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Exploring the role of novel technologies in hospitals' patients' data management

Vasco Lourenço Drumonde Melo

Master's in Management

Supervisor:

PhD, Ulpan Tokkozhina, Invited Assistant Professor

Iscte – Instituto Universitário de Lisboa

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BUSINESS
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Department of Marketing, Operations and General Management

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Acknowledgment

As I prepare to deliver this dissertation, I feel compelled to include a brief acknowledgment. Reflecting on the experiences of this past year, “thankfulness” alone does not fully capture my feelings, but I will try to provide an understanding of the depth of my gratitude.

First, I extend my heartfelt thanks to my family. This academic journey has been a profoundly rewarding experience, one made possible only by their unwavering support. Without their encouragement and belief, I would not have had the opportunity to pursue this master’s degree and embark on this enriching journey, one I am certain provided growth in multiple aspects.

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Words alone cannot convey the depth of my gratitude, but I hope these words offer some insight into my heartfelt appreciation.

Resumo

Esta dissertação explora o potencial transformador das tecnologias emergentes, especificamente blockchain e inteligência artificial, no sector da saúde. A estrutura descentralizada do blockchain melhora significativamente a integridade dos dados e protege a privacidade dos pacientes, enquanto a inteligência artificial avança nos diagnósticos, na medicina personalizada e otimiza tarefas administrativas.

A sinergia entre estas duas tecnologias enfrenta desafios verificados de longa data na saúde, desde a otimização de recursos até à melhoria dos resultados dos pacientes e à redução de custos operacionais. No entanto, o sucesso destas tecnologias não depende somente das suas capacidades técnicas; também se baseia no feedback e no envolvimento dos profissionais de saúde que irão interagir diretamente com elas. Para obter informações sobre as perspetivas, sugestões e receios destes profissionais relativamente a estas tecnologias, foi realizada uma pesquisa qualitativa semiestruturada com participantes de diferentes áreas de especialização, anos de experiência e hospitais. Envolver médicos, enfermeiros e funcionários administrativos, na fase inicial do desenvolvimento e implementação destas tecnologias ajuda a identificar desafios práticos, assegurar uma integração harmoniosa nos fluxos de trabalho clínico e melhorar a aceitação dos envolvidos.

De acordo com estas conclusões, para beneficiar plenamente destas vantagens, deve haver um investimento contínuo na formação dos profissionais, estruturas regulamentares claras e um compromisso com considerações éticas e sociais. Esta dissertação enfatiza que, embora tecnologias como o blockchain e a inteligência artificial ofereçam uma via promissora para tornar o sector da saúde mais resiliente no futuro, a sua adoção efetiva exigirá não só inovação, mas também o envolvimento ativo dos profissionais de saúde, desde o desenvolvimento até à implementação. Este é um passo fundamental para mitigar os riscos e desafios associados a estas tecnologias.

Palavras-chave: Gestão de saúde, tecnologias emergentes, blockchain, inteligência artificial, otimização de processos

JEL Codes: Q55 (Technological Innovation), C61 (Optimization Techniques), M21 (Business Economics), M53 (Training)

Abstract

This dissertation explores the transformative potential of emerging technologies, specifically blockchain and artificial intelligence, within the healthcare sector. Blockchain's decentralized framework significantly improves data integrity and safeguards patient privacy, while AI advances diagnostics, personalized medicine, and optimizes administrative tasks.

The synergy these two technologies present addresses longstanding challenges in healthcare, from optimizing resources to improving patient outcomes and reducing operational costs. However, the success of these technologies is not solely reliant on technical capabilities; it also depends on the feedback and engagement of healthcare professionals who will directly interact with them – To obtain insight into the healthcare workers in terms of their perspectives, suggestions, and fears about these technologies, semi-structured qualitative research was realized with participants across different areas of expertise, years of knowledge and current hospital. Involving doctors, nurses, and administrative staff can help identify practical challenges, ensure a smooth integration into clinical workflows, and improve stakeholder acceptance. According to these findings, to fully benefit from these advantages, there must be ongoing investment in staff training, clear regulatory frameworks, and a commitment to ethical and social considerations. This dissertation emphasizes that while technologies like blockchain and AI offer a promising pathway to future-proof healthcare, their effective adoption will require not only innovation but also the active involvement of healthcare workers, from their development to their implementation. This is instrumental in mitigating the risks and challenges associated with these technologies.

Keywords: healthcare management, emerging technologies, blockchain, artificial intelligence, process optimization

JEL Codes: Q55 (Technological Innovation), C61 (Optimization Techniques), M21 (Business Economics), M53 (Training)

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Chapter i: Introduction

Emerging technologies are increasing their already prevalent role in companies' functions and operations, with the difference in results and accuracy presented. Their inclusion starts to become a matter of "when" rather than "if" they should be implemented.

