealing with sensitive information, especially when clients want to retract consent*." IT Technician participant P2 noted that, *"If society does not regulate, we are at risk of abusing personal health information."* The inability to change data in this way complicates patient data management and demonstrates the need for consent infrastructure. As noted by the pharmacist, P14, *"patients may not feel comfortable with their health information being on a public ledger, and although this may be encrypted,"*

The cost and issues of system failures are also important barriers. As noted by Participant P6, a nurse noted, *"implementing distributed ledger technology will require that providers invest money into infrastructure and technology resources, which can be challenging for smaller providers*". IT Administrator P4 described the difficulties surrounding initial costs as, "*Many healthcare facilities do not have the budget capacity to absorb the price of entry to these new systems*." Such costs reinforce barriers to blockchain technology adoption. In addition to this, there are also problematic issues of system failures due to power loss, systems or networking issues, and various software issues that can disrupt the proper utilization of blockchain A nurse P6 noted, *"The system goes down or crashes, and patient care is disrupted, and this could have major implications."* This kind of disruption could impede the benefits blockchain technology hopes to foster. Furthermore, blockchain's complexity can be daunting for healthcare staff unfamiliar with the new technology. A doctor, P8, stated, "*While training staff to use new technologies and systems is important, it can also be difficult and expensive."* It is essential to ensure that everyone is adequately trained to use blockchain systems to get the most value out of them. In addition, a public health officer, P10, also stated that connecting blockchain with health care systems can be complicated. P10 stated, "*Some legacy systems may not connect easily to the new technology solution, and this could mean that there may be data silos causing inefficiencies*." Issues with connecting blockchain solutions to legacy systems can also be a barrier to using the technology in health.

Regulatory and legal concerns can severely hinder blockchain technology implementations within Zimbabwe's healthcare system. Many existing laws do not specifically address blockchain, and there are concerns about whether current regulatory frameworks are compliant. For example, a public health officer, P10, said, "*The lack of regulation means that how I should handle patient information in a blockchain is unclear."* Meanwhile, concerns were compounded by increased concerns regarding data privacy. In this case, privacy was a concern given its decentralized nature, which means shared and joint access to private information. An IT technician, P2, indicated, "*Blockchain is complex enough, but now you need to make sure you act in accordance with data protection laws"* when using blockchain. There is a clear need for patient consent guidelines and patient data access. Moreover, the decentralized nature brings up liability and accountability issues for data breaches. As one doctor put it, P8, *"With no clear answer on who is responsible for data security,*

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providers will be reluctant to implement blockchain solutions." The issue of regulatory fragmentation also adds to confusion, as different organizations can issue and demand different standards, which can create inefficiencies and confusion. Regulatory ambiguity can stifle innovation. A nurse, P6, noted, "If there are no rules, it is hard to justify implementing a *distributed ledger and the costs associated."* Therefore, addressing regulatory and legal issues will require all stakeholders (governments, healthcare providers, and others involved in the implementation, regulation, and legal aspects) to work collaboratively to establish usable regulations that enable the use of blockchain technology, and still exist to protect patients, while creating an environment where stakeholders are free to innovate.

3.4. The Application Area of Blockchain Technology in Healthcare

Patient Data Management: A Public Health Officer, P10, said that blockchain could change the way we store and access patient data through a secure, decentralized, accessible record system. According to P10, "*This allows healthcare providers to have easy access to updated patient information while ensuring that the integrity of the records is assured,*" which helps enhance care coordination across multi-disciplinary teams. Moreover, this decentralized method allows individuals greater agency over their health information. This public health officer elaborated, "*Patients can give or deny access to their records when needed. This also ensures any sensitive information is restricted to authorized individuals."* This creates trust and enhances patient involvement in their care. In addition, the immutability of blockchain means that once data is recorded, it cannot be altered or deleted without authorization. This provides more certainty that the data has not been manipulated or compromised. A Nurse P6 stated, "*Just knowing the data is protected and cannot be tampered with gives us more confidence in the information we are using to make treatment decisions."* Another significant benefit is the interoperability of different health care organizations. An IT administrator P4 explained why this is important: "*Because a shared network can allow us to share data across multiple platforms without significant restrictions and obstacles, it can create an environment that allows for better collaboration between providers and specialists.*" This is particularly significant for emergency cases, as accessing a patient's medical history may be the difference between life and death.

Supply Chain Management: An IT administrator, P4, emphasized the potential of blockchain technology to help ensure the transparency of medical supplies. Stated, "*Healthcare organizations could potentially track items throughout the supply chain by putting information onto a tamper-proof ledger."* This could be especially important in preventing counterfeit drugs and meeting safety compliance standards. In addition to increasing safety compliance, blockchain will also facilitate increased traceability, which will help users verify where products came from, or, in the healthcare sector, what was sourced at certain points in the supply chain. As a Pharmacist P7, stated, "*if something is wrong with a batch of medication, we can trace it back to its source very quickly.*

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That is really important for patient safety." In contrast to exploring the origin of contaminated products, this capability to respond quickly helps to mitigate the risks of accessing contaminants and unsafe products. Moreover, by maintaining a clear and accessible record through blockchain, a supply chain can enhance collaboration among stakeholders and suppliers involved in the supply chain.

Clinical Trials and Research: A Public Health Officer P12 emphasized that blockchain can improve clinical trials by providing a verifiable method for documenting data. "*The distributed ledger guarantees [the integrity] of the trial results, as well as sharing and documenting patient consent records," which also "creates [the] trust of stakeholders involved in research."* The integrity of data present in a clinical trial can be vastly improved by employing blockchain, as it would provide an immutable record of all data associated with the trial, which means that this data cannot be deleted or changed without proper protocol. A Doctor P11 noted, "*This will either limit the manipulation of data by providing transparency, or if data cannot be manipulated, other researchers will see that there is integrity in our findings,*" which is especially important for regulatory approval. Blockchain likewise supports collaboration by offering a secure way for researchers and institutions to share data. An IT Administrator P4 said, "*With blockchain, we can share data from multiple institutions without compromising patient privacy or data security*." This feature is advantageous for multi-site trials because they incorporate stakeholders with different data elements that must be analyzed together.

Additionally, by documenting consent on the blockchain, researchers can honor patient consent throughout the research process. A doctor, P8, suggested, "*With blockchain, we can see consent in real-time, which helps us support and keep patients' wishes."* This will improve the ethical practice of clinical research and help establish trust with participants, which might encourage ongoing participation. Participant articulated how blockchain could address age-old data transparency and traceability issues in clinical trials. As noted by a lab scientist, P15, "With technology, I can create a tamper-proof record of all of the trial data, trust that, and demonstrate to the public and regulatory bodies that my findings are credible," highlighting the trust gained through blockchain's capabilities amongst researchers, regulatory bodies, and the public. Similarly, a pharmacist, P14, indicated regarding the comments around trust, "*The new technology will let us see every change to the data in real time, which is critical to ensure all clinical research is valid."*

Telemedicine and Remote Patient Monitoring: An IT Technician P2 observed that while telemedicine evolves, blockchain can establish *"secure platforms for the interactions of patients and providers,"* which can protect medical consultation and data transfers. Furthermore, *"This protects patient privacy and establishes trust in remote healthcare services,"* which is critical for getting more patients to access telehealth solutions. The application of blockchain in telehealth ensures that all the data

shared in the consultation is encrypted and securely archived, which leads to a lower chance of unauthorized access. A public health officer, P10, said, "But if the data is in a secure data management repository, the patients are more willing *to share personal sensitive information when they access services via virtual visits, which provides better care delivery outcomes. "*In addition, blockchain provides the ability to help with simple onboarding of credentials for providers and verifying the identity of patients, which further adds trust to telemedicine. A nurse, P6, shared, "*It is important to ensure patients only interact with verified providers to ensure the quality of remote healthcare products and services*." Smart contracts could also enable easier appointment scheduling and billing, Pharmacist P9 said, "using an actual automation to automate the payment process and confirm appointments, *which will decrease administrative workload for providers and patients."*

Health Information Exchange: A Doctor stated, *"This availability to share health information can provide better outcomes for patients overall because providing access to health histories is a way of improving access to the best health possible."* The ability to share health information with hospitals and specialists means that a patient's privacy can be respected while sharing their health history. An IT admin noted, *"The distributed aspect of blockchain means that only trusted users can access health findings, allowing patients and providers to build trust."* Further, the ability for patients to combine multiple health records through blockchain technology and share them all in one space facilitates comprehensiveness. The nurse mentioned their patient's health history: "*When we do not have full access to our patient's health history*, *this leaves us making assumptions about their healthcare history. This is detrimental when we need accurate treatment in the moment of an emergency."* The technology further allows patients to have more authority over their health data. A Public Health Officer P10, shared that *"patients control their own records, granting or revoking access as necessary, which is empowering with respect to their health,"* and that increased authority may foster greater patient engagement and adherence. The advent of blockchain can also allow for automation to expedite data exchange related to health data and to mitigate the risk of delay or lag. A lab technician, P13, cited, *"Automated information exchange can eliminate unnecessary paperwork and slow communication between healthcare providers."*

Billing and Payments: A nurse, P6, felt adamant that blockchain would eliminate fraud in billing and payment. Noted that, *"Automate billing cycles so the bills get paid in a way, so there is no dispute, making it an easier process for all financial people for all healthcare."* Healthcare organizations would have a transparent, tamper-proof record of everything that got done by the organization if they used blockchain technology. An IT technician, P1, said, *"Being able to look at all of our transactions removes fraudulent claims, minimizes timeframes for audits while allowing for fast transactions because it is all verifiable."* Smart contracts can trigger automatic payments once a predetermined condition has been met. A public health officer, P10, said, "*The automated contracts*

can relieve some of the paperwork stress put on staff and will allow staff more time in patient care."

Additionally, blockchain can allow for real-time billing and payment status updates. Hence, providers and patients have good, up-to-date data. A Pharmacist P9 noted, *"Patients know exactly what they owe, what their payments are due, which promotes transparency and trust in the billing process."* By reducing fraud, streamlining processes, and providing more accurate and timely information, blockchain also helps improve patient satisfaction. A doctor, P11, stated, *"Clear and accurate billing processes lead to fewer disputes and provide a better experience for patients."*

3.5. Discussion

1) Factors of adopting blockchain technology in healthcare

Numerous factors shape the adoption of blockchain technology in the health care sector. Factors can be categorized as organizational support, regulatory compliance, ease of use, perceived usefulness, and technical infrastructure [32]. Organizational support includes leadership commitment, resources with financial and people, and alignment around strategic goals[33]. Strong organizational support is paramount for blockchain initiatives to be successfully implemented, as it involves leadership commitment, resource availability, and alignment with strategic goals. Participants consistently reported that leadership support is critical in establishing a culture that supports technological innovation.[34] concurred that leadership provides a clear vision to inform and support the culture for change needed to take teams through the process of adopting new technology. Participants agreed that without adequate organizational support and funding, projects would not be able to get started or would fail. It was supported by [35] that financial investment is required to support these projects, such as acquiring the technology, hiring skilled personnel, and training existing personnel. The blockchain initiative must also be aligned with the organization's overall goals in order for it to be valuable and prioritized appropriately[36]. This means collaborating with different departments, before, during, and after the blockchain project, to integrate seamlessly with existing systems, establish governance, and manage risk and regulatory compliance. The healthcare sector must then use ongoing training and real-time feedback from the information gained in the blockchain project to inform its strategies[37]. By addressing these areas, the sector can take full advantage of blockchain technology's innovation to help it best achieve its strategic organizational goals.

Regulatory compliance in the health care sector can be particularly arduous as it involves compliance with evolving data privacy laws that may be severely prescribed, like Zimbabwe's Cyber and Data Protection Act and other laws, like

the USA's Health Insurance Portability and Accountability Act(HIPAA) and the EU's General Data Protection Regulation (GDPR) [38],[5]. In an ever-changing landscape, relatively few organizations are specifically tasked with maintaining compliance with legal obligations regarding patient information protection and confidentiality. Blockchain solutions present benefits for secure data sharing and improving interoperability[39]. Participants noted that supportive and clear regulations are important to protect patients' data and support an environment fostering innovation. However, compliance with regulatory standards requires that appropriate safeguards be applied. Audit trails must provide accurate information about access to the data and modifications to the data[40],[41]. Healthcare organizations must also consider how their blockchain solution intersects with existing requirements for compliance with legally binding regulations[42]. As well as the implications of operating on a decentralized system involving sensitive health data being stored on a potentially unregulated platform. Healthcare organizations focus on what needs to be done to comply with regulatory requirements regarding data privacy, and ongoing risk assessments can assist with changes in regulations from the current state to the future[7]. Prioritizing regulatory compliance can facilitate the application of blockchain application efforts by improving security and trust and reducing the risk of data loss and exposure to monetary penalties[43].

Ease of use is also an important consideration for blockchain technology adoption in healthcare applications, focusing on ease of use for all healthcare professionals.[32][44].Healthcare professionals need applications that simplify their workflows and increase productivity and efficiency with minimal disruption [45]. Participants noted that easy-to-use and intuitive interfaces could increase acceptance, especially among the more reluctant users. Patients will also benefit from user-friendly interfaces that make it easier to access their health records and transfer and share the data safely with their health care providers[6][46]. Further, seamless integration with existing systems is also vital to the blockchain application and acceptance process, to ensure that it works seamlessly with existing workflows; otherwise, you may cause workflows to be disrupted[47]. Seamless integration also helps support data continuity and consistency and lessens the impact of transition into the new technology. By considering and addressing ease of use, the healthcare sector can increase end-user satisfaction levels, encourage widespread adoption, and ultimately enable organizations to leverage the technology to improve patient care[48].

Perceived usefulness is a key predictor of adopting blockchain technology in healthcare, as it represents stakeholder beliefs about how blockchain can produce better health outcomes, ensure data security, and improve processes[19][22]. When healthcare professionals see that using blockchain can lead to better patient care, for example, more complete or more convenient health records, they are more

likely to adopt that technology[26],[49]. Participants noted it and collectively felt that blockchain can optimize efficiencies and patient outcomes at a minimum. The perceived usefulness of more data security is compelling, as it can protect sensitive patient information with encryption and decentralized data storage[50]. Data security in this age of data breaches and security threats is critical. Blockchain can enhance processes such as the transfer of data from various stakeholders in healthcare, lessen heavy reliance on administrative processes, and enhance interoperability when coordinating care with disparate health systems.[13]. When stakeholders understand the added value of blockchain, for example, hospitals will refer to blockchain as an enabling technology (to create efficiencies), which will lead to improved patient experience, enhanced trust, better patient-centered care, and stimulate new health innovations. [51]. The perceived usefulness of blockchain technology is an important precursor for mass adoption and integration of more blockchain solutions with organizational health systems in providing care.

Technical infrastructure is a crucial factor in the effective implementation of blockchain in healthcare, encompassing the analysis of existing IT capabilities, blockchain network scalability, and integrating blockchain technology with existing or pre-existing systems[52]. Due to the multifaceted structure of healthcare, it should go without saying that having a strong and effective information technology system goes a long way towards success. Participants expressed concern about the viability of the current systems; some even stated they may need drastic updates for their systems to flourish. It was supported by[51]and[53] that the healthcare sector needs to first evaluate its structures fully to understand its IT capacity to satisfy the demand for blockchain applications.[54] suggested that to evaluate existing infrastructure, the sector needs to assess all hardware components, software components, and network capacity to understand how expanded data loads will affect the use of blockchain technology. Part of this evaluation process is also to consider scaling. As an organization grows, data needs to grow. Ideally, blockchain networks will be able to scale to meet growing data demand without hindering future performance. Interoperability means that existing or pre-existing systems will share information with blockchain or new healthcare systems[5]. In addition to scalability, standardized interoperability would mean that new solutions will work together or exchange data with existing healthcare solutions. Interoperability helps to create continuity in patient care and operational efficiency while also allowing organizations to use the benefits of blockchain technology, like data accuracy, better data security, and streamlined operational processes[7][55][26]. Suppose healthcare organizations assess and leverage their technical infrastructure appropriately. In that case, they will likely be able to implement blockchain technology to further their services and ultimately provide improved healthcare services and outcomes. However, they are different blockchains architecture that are used for the healthcare sectors which include Private blockchain, which help ensure data privacy, Consortium blockchain, which

can collaborate with numerous stakeholders, Hybrid blockchain, which can preserve privacy and transparency, Interoperable solutions that connect current systems and Layers of architecture that can be scaled up or down based on circumstances[51][56]. Data assessment and the ability to utilize technical infrastructure mean that healthcare organizations can use blockchain technology efficiently and improve their services to ultimately improve health outcomes[5].