A significant challenge for the healthcare industry is the proper management and safe retrieval of the massive amount of personal health data generated by the normal activities of conducting business and providing services. Blockchain presents an amazing opportunity to provide access to multiple elements of the hospitals (and possibly beyond these members), with transparency and trackability, while also promoting security of this private information. This technology can be applied to an individuals' electronic health record (EHR) in confidentiality and privacy is a main concern (Girardi et al, 2020). The systems need to share this data in a secure manner to promote accessibility from individuals with authorization to it, which is a topic that will be approached in one of the proposals presented in this dissertation.

Currently, the healthcare industry in Portugal, especially for public health, is facing concerns in terms of quality of service and its conditions - the amount of burnout and depression in Portuguese healthcare that it is starting to surface, especially verified during the Covid-19, presented an issue in terms of the assistance that the workforce possesses in their processes and what is being demanded from them (Duarte et al, 2020). These technologies, that are not as present as they should, grant tremendous assistance in these procedures and their quality which would benefit every intervenient involved in them. Artificial Intelligence presents the chance to improve the results in terms of accuracy and creations of clusters of information that can be decisive in an industry that does not provide margin for error. The potential that AI presents is exciting for this field, especially for diagnosis present.

These technologies provide an expressive improvement to already existing processes, but it is important to analyze how these implementations and incorporations should be done. In order to obtain a better insight in relation to this, qualitative research with workforce of hospital, across different locations, will be conducted to obtain their insight and suggestions related to the issues they are facing, in search of adjustments and perhaps clusters absent from the articles analyzed.

For this dissertation, research will be conducted to see the potential, necessary steps and recommendations of the implementation of these technologies, in an industry that is facing criticism from the public due to their quality of services. The population growth creates a situation in which the healthcare providers are unable to provide a service (Mamede, 2020) of the desired quality, which creates a need for assistance. The technologies considered for this are (a) Blockchain and (b) Artificial Intelligence – the reason behind this choice is the synergy in processes, in relation to implementing new, and already existing ones, and the ability to increase the efficiency and improve the processes and administrative procedures.

The objective with the development of this dissertation is the presentation of insights about the implementation of these novel technologies by healthcare professionals, as the current literature provides the advantages of these technologies, but not the perspective of the healthcare professionals in relation to their introduction and implementation. AI can reduce administrative burdens by automatically populating structured data areas from therapeutic notes, retrieving key data from past medica records, and collecting documented patient encounters (Kuwaiiti, et al,. 2023). The efficiency of processes that AI can present to the healthcare sector is tremendous, with multiple roles presenting significant improvement.

The following Research Questions were formulated to be addressed in this master dissertation:

(1) How can healthcare services efficiency and accessibility improve with decentralized diagnostic platforms powered by blockchain and AI?
(2) What is the opinion of the healthcare professionals in relation to the implementation of these technologies?
(3) What are their insights and recommendations that could support in mitigating the risks and challenges associated with these technologies and optimize their implementation?

Considering the lack of exploration of this subject, in relation to the sector in question, qualitative data collection will be conducted with different healthcare professionals in order to see their insights and understanding around their processes highlighted through these technologies.

The document has the following structure:

(1) Introduction – A contextualization is provided in terms of what will be discussed in this dissertation, in terms of Blockchain, Artificial Intelligence - The research problem and

insights about the main topics discussed in this dissertation;

(2) Literature review – The development of the technical aspects associated with these technologies, from how they work, their advantages, challenges and risks;

(3) Methodology – The explanation of the interview process. It developed the reason this type of research was conducted and what were the main points in terms of selection criteria; participant's information (respecting the anonymity of) and the information hoping to be obtained from it;

(4) Findings – The analysis of the interviews and the participant's responses, with key points being highlighted, that will be further developed in the discussion

(5) Discussion – Cross analysis of the findings with literature about the aspects obtained and referenced in the findings

(6) Conclusion – Conclusion of the dissertation and overall analysis of the information retrieved and obtained during its elaboration

1.2. Research Problem

This investigation will focus specifically on how these novel technologies could address the growing concerns the healthcare industry is facing regarding security, data access, and data management. The rapid advances on the Blockchain, with alongside the innovations verified from Internet of Medical Things have revolutionized the healthcare sector by significantly improving e-health/medical records (EHR/EMR), prescription drug data, insurance information (Yaqoob et al., 2022), and more. This study will enable us to assess the potential need for implementing these technologies and identify the process changes associated with them, due to the verification that where data and information-access are critical to the development of any industry.