The interplay between factors regarding the adoption of blockchain in healthcare context demonstrates a complicated relationship that impacted the overall effectiveness of implementation. One of the strongest relations is the one between Organizational support and Ease of use. If you have an organization with strong organizational support, either in the form of leadership who are committed to an initiative or through the allocation of resources towards an endeavour, it creates an environment to support training and development. When healthcare practitioners have the training and resources available to them, they are more likely to experience blockchain applications as intuitive to use, which in turn heightens the perceived ease of use. The ease of use will lead to a higher perceived usefulness; healthcare practitioners will have an inclination to see a technology as beneficial to enhancement of patient care and operational efficiency if they have a technology that is easy to navigate.

In contrast, if an organization does not demonstrate support for an initiative, it may become difficult for health care workers to understand the implementation and functionalities, leading to frustration and resistance to the new system. Furthermore, Regulatory compliance also contributes to this dynamic. If the organization supports teams, it can help keep the teams aware of the regulatory requirements and how blockchain can support them, which may alleviate concerns surrounding compliance and contribute to the perceived ease of such technology adoption. In addition, the technical infrastructure objective is connected. A supportive organizational culture can then spur investment in relevant infrastructure improvements that could otherwise limit adoption of blockchain; this can lessen users' burden to implement solutions they may have to adopt. If the infrastructure supports a user-friendly interface, then the chances of technology adoption increase.

2) The benefits of adopting blockchain technology

The benefits of adopting blockchain technology are categorized as system decentralization, patient record management, data security, facilitating research, and data sharing[30].

Decentralization is a core tenet of blockchain technology and has many benefits in the healthcare industry[57]. Participants emphasized that a decentralized database

could link major hospitals and clinics, allowing for secure and accessible data management. [47] acknowledges that blockchain's decentralized nature spreads information across decentralized nodes and decentralizes data, which removes risk associated with a centralized node failure and increases resilience, as it cannot be attacked or taken down. Furthermore, [22] highlighted that this decentralized data security helps increase data integrity; once information is written to the blockchain, it cannot be changed without a consensus of the rest of the network, preventing malicious changes. It can give patients control over their health records and the ability to grant or deny access to information about patient health, which engages them and controls their medical journey. Moreover, a decentralized network enables providers, labs, and researchers to collaborate and share information, fostering secure information sharing that maintains patient privacy, improves coordination, and improves health outcomes[58]. By decentralizing the healthcare process, healthcare organizations can build a resilient, secure, and efficient system for their patients and healthcare providers.

Patient record management is an essential healthcare application of blockchain technology that brings many advantages that enhance the quality and efficiency of care[59]. Blockchain provides a secure and immutable way to keep patients' records, allowing all the records to be kept accurate and secure. As indicated by the Participants, blockchain's immutability creates trust through transparency and accountability. With a blockchain patient record management tool, healthcare providers can access the latest patient data and updates and provide continuous and complete patient care[60]. When health providers do not have the correct or latest information, the health is compromised, and errors can arise. Generating interconnections improves information flow amongst healthcare providers and across the healthcare sector, increasing opportunities for informed decision-making and improving the delivery of healthcare services[48]. When patients change healthcare providers amongst the disconnected, siloed aspects of healthcare, there is a lag, and it takes time for healthcare records to be retrieved and then shared, so patients receive incomplete care. Implementing blockchain, healthcare stakeholders, i.e., hospitals, clinics, specialists, and patients, can capture their information cooperatively and effectively[61][13]. In addition, patients experience a significant increase in control over their health data. They can grant or revoke healthcare providers' access to patients' records with blockchain. Revoking provider access limits unauthorized personnel from accessing their health records, minimizing their health information exposure. When patients can control their access, it promotes trust in their providers, and they feel more secure knowing who is accessing (or what) information is being accessed in their health records[50].

Securing data is one of the most notable benefits of utilizing blockchain technology in the healthcare industry. Participants stated that blockchain uses encryption and

smart contracts to anonymize patients and ensure compliance with regulations for patient privacy. Furthermore, [35][49]indicated that the use of decentralization, encryption, and immutability is inherent to the blockchain and helps to safeguard confidential patient data. In Estonia, Guardtime implemented a blockchain application to secure health records in order to ensure that records can be updated and that sensitive information can only be accessed by authorized personnel, improving trust between patients and the provider[62]. [63] highlighted that the decentralization of data in blockchain technology eliminates the vulnerabilities that centralized data storage inherently possesses, whereby the entire data set can be affected if there is a breach. In blockchain technology, patient data is stored on multiple nodes within a network that may not be related[51]. This decentralized feature significantly reduces an unauthorized individual's likelihood of accessing the patient data. [56] noted that employing encryption of data in blockchain ensures cyber safety through the use of cryptographic techniques. Additionally, blockchain can assist with the secure storage of information through identity authentication and access control roles[54]. Blockchain only identifies and provides access to relevant information to individuals with authorized identities. Patients can also manage who sees their data[32].

Research and data sharing, the impact of blockchain technology is altering medical research and the exchange of data in healthcare. Blockchain offers efficiency and effectiveness for the research initiative while protecting a patient's right to privacy[64]. Blockchain creates opportunities to exchange data securely, transparently, and decentralized. The primary benefit of blockchain for research is the time savings in data collection and data sharing. Participants responded that their anonymized data could improve timelines for medical research and provide a better opportunity to collaborate with other healthcare organizations. [65] agreed that researchers will have a better opportunity to access anonymized patient data from several sources without the burdensome data extraction processes. Researchers have more opportunities to finalize studies in a timely and more complete way, leading to timelier insights, contributions to, and advancements in medical knowledge. Apart from the benefits already addressed, perhaps more important is the goal of ensuring that the raw data from which sharing is conducted is of a very high level of integrity and authenticity[31]. [63] emphasized that blockchain takes all the activities with a timestamp and a cryptographic signature to create an immutable audit trail. These features create trust that enables researchers to reliably verify the source of data shared and feel secure when using the data for findings, which is critically important for clinical studies regarding credibility. Blockchain also supports collaboration among various stakeholders, such as hospitals, researchers, patients, and drug manufacturers[41]. Blockchain helps prevent silos by allowing trusted and secure sharing of data. This can generate new partnerships that foster new treatments and therapies. Finally, it allows patients to consent to use their data for research. Patients can control who can

view their data, putting them in a position of ownership and respect for their privacy, while still being able to contribute to better medical research[50].

3) Challenges of adopting blockchain technology

Blockchain technology adoption in healthcare is determined by eliminating challenges and risks that include security and privacy concerns, the cost and issues of system failures, and regulatory and legal concerns [22].

Security and privacy concerns in healthcare, ensuring adequate protection, are essential to gain the trust of healthcare providers and patients. Participants in the study were concerned with data breaches and how their sensitive patient information should be safeguarded. Blockchain technology relies on robust encryption and consensus models, but weaknesses exist [66]. For example, if private keys are compromised, anyone using the private key can gain unauthorized access to patient information. Privacy issues are an important concept that boils down to whether individuals can trust that their personal health information will be secure and accessed only by authorized players[57]. The participants also recognized the changing regulatory landscape related to data privacy. The audit ability of blockchain could likely breach independent patient privacy legislations, as auditors can browse and gain access to the blockchain public ledger to conduct their audit process, which includes appraising transactions that would disclose all patient identifiable information[49][51]. Moreover, participants were concerned with the decentralized nature of the system. They indicated concerns about who will have access to the data and how that data will be managed. Access control mechanisms must be explicit about who, where, and when particular access will be made by independent parties[67]. Patients need to approve access control mechanisms and know who owns the data and how their data will be available to specifically identified parties, especially in a decentralized environment.

The cost and issues of system failures related to these costs can also influence the adoption of blockchain technology in healthcare. Blockchain implementations in healthcare may have an initial cost, such as technology, infrastructure, and user training[22][56]. Participants indicated that the initial cost to build infrastructure and technology can be daunting, especially among small health care providers. The potential value of the long-term benefits of greater efficiencies and reduction of administrative work must be weighed against the initial costs. Careful consideration should also be taken of any ongoing maintenance and operation costs that will be incurred. In order to adopt blockchain technology, healthcare organizations need to see a tangible ROI (return on investment) through efficiencies and decreased costs over time, or it will not be viable[19]. The reliance of healthcare on systems is critical to patient care, where downtime and failures can be life-threatening. Participants cautioned that power failure, networking issues, and software crashes

could significantly disrupt patient care. Concerns around failures of systems, whether they relate to technology breakdowns, network failures, or cyberattacks, can detract from considerations to adopt blockchain technology. According to [68], blockchain networks must be resilient. To demonstrate resiliency, healthcare organizations must have the technical infrastructure and sufficient contingency plans to mitigate potential failures, including short response times to keep availability high. Therefore, weaknesses in a blockchain application's integration with pre-existing healthcare systems can result in unexpected problems[51]. If there is not adequate integration, there will likely be impacts on operations (delays and workflow) and patient care (timely access to care). As such, it is prudent to evaluate, test, and validate all aspects of a blockchain implementation to determine its performance level before it is broadly implemented.

Regulatory and legal concerns can be significant barriers to using blockchain technology in healthcare. The details of existing regulations and the nature of blockchain, which are changing rapidly, could create uncertainty for healthcare organizations looking to adopt this technology[13]. The lack of regulatory guidance creates uncertainty in maintaining the confidentiality and security of patient data, especially when considering the protection standards provided by HIPAA in the United States. Healthcare is a heavily regulated environment, and organizations are governed by strict laws regarding the handling of patient information[32].In Zimbabwe, the Data Protection Act governs personal information use, collection, and sharing [69],[70].

Nevertheless, regulations specifically related to blockchain applications remain scarce. Verification of conduct, regulations, and compliance with regulatory frameworks will be important for developing blockchain solutions[5]. This is highlighted by the African Union's Convention on Cyber Security and Personal Data Protection, which aims to harmonize the complexities of data laws across the continent to pursue opportunities while dealing with data protection; however, the difference in laws can be complex and messy for cross-border blockchain initiatives[71]. Suppose the blockchain systems can demonstrate they were developed in accordance with laws regarding privacy. In that case, it can enhance certainty associated with legal liability and increase overall agreement and acceptance with the stakeholders [42]. Blockchain technology in healthcare can raise liability issues. Suppose a data breach occurs or inaccurate data is entered into the blockchain. In that case, determining who would be liable may not be simple. Stakeholders must address potential liability issues and processes for resolution for issues relating to data security or integrity[41]. In addition, the legal frameworks for blockchain technology still need to be developed. The prospect of future regulatory change may discourage healthcare organizations from implementing blockchain solutions due to uncertain future operations[7]. The ongoing discussions with regulators remain important to provide an environment for

innovation. Various jurisdictions globally are working on legal frameworks surrounding blockchain, and it follows that as countries develop legal frameworks for blockchain that balance regulatory oversight with innovation, they need clear regulatory guidelines[72]. Policymakers must partner with diverse stakeholders in practice communities, including health care provider organizations, developers, and the legal community, to develop regulatory guidance that suits the unique context and challenges of using blockchain technology in healthcare[73].

4) The Application Area of Blockchain Technology in Healthcare

Blockchain technology is one of the most paramount advances of our lifetime and can potentially transform many areas of Zimbabwe's healthcare[26]. Therefore, there are many possible applications of blockchain to the health care, including Patient Data Management, Supply Chain Management, Clinical Trials and Research, Telemedicine and Remote Patient Monitoring, Health Information Exchange, and Billing and Payments.

Patient Data Management Blockchain technology can fundamentally transform how patients manage and store data and navigate the healthcare systems [51]. Participants noted that using blockchain, patients could establish a secure, decentralized record, allowing healthcare providers access to the latest patient information while preserving the fact that this information is accurate and safe. This is important for improving multiple discipline coordination of care and could be used for emergency access, when real-time access to accurate data could save lives [17]. In addition to enhanced health information security, decentralization can encourage patients to take more ownership of their health by granting them greater agency in who can access their specific records, while still allowing healthcare providers to coordinate care better [50]. A participant noted that trust comes when patients determine who can view their records. When patients can grant or revoke access to their personal health information, it may give them a greater sense of ownership of that information and trust in the healthcare system[74]. It encourages engagement and participation in patient care. For instance, Patientory provides a personal health management program that allows patients to manage their health data on a secure platform to improve care coordination and satisfaction. The immutability of blockchain has implications for this nature of trust [63]. When patient records are entered into the system, they cannot be changed or deleted without authorization [15]. Blockchain gives assurance that records will not be altered or accessed without authorization.[36][19]. As noted by the participant, the fact that records are immutable gives them confidence in the information they are using to assist in deciding treatment. Interoperability between different healthcare organizations is a further important advantage of blockchain technology[30]. As highlighted by participants, data can be shared across multiple platforms with few restrictions

because multiple organizations can share a blockchain network. This can improve collaboration between healthcare providers and specialists. This functionality is critical in emergencies when a glance at a patient's medical history can affect outcomes.

Supply Chain Management:: Integrating blockchain technology into supply chain management greatly increases transparency and traceability of medical supplies[56]. Using a tamper-resistant ledger significantly improves the ability to track products throughout a product's life cycle, which helps to combat counterfeit drugs and enable the healthcare sector to ensure safety compliance[26][59]. As the participant noted, this is critical since this particular technology enables organizations to track items down within the supply chain, which helps mitigate the risk of counterfeit or unsafe products. The participants noted the importance of supply chain management. If a batch of medication is determined to be faulty for some reason, with blockchain, they can trace the batch back to the source immediately, which is critical for patient safety. This contextual traceability and ability to rapidly respond make the supply chain less risky and potentially save the organization time and finances while addressing potentially dangerous contaminants or products[32]. For example, Chronicled, whose blockchain technology is geared more towards supply chain management, uses blockchain to track the supply of pharmaceutical drugs to mitigate the risk of counterfeit or misbranded drugs, which puts patients at risk, and improves patient safety[75]. Overall, having an accurate and auditable record through blockchain allows for easier collaboration amongst stakeholders and suppliers working for healthcare in the supply chain.

Clinical Trials and Research Blockchain technology drastically improves the trustworthiness of clinical trials by providing a verifiable data record, thereby documenting patient consent [56][26]. This accountability through transparency is intended to minimize the possibility of data manipulation, an important consideration when participant regulatory approval is desired and stakeholder trust is warranted[51]. Participants emphasized that distributed ledger technology guarantees that trial results cannot be tampered with, nor can the documentation of patient consent be tampered with, demonstrating that this is reliable. The immutability of a Blockchain creates constraints for both the deletion of data and the modification of data as they apply to protocols. This limits the ability to manipulate data, maximizing the dependability of the evidence. The participants mentioned that the transparency afforded by this format also allows researchers to demonstrate that the data integrity was maintained, which is important to various regulations. In addition, this means that data can be securely shared between researchers and institutions, which enables collaboration for multi-site trials that consist of many data elements [40]. As indicated by the participant, the ability to share data without sacrificing patient privacy or security is a powerful benefit. Further, researchers can ensure patient wishes are honored throughout the

research process by recording consent using blockchain[76]. As the participant pointed out, the fact that consent can be visible in real time encourages ethical behaviors from researchers, which cultivates trust from the participant, and can encourage the participant to stay involved in clinical research. By empowering consent visibility and, thus, ethical medical research, blockchain strengthens the ethics and integrity of research data[51].

Telemedicine and Remote Patient Monitoring. Incorporating blockchain technology into telemedicine and remote patient monitoring creates a secure environment between patient-applicable providers, which is extremely valuable[40][44]. According to participants, this secure environment protects medical consultations and data transfers. This is paramount in ensuring patient privacy and trust in their experiences with remote healthcare services. Trust is critical to propelling patients into a more embracing posture toward telehealth solutions[77]. From a security perspective, encrypting and securely retaining all data transmitted with consultation inherently reduces the risk to patient data through unauthorized access[41]. As highlighted by the participant, secure data management allows patients to feel comfortable sharing sensitive information during a virtual visit, resulting in better care delivery. The blockchain automated the lengthy onboarding process associated with provider credentials and patient identity verification, furthering the element of telemedicine trust [40]. According to the participant, it's critical for patients to see and interact only with verified providers to protect the quality of remote care delivery. Through carefully defined smart contracts, blockchain can help with many other aspects of health administration[51]. Smart contracts can help to make appointment scheduling and billing less tedious[78]. As noted by the participant, fewer wasted potential costs with confirming appointments or automating payment dictated further fewer administrative chores for both service providers and patients. Improved elements with blockchain can enhance the security, efficiency, and authenticity of telemedicine and remote patient monitoring, with the expectation that patients have service more readily available[13][58]. Solve. Care takes care coordination to a new level using a blockchain platform that uses smart contracts to automate tasks such as appointment scheduling and other administrative burdens that improve patient follow-through and adherence to care plans.

Health Information Exchange Blockchain ensures that health information is seamlessly shared between numerous providers and preserves the patient's privacy[53][5]. In situations where time is of the essence for providing treatment with accuracy, leveraging interoperability is so important to address patient privacy risk needs. Participant noted that sharing health information can lead to better results because it opens access to laboratory tests and other areas of the patient's comprehensive health history. The ability to secure health records and share them once uploaded with a hospital or specialist allows hospitals to treat patients with a

certain degree of respect for their patients' privacy[50][79]. Participants also highlighted that a blockchain is distributed, meaning that health findings only get to trusted users, as the healthcare provider intended to exhibit trust between the healthcare provider and patient. The evolution of blockchain has empowered patients to have a common place where multiple health records can be found in one readily available place, making their health information complete[13]. Participants concurred that if they, as health care providers, did not have access to the patient's entire health history, they could make a leap and make assumptions that could interfere with accurate treatment, especially in an emergency.

Furthermore, blockchain gives patients control; that is, they have access to their records and control how they reveal or withdraw that access [5]. According to the participant, this allows for a sense of agency and evidence that goes a long way to support the involvement of patients on their treatment journey. The participants also shared that enabling the automatic exchange of data due to blockchain interoperability provides the connected health system with automated health record information that decreases wait times for patients and decreases double documentation of a health record[19][56]. Participants mentioned that the automatic exchange of information improves the ability to communicate test results between health care providers and improves health information exchange. Blockchain represents a meaningful change for health information exchange and outcomes, where patients become empowered [53].

Billing and Payments Blockchain technology improves billing systems to be free of fraud and errors[36]. A complete account of all transactions is followed on a ledger that allows the healthcare sector to mitigate disputes and confusion, and is better for audits[80]. The participants noted that automated billing cycles remove disputes and allow for simple financial transactions in healthcare. Using blockchain allows incorruptible records of the services provided and, therefore, some accountability[54][63]. Participants noted that having access to documents that verify transactions minimizes fraudulent claims and expedites the audit period while allowing rapid transactions to occur. Smart contracts further enhance the ease of use by automatically paying when conditions agreed upon are met[36][81]. As the participant stated, using automated smart contracts could significantly decrease the staff's administrative work, permitting more patient engagement. In addition, because of blockchain, everyone can continually update billing and payments from the public ledger to enhance the available knowledge of providers and patients[26]. The participant further highlighted that this understanding allowed patients to know the costs involved, only highlighting increased patient trust. Transparency may maintain fees associated with medications and help reduce fraud. It allows more operational efficiencies among providers and reduces problems at the point of billing and paid claims, but overall, it enhances satisfaction. Overall, participants indicated that when providers clearly understood

billing, there were fewer issues and disputes, and patients were ultimately better for it. The impact of blockchain on improving billing and payments in healthcare is significant[56].

5) Comparative Analysis Findings

In Zimbabwe, blockchain adoption in healthcare faces distinctive challenges and opportunities compared with other countries. Different aspects that affect blockchain adoption in Zimbabwe include organizational support, regulatory compliance/accessibility, ease of use, perceived usefulness of blockchain, and technical infrastructure issues, which were a repeated theme for participants. Participants emphasized the need for strong leadership and training for all providers. Alternatively, developed countries such as the USA and Germany experience the same factors that affect blockchain adoption but also have established underlying infrastructure, processes, and regulatory frameworks (e.g., HIPAA), which can inhibit innovation while serving as a guide to innovation. An example is Estonia, where the healthcare system uses blockchain for e-health records, allowing for high levels of interoperability and patient control of individual data sets, which is still being developed in Zimbabwe. While security and privacy concerns are paramount in the USA and Germany, the topic of security around using blockchain was not raised in Zimbabwe, mainly because of technical infrastructure issues, which have very limited infrastructure or cybersecurity literacy. Zimbabwe, with participants expressing desires for clear policies regarding access to data, whereas Singapore had developed robust data protection policies, which helped alleviate these apprehensions. Costs generally remain a hurdle in Zimbabwe, particularly for small healthcare facilities, where many cannot bear the cost of new technologies. In the UK, however, government initiatives are pushing digital health innovation and small practices find it easier to adopt these technologies. Patient empowerment is another area of interest, as participants wanted more control over their health data through blockchain, similar to Canadian cases that have relied on consumer engagement to drive change. Yet Zimbabwe lacks a sufficient technical infrastructure, especially in rural areas with little or no internet access, in contrast to the Netherlands, where there have been considerable investments in healthcare IT infrastructure, helping to promote the scalable use of blockchain and consumer engagement practices. These examples point to the need for locally relevant and contextually appropriate strategies for designing data practices in low- and middle-income countries, based on examples of earlier success.

6) Implications

In developing countries like Zimbabwe, the prospects of using blockchain in healthcare are especially significant, both practically and theoretically.

Blockchain will facilitate interoperability through connected data exchanges across many other health systems relevant to better care coordination and patient outcomes, especially in the fragmented healthcare sector. The decentralized nature of blockchain increases data security, reducing the chance of unauthorized data breaches and access, thereby increasing patient trust. This is particularly important in an environment where data privacy is always scrutinized. In addition, because blockchain allows patients control over their health data, it promotes a commitment to their health journeys and possibly increased health literacy. In Zimbabwe, administrative tasks can prove to be very tedious; however, with blockchain, we could fix efficiency and accuracy for patient records, which facilitates speedy research processes, improving ease for expedited approvals and access to anonymized data more quickly, potentially facilitating further research speeds and possibly new advancements in medical treatment more applicable to local problems. The unintended benefit is compliance with country laws/regulations, where the observables of regulation, audit trails, and the data integrity of the blockchain are very feasible for navigating the headaches of regulation in the country. In order to achieve these advantages, training on blockchain basics, strategies for patient engagement, and compliance and regulation is essential. Investment in the infrastructure should focus on implementing secure blockchain systems, strengthening cybersecurity practices, and ensuring interoperability of blockchain systems with current health information technology systems and practices. This comprehensive approach tackles existing issues in our fragmented healthcare system while encouraging an innovative and responsive environment that brings measures to improve patient outcomes and healthcare service delivery further.

The theoretical implication is important, as it provides results for care delivery in Zimbabwe and influences theoretical overtures for technological integration and adoption of blockchain. The implications will inform models and theories like TAM, given that they provide introductory perceived usefulness and perceived ease of use relative to adopting blockchain for Zimbabwe healthcare. Furthermore, the implications support the TOE framework in endorsing organizational support and regulation concerning the next-generation technologies adopted in low-resource environments. The emphasis on patients controlling access to their health information may also contribute to and advance general discussion on patient-centered care and health informatics. The request for organizational support is potentially aligned with models about change management relative to blockchain adoption.

3.6. Proposed Healthcare Blockchain Adoption Framework (Hbaf)

The HBAF (Figure 2) is ideally suited to provide an overall approach to implementing blockchain technology into healthcare systems. It will provide

insights into the factors impacting adoption while presenting the possibilities of benefits, raising awareness of challenges, and highlighting where the potential for application might occur. The framework will assist healthcare organizations in Zimbabwe and similar environments in improving their patient care by ensuring the interoperability and security of data.

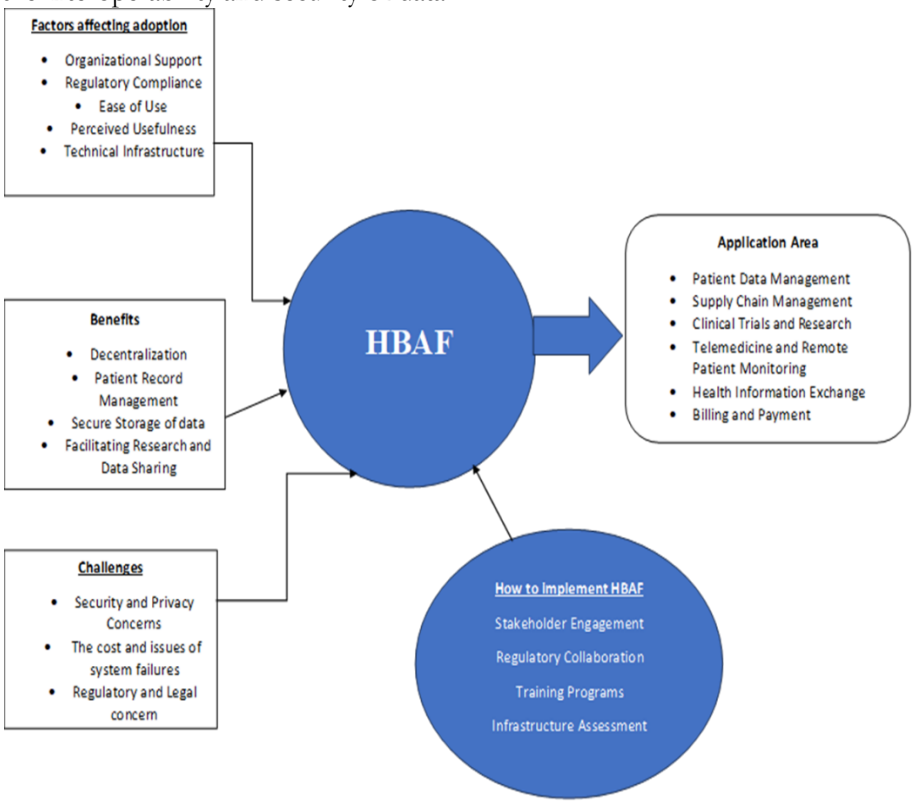

Figure 2. Proposed Healthcare Blockchain Adoption Framework

4. CONCLUSION

Blockchain offers a decentralized approach to data management, enhancing data integrity and safeguarding patient privacy. The core attributes of decentralization, immutability, and cryptographic protection make it a perfect choice for managing sensitive health information. Protecting sensitive patient information is important for trust, and financial costs can be challenging, especially for smaller providers, to account for as it relates to blockchain adoption and utilization. It is also vital that patients and health care professionals develop sufficient digital literacy to capitalize on implementing blockchain technology in health care. Important decisions surrounding data access, sharing, security, and compliance with IT policies are imperative for recommendations regarding the management of blockchain

systems. Ongoing engagement with stakeholders to build comprehensive education programs is crucial in addressing education barriers to employee engagement while harnessing the transformative potential of blockchain technology in Zimbabwe's healthcare landscape, focusing on higher-quality patient care through improved data integrity and protection. The proposed framework sets out to develop a structured pathway for healthcare organizations to successfully adopt blockchain technology, realizing the intended improvements to interoperability, security of data, and patient care outcomes.

The study's limitations include the relatively small sample size of 15 participants, which limits the research's ability to represent the diverse perspectives across the broader Zimbabwean healthcare workforce. The research also focused on certain geographical locations, mostly Harare and Mutare; therefore, the findings may not extrapolate well to areas where health infrastructures and practices differ. Although the methods employed were qualitative in nature, likely that the viewpoints obtained in the study will not capture all the variables that may influence blockchain adoption. The research findings may quickly become obsolete as technology and regulatory structures change rapidly.

Future research should also consider increasing the sample size and diversity of participants from various regions and sectors of healthcare to make findings more generalizable to other patients and healthcare settings. Future researchers should consider longitudinal studies that track the effects of blockchain implementation and use over time and collect empirical information regarding the impact of blockchain on improving patient care and secure data handling in practice. Future research should also explore the scalability of the HBAF research across healthcare environments, especially rural and underserved communities. Researching a patient's perspective on controlling the health data and consent process is also important. In order to put the proposed blockchain framework into practice in Zimbabwe and other similar healthcare systems, a pilot project implementation in an actual practice environment is proposed. Components of the pilot implementation will include: training on aspects of digital literacy, engaging stakeholders to understand different perspectives, and assessing the framework's capacity to manage sensitive patient data. The potential outcome of the piloting implementation approach is to contribute to improved data integrity and patient care in the healthcare system. Lastly, future empirical research on integrating blockchain into existing healthcare practices and the measurable impact of blockchain on operational efficiencies and patient outcomes will be needed to develop best practices and implementation guidelines for future research on blockchain features and functionalities in healthcare.

REFERENCES

[1] D. M. Walker, W. L. Tarver, P. Jonnalagadda, L. Ranbom, E. W. Ford, and S. Rahurkar, "Perspectives on Challenges and Opportunities for Interoperability: Findings From Key Informant Interviews With Stakeholders in Ohio.," *JMIR Med. informatics*, vol. 11, p. e43848, Feb. 2023, doi: 10.2196/43848.

[2] M. A. Saberi, H. Mcheick, and M. Adda, "From Data Silos to Health Records Without Borders: A Systematic Survey on Patient-Centered Data Interoperability," *Inf.*, vol. 16, no. 2, pp. 1–31, 2025, doi: 10.3390/info16020106.

[3] J. S. S. Mole and R. S. Shaji, "Ethereum blockchain for electronic health records: securing and streamlining patient management," *Front. Med.*, vol. 11, 2024, doi: 10.3389/fmed.2024.1434474.

[4] R. Sibanda, B. Ndlovu, S. Dube, and K. Maguraushe, "Towards Health 4 . 0 : Blockchain-Based Electronic Health Record for Care Coordination," pp. 712–720, 2024, doi: 10.34190/ecie.19.1.2606.

[5] F. A. Reegu *et al.*, "Blockchain-Based Framework for Interoperable Electronic Health Records for an Improved Healthcare System," *Sustain.*, vol. 15, no. 8, Apr. 2023, doi: 10.3390/su15086337.

[6] A. Ademola, C. George, and G. Mapp, "Addressing the Interoperability of Electronic Health Records: Proposing the TASSIPS Framework," *Preprints*, 2024.

[7] J. Carlos Ferreira, L. B. Elvas, R. Correia, and M. Mascarenhas, "Enhancing EHR Interoperability and Security through Distributed Ledger Technology: A Review," *Healthcare (Switzerland)*, vol. 12, no. 19. Multidisciplinary Digital Publishing Institute (MDPI), Oct. 2024, doi: 10.3390/healthcare12191967.

[8] H. Fatoum, S. Hanna, J. D. Halamka, D. C. Sicker, P. Spangenberg, and S. K. Hashmi, "Blockchain integration with digital technology and the future of health care ecosystems: Systematic review," *Journal of Medical Internet Research*, vol. 23, no. 11. JMIR Publications Inc., Nov. 2021, doi: 10.2196/19846.

[9] M. B. Horton *et al.*, "Practice Guidelines for Ocular Telehealth-Diabetic Retinopathy, Third Edition," *Telemed. J. E. Health.*, vol. 26, no. 4, pp. 495–543, 2020, doi: 10.1089/tmj.2020.0006.

[10] A. Solanke, "Blockchain Implementation for Enterprise Data Integrity : Distributed Ledger Strategies for Supply Chain Transparency and Trustworthy Data Abstract :," no. March, 2025.

[11] B. L. Jimma and D. B. Enyew, "Barriers to the acceptance of electronic medical records from the perspective of physicians and nurses:A scoping review," *Informatics Med. Unlocked*, vol. 31, no. May, p. 100991, 2022, doi: 10.1016/j.imu.2022.100991.

[12] N. Ncube, B. Mutunhu, and K. Sibanda, "Land Registry Using a Distributed Ledger," in *2022 IST-Africa Conference, IST-Africa 2022*, 2022, pp. 1–7, doi: 10.23919/IST-Africa56635.2022.9845584.
[13] P. K. Ghosh, A. Chakraborty, M. Hasan, K. Rashid, and A. H. Siddique, "Blockchain Application in Healthcare Systems: A Review," *Systems*, vol. 11, no. 1, 2023, doi: 10.3390/systems11010038.
[14] Vimbai Alice Muderere, Belinda Ndlovu, and Kudakwashe Maguraushe, "Framework for Enhancing Interoperability, Data Exchange, and Security in Healthcare through Blockchain Technology," *Indones. J. Comput. Sci.*, vol. 12, no. 2, pp. 284–301, 2023, doi: 10.33022/ijcs.v14i4.4950.
[15] N. N. Basil, S. Ambe, C. Ekhator, and E. Fonkem, "Health Records Database and Inherent Security Concerns: A Review of the Literature," *Cureus*, 2022, doi: 10.7759/cureus.30168.
[16] N. K. Mensah *et al.*, "Health Professionals' Ethical, Security, and Patient Safety Concerns Using Digital Health Technologies: A Mixed Method Research Study," *Heal. Serv. Insights*, vol. 17, 2024, doi: 10.1177/11786329241303379.
[17] A. Gedikci Ondogan, M. Sargin, and K. Canoz, "Use of electronic medical records in the digital healthcare system and its role in communication and medical information sharing among healthcare professionals," *Informatics Med. Unlocked*, vol. 42, no. October, p. 101373, 2023, doi: 10.1016/j.imu.2023.101373.
[18] S. Upadhye, S. Uparkar, A. Bhave, and P. O. Bagde, "Optimism or Pessimism: Is Blockchain Technology Helping the Healthcare Industry?," 2022, doi: 10.1109/ICBDS53701.2022.9935891.
[19] F. M. AbdelSalam, "Blockchain Revolutionizing Healthcare Industry: A Systematic Review of Blockchain Technology Benefits and Threats.," *Perspect. Heal. Inf. Manag.*, vol. 20, no. 3, pp. 1–19, 2023.
[20] B. Mutunhu, B. Chipangura, and H. Twinomurinzi, "Internet of Things in the Monitoring of Diabetes: A Systematic Review," *Int. J. Heal. Syst. Transl. Med.*, vol. 2, no. 1, pp. 1–20, 2022, doi: 10.4018/IJHSTM.300336.
[21] H. Taherdoost, "A Critical Review of Blockchain Acceptance Models—Blockchain Technology Adoption Frameworks and Applications," *Computers*, vol. 11, no. 2, 2022, doi: 10.3390/computers11020024.
[22] M. A. Bazel, F. Mohammed, M. Ahmad, A. O. Baarimah, and T. Al Maskari, "Blockchain technology adoption in healthcare: an integrated model," *Sci. Rep.*, vol. 15, no. 1, pp. 1–26, 2025, doi: 10.1038/s41598-025-95253-x.
[23] M. Sciarelli, A. Prisco, M. H. Gheith, and V. Muto, "Factors affecting the adoption of blockchain technology in innovative Italian companies: an extended TAM approach," *J. Strateg. Manag.*, vol. 15, no. 3, pp. 495–507, 2022, doi: 10.1108/JSMA-02-2021-0054.

[24] Z. A. Al-Sulami, N. Ali, and R. Ramli, "Blockchain adoption in Healthcare: Models, Challenges, and Future Work," *Basrah Res. Sci.*, vol. 49.2, no. 2, pp. 79–93, 2023, doi: 10.56714/bjrs.49.2.8.

[25] J. D. Bryan and T. Zuva, "A Review on TAM and TOE Framework Progression and How These Models Int egrate," *Adv. Sci. Technol. Eng. Syst. J.*, vol. 6, no. 3, pp. 137–145, 2021, doi: 10.25046/aj060316.

[26] A. Haleem, M. Javaid, R. P. Singh, R. Suman, and S. Rab, "Blockchain technology applications in healthcare: An overview," *Int. J. Intell. Networks*, vol. 2, no. May, pp. 130–139, 2021, doi: 10.1016/j.ijin.2021.09.005.

[27] J. Chaloner *et al.*, "A qualitative study exploring healthcare workers' lived experiences of the impacts of COVID-19 policies and guidelines on maternal and reproductive healthcare services in the United Kingdom.," *Eur. J. midwifery*, vol. 7, p. 30, 2023, doi: 10.18332/ejm/171802.

[28] J. Pyo, W. Lee, E. Y. Choi, S. G. Jang, and M. Ock, "Qualitative Research in Healthcare: Necessity and Characteristics," *J. Prev. Med. Public Heal.*, vol. 56, no. 1, pp. 12–20, 2023, doi: 10.3961/jpmph.22.451.

[29] V. Braun and V. Clarke, "Thematic analysis.," *APA Handb. Res. methods Psychol. Vol 2 Res. Des. Quant. Qual. Neuropsychol. Biol.*, vol. 2, pp. 57–71, 2012, doi: 10.1037/13620-004.

[30] I. Abu-elezz, A. Hassan, A. Nazeemudeen, M. Househ, and A. Abd-alrazaq, "The benefits and threats of blockchain technology in healthcare: A scoping review," *International Journal of Medical Informatics*, vol. 142. Elsevier Ireland Ltd, Oct. 2020, doi: 10.1016/j.ijmedinf.2020.104246.

[31] H. Taherdoost, "The Role of Blockchain in Medical Data Sharing," *Cryptography*, vol. 7, no. 3, pp. 1–20, 2023, doi: 10.3390/cryptography7030036.

[32] M. Attaran, "Blockchain technology in healthcare: Challenges and opportunities," *International Journal of Healthcare Management*, vol. 15, no. 1. Taylor and Francis Ltd., pp. 70–83, 2022, doi: 10.1080/20479700.2020.1843887.

[33] T. E. White, W. B. Wong, D. Janowiak, and L. H. Hilborne, "Strategies for laboratory professionals to drive laboratory stewardship," *Pract. Lab. Med.*, vol. 26, no. April, p. e00249, 2021, doi: 10.1016/j.plabm.2021.e00249.

[34] O. Karneli, "The Role of Adhocratic Leadership in Facing the Changing Business Environment," *J. Contemp. Adm. Manag.*, vol. 1, no. 2, pp. 77–83, 2023, doi: 10.61100/adman.v1i2.26.

[35] A. S. George, "Partners Universal Innovative Research Publication (PUIRP) India ' s Ascent as the Global Epicenter of Artificial Intelligence Partners Universal Innovative Research Publication (PUIRP)," no. February, pp. 1–15, 2024, doi: 10.5281/zenodo.10936490.

[36] M. Javaid, A. Haleem, R. P. Singh, R. Suman, and S. Khan, "A review of Blockchain Technology applications for financial services," *BenchCouncil Trans. Benchmarks, Stand. Eval.*, vol. 2, no. 3, p. 100073, 2022, doi: 10.1016/j.tbench.2022.100073.

[37] R. Brandín and S. Abrishami, "Information traceability platforms for asset data lifecycle: blockchain-based technologies," *Smart Sustain. Built Environ.*, vol. 10, no. 3, pp. 364–386, 2021, doi: 10.1108/SASBE-03-2021-0042.

[38] S. M. Williamson and V. Prybutok, "Balancing Privacy and Progress: A Review of Privacy Challenges, Systemic Oversight, and Patient Perceptions in AI-Driven Healthcare," *Appl. Sci.*, vol. 14, no. 2, p. 675, 2024, doi: 10.3390/app14020675.

[39] R. Jabbar, N. Fetais, M. Krichen, and K. Barkaoui, "Blockchain technology for healthcare: Enhancing shared electronic health record interoperability and integrity," in *2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies, ICIoT 2020*, Feb. 2020, pp. 310–317, doi: 10.1109/ICIoT48696.2020.9089570.

[40] S. Saratkar, M. Langote, A. Chaudhari, T. Thute, R. Raut, and G. Thakre, "Enhancing Healthcare: Incorporating Blockchain into Electronic Health Records," in *7th International Conference on Inventive Computation Technologies, ICICT 2024*, 2024, pp. 1546–1551, doi: 10.1109/ICICT60155.2024.10544952.

[41] R. Raj and S. P. Raja, "Revolutionizing Healthcare: Blockchain's Transformative Applications for Data Security, Privacy, and Interoperability," 2024, doi: 10.1109/I2CT61223.2024.10544066.

[42] S. Ramzan, A. Aqdus, V. Ravi, D. Koundal, R. Amin, and M. A. Al Ghamdi, "Healthcare Applications Using Blockchain Technology: Motivations and Challenges," *IEEE Trans. Eng. Manag.*, vol. 70, no. 8, pp. 2874–2890, Aug. 2023, doi: 10.1109/TEM.2022.3189734.

[43] C. Daah, A. Qureshi, I. Awan, and S. Konur, "Enhancing Zero Trust Models in the Financial Industry through Blockchain Integration: A Proposed Framework," *Electron.*, vol. 13, no. 5, 2024, doi: 10.3390/electronics13050865.

[44] D. Singh, S. Monga, S. Tanwar, W. C. Hong, R. Sharma, and Y. L. He, "Adoption of Blockchain Technology in Healthcare: Challenges, Solutions, and Comparisons," *Applied Sciences (Switzerland)*, vol. 13, no. 4. MDPI, Feb. 2023, doi: 10.3390/app13042380.

[45] M. Wosny, L. M. Strasser, and J. Hastings, "Experience of Health Care Professionals Using Digital Tools in the Hospital: Qualitative Systematic Review," *JMIR Hum. Factors*, vol. 10, no. 1, pp. 1–21, 2023, doi: 10.2196/50357.

[46] A. A. Kawu, L. Hederman, J. Doyle, and D. O'Sullivan, "Patient generated health data and electronic health record integration, governance and socio-technical issues: A narrative review," *Informatics Med. Unlocked*, vol. 37, no. September 2022, p. 101153, 2023, doi: 10.1016/j.imu.2022.101153.

[47] L. Theodorakopoulos, A. Theodoropoulou, and C. Halkiopoulos, "Enhancing Decentralized Decision-Making with Big Data and Blockchain Technology: A Comprehensive Review," *Appl. Sci.*, vol. 14, no. 16, 2024, doi: 10.3390/app14167007.

[48] D. Bhati, M. S. Deogade, and D. Kanyal, "Improving Patient Outcomes Through Effective Hospital Administration: A Comprehensive Review," *Cureus*, vol. 15, no. 10, 2023, doi: 10.7759/cureus.47731.

[49] M. A. Al-Khasawneh, M. Faheem, A. A. Alarood, S. Habibullah, and A. Alzahrani, "A secure blockchain framework for healthcare records management systems," *Healthc. Technol. Lett.*, no. September, pp. 461–470, 2024, doi: 10.1049/htl2.12092.

[50] P. Shojaei, E. Vlahu-Gjorgievska, and Y. W. Chow, "Security and Privacy of Technologies in Health Information Systems: A Systematic Literature Review," *Computers*, vol. 13, no. 2, 2024, doi: 10.3390/computers13020041.

[51] A. J, D. P. Isravel, K. M. Sagayam, B. Bhushan, Y. Sei, and J. Eunice, "Blockchain for healthcare systems: Architecture, security challenges, trends and future directions," *Journal of Network and Computer Applications*, vol. 215. Academic Press, Jun. 2023, doi: 10.1016/j.jnca.2023.103633.

[52] A. Ali *et al.*, "Blockchain-Powered Healthcare Systems: Enhancing Scalability and Security with Hybrid Deep Learning," *Sensors*, vol. 23, no. 18, pp. 1–33, 2023, doi: 10.3390/s23187740.

[53] N. Ettaloui, S. Arezki, and T. Gadi, "Blockchain-Based Electronic Health Record: Systematic Literature Review," *Hum. Behav. Emerg. Technol.*, vol. 2024, no. 1, 2024, doi: 10.1155/hbe2/4734288.

[54] A. Punia, P. Gulia, N. S. Gill, E. Ibeke, C. Iwendi, and P. K. Shukla, "A systematic review on blockchain-based access control systems in cloud environment," *J. Cloud Comput.*, vol. 13, no. 1, 2024, doi: 10.1186/s13677-024-00697-7.

[55] S. Ben Othman and M. Getahun, "Leveraging blockchain and IoMT for secure and interoperable electronic health records," *Sci. Rep.*, vol. 15, no. 1, pp. 1–25, 2025, doi: 10.1038/s41598-025-95531-8.

[56] M. S. B. Kasyapa and C. Vanmathi, "Blockchain integration in healthcare: a comprehensive investigation of use cases, performance issues, and mitigation strategies," *Frontiers in Digital Health*, vol. 6. Frontiers Media SA, 2024, doi: 10.3389/fdgth.2024.1359858.

[57] Z. Wenhua, F. Qamar, T. A. N. Abdali, R. Hassan, S. T. A. Jafri, and Q. N. Nguyen, "Blockchain Technology: Security Issues, Healthcare Applications, Challenges and Future Trends," *Electron.*, vol. 12, no. 3, 2023, doi: 10.3390/electronics12030546.

[58] H. Sahu, S. Choudhari, and S. Chakole, "The Use of Blockchain Technology in Public Health: Lessons Learned," *Cureus*, Jun. 2024, doi: 10.7759/cureus.63198.
[59] Y. Blockchain- *et al.*, "Citation: Blockchain-Based Healthcare Records Management Framework: Enhancing Security, Privacy, and Interoperability," pp. 1–19, 2024.
[60] Y. Han, Y. Zhang, and S. H. Vermund, "Blockchain Technology for Electronic Health Records," *Int. J. Environ. Res. Public Health*, vol. 19, no. 23, Dec. 2022, doi: 10.3390/ijerph192315577.
[61] H. Saeed *et al.*, "Blockchain technology in healthcare: A systematic review," *PLoS One*, vol. 17, no. 4 April, Apr. 2022, doi: 10.1371/journal.pone.0266462.
[62] Y. Shynar *et al.*, "Comprehensive Analysis of Blockchain Technology in the Healthcare Sector and Its Security Implications," *Int. J. E-Health Med. Commun.*, vol. 15, no. 1, 2025, doi: https://doi.org/10.4018/IJEHMC.372423.
[63] G. Tripathi, M. A. Ahad, and G. Casalino, "A comprehensive review of blockchain technology: Underlying principles and historical background with future challenges," *Decis. Anal. J.*, vol. 9, no. October, p. 100344, 2023, doi: 10.1016/j.dajour.2023.100344.
[64] P. Durneva, K. Cousins, and M. Chen, "The current state of research, challenges, and future research directions of blockchain technology in patient care: Systematic review," *Journal of Medical Internet Research*, vol. 22, no. 7. JMIR Publications Inc., Jul. 2020, doi: 10.2196/18619.
[65] A. Sepas, A. H. Bangash, O. Alraoui, K. El Emam, and A. El-Hussuna, "Algorithms to anonymize structured medical and healthcare data: A systematic review.," *Front. Bioinforma.*, vol. 2, p. 984807, 2022, doi: 10.3389/fbinf.2022.984807.
[66] M. Faheem, M. A. Al-khasawneh, S. Habibullah, and A. Alzahrani, "A secure blockchain framework for healthcare records management systems," no. September, pp. 461–470, 2024, doi: 10.1049/htl2.12092.
[67] X. Zhang and R. Saltman, "Impact of Electronic Health Record Interoperability on Telehealth Service Outcomes," *JMIR Med. Informatics*, vol. 10, no. 1, pp. 1–9, 2022, doi: 10.2196/31837.
[68] M. Faheem, B. Raza, M. S. Bhutta, and S. H. H. Madni, "A blockchain-based resilient and secure framework for events monitoring and control in distributed renewable energy systems," *IET Blockchain*, vol. 4, no. S1, pp. 644–658, 2024, doi: 10.1049/blc2.12081.
[69] K. Maguraushe, "Development of a diagnostic instrument and privacy model for student personal information privacy perceptions at a Zimbabwean university," pp. 1–383, 2021, [Online]. Available: http://hdl.handle.net/10500/27557.

[70] K. Maguraushe, A. Da Veiga, and N. Martins, "Validation of an Information Privacy Perception Instrument at a Zimbabwean University," in *14th International Symposium on Human Aspects of Information Security and Assurance (HAISA)*, 2020, pp. 300–314.
[71] M. Bouke, A. Abdullah, S. ALshatebi, H. E. Atigh, and K. Cengiz, "African Union Convention on Cyber Security and Personal Data Protection: Challenges and Future Directions," pp. 1–15, 2023.
[72] S. S. Mohammed Abdul, "Navigating Blockchain's Twin Challenges: Scalability and Regulatory Compliance," *Blockchains*, vol. 2, no. 3, pp. 265–298, 2024, doi: 10.3390/blockchains2030013.
[73] S. Talwar, A. Dhir, N. Islam, P. Kaur, and A. Almusharraf, "Resistance of multiple stakeholders to e-health innovations: Integration of fundamental insights and guiding research paths," *J. Bus. Res.*, vol. 166, no. June, p. 114135, 2023, doi: 10.1016/j.jbusres.2023.114135.
[74] J. Piasecki and P. Y. Cheah, "Ownership of individual-level health data, data sharing, and data governance," *BMC Med. Ethics*, vol. 23, no. 1, pp. 1–9, 2022, doi: 10.1186/s12910-022-00848-y.
[75] S. Abdallah and N. Nizamuddin, "Blockchain-based solution for Pharma Supply Chain Industry," *Comput. Ind. Eng.*, vol. 177, p. 108997, 2023, doi: https://doi.org/10.1016/j.cie.2023.108997.
[76] S. Porsdam Mann, J. Savulescu, P. Ravaud, and M. Benchoufi, "Blockchain, consent and prosent for medical research.," *J. Med. Ethics*, vol. 47, no. 4, pp. 244–250, May 2020, doi: 10.1136/medethics-2019-105963.
[77] G. Bahari, I. Mutambik, A. Almuqrin, and Z. H. Alharbi, "Trust: How It Affects the Use of Telemedicine in Improving Access to Assistive Technology to Enhance Healthcare Services.," *Risk Manag. Healthc. Policy*, vol. 17, pp. 1859–1873, 2024, doi: 10.2147/RMHP.S469324.
[78] W. Yang *et al.*, "Adaptive Parallel Scheduling Scheme for Smart Contract," *Mathematics*, vol. 12, no. 9, 2024, doi: 10.3390/math12091347.
[79] P. Jhamba, B. Ndlovu, S. Dube, K.Maguraushe M. Muduva, and F. Jacqueline, "A Blockchain-based Patient Portal for Mental Health Management," 2024, doi: 10.46254/AF05.20240251.
[80] S. Sheela, A. A. Alsmady, K. Tanaraj, and I. Izani, "Navigating the Future: Blockchain's Impact on Accounting and Auditing Practices," *Sustainability*, vol. 15, no. 24, 2023, doi: 10.3390/su152416887.
[81] H. B. Ncube, B. M. Ndlovu, K. Maguraushe and S. Dube, "Blockchain-Based Fraud Detection System for Healthcare Insurance Claims," no. 2023, pp. 540–547, 2024, doi: 10.34190/ecie.19.1.2558.