There is a persistent fear surrounding AI, linked to concerns about job displacement, ethical dilemmas, and the depersonalization of care (Alhutelh et al., 2022), which hampers the smooth integration of these novel technologies. Ensuring flawless implementation among the various stakeholders is crucial for optimizing the processes associated with these technologies and their use. However, gaining trust and understanding of these technologies is not easy, as there is a significant knowledge gap among healthcare workers regarding their applications. Despite this, Woods et al. (2021) highlight that medical students and faculty recognize the importance of AI literacy training and believe AI education should be included in medical curricula. Unfortunately,

these technologies have not been widely adopted in the public healthcare sector, as most countries have not yet established public standards (Kumar et al., 2020).

Chapter ii: Literature Review

In recent years, the healthcare sector has been transformed by rapid advancements in technology, bringing both opportunities and challenges. Key topics in relation to modern healthcare include the role of the Blockchain, and Artificial Intelligence. These technologies promise to improve diagnostics, secure data sharing, and improve interoperability, but they also introduce new complexities and security risks. An exploration of how these innovations function, alongside an analysis of the challenges they present, showcasing the potential and limitations of integrating these novel technologies into healthcare systems. This will cover critical areas such as data security, the integration of Blockchain and AI, and the various challenges associated with adopting these transformative technologies.

2.1. Challenges of the Healthcare sector

Governments worldwide recognize the urgency to manage escalating healthcare costs, optimize workflows, and improve care processes - This effort is driven by the goal of enhancing patient care and, consequently, improving the effectiveness and efficiency of the healthcare sector. The resultant high-pressure environment compels healthcare providers to not only increase productivity but also to institute cost-cutting measures which can compromise processes and results (Helfert, 2009).

In the context of the Portuguese National Health Service (PNHS), amid these challenges, the focal point becomes the revitalization and recovery of access, quality, and performance. (Nunes, 2017). The need to address these issues is underscored by the realization that diagnostic and treatment choices often hinge on physicians' opinions rather than being solely rooted in scientific evidence. As expressed by Girardi et al. (2020), it is common for patients to receive disparate advice for identical medical problems from different physicians. This scenario accentuates the significance of Medical Error Prevention, particularly considering that effective and high-quality processes may still be vulnerable to incorrect interpretations by healthcare professionals. The inherent variability, for example, in physicians ‘opinions underscore the need for assistance in the decision-making process, acknowledging the potential for discrepancies that could impact patient outcomes.

To alleviate the mounting pressure on healthcare providers and ensure the recovery of quality in healthcare services, Blockchain and AI emerge as formidable solutions (Saker et al, 2023; Farouk et al., 2020; Mylavarapu et al. 2023) These technologies offer promising avenues to address the identified challenges, providing robust support in the decision-making process and enhancing the overall quality of healthcare delivery (Mylavarapu et al., 2023). By leveraging the capabilities of Blockchain and AI, the healthcare sector stands to benefit from optimized workflows, improved diagnostic accuracy, and a reduction in the frequency of medical errors, promoting a more resilient and effective healthcare system (Al Kuwait, 2023). Critical facets of hospital operations, such as (a) supply chain management; (b) data collection, and security, play pivotal roles in determining the success of healthcare facilities. Implementing advanced technologies can not only optimize these aspects but also contribute to the overall efficiency and resilience of healthcare systems.

2.2. Internet of Medical Things in Healthcare

According to Rashid et al (2023), "The Internet of medical things (IoMT) brings together the Internet of things (IoT) and medical equipment. The IoMT is expected to form the foundation of future healthcare systems in which all medical equipment are connected to the Internet and operating under the supervision of medical experts" (p.1).

In the healthcare sector, this involves integrating smart sensors, devices, actuators, medical equipment, and mobile objects to enable real-time connectivity for various healthcare applications. IoT consistently connects diverse medical sensors, devices, and systems to establish a comprehensive network that supports automated sensing, data processing, and communication (Ahmed et al., 2022; Chattu, 2021)

The advances being registered in terms of the technology the devices available in this industry present an excellent solution for monitoring. As it evolves, the Internet of Medical Things (IoMT) provides faster and more cost-effective healthcare solutions. IoMT-enabled devices encompass smartwatches, smart shoes, electroencephalogram (EEG) and electrocardiography (ECG) machines, as well as various sensors for airflow, blood pressure, and motion detection. The vital signs collected by these sensors are transmitted over the Internet to an IoMT application, which forwards the data to healthcare professionals and medical staff, and then relays responses

back to the patients. The sensor data is directly uploaded to a large cloud storage system for further analysis and access (Chattu, 2021; Ameen et al., 2023)

2.3. Blockchain in Healthcare

Blockchain emerged as a transaction network and its ongoing exploration extends beyond the financial domain, with the healthcare sector emerging as a noteworthy beneficiary of this expansion (David et al., 2023). In the intricate web of the blockchain system, participants engage with nodes, utilizing a Public Key Infrastructure to propose transactions. Each participant possesses a unique set of public and private keys, where the public key functions as the user's public address, and the private key serves to validate the user's identity (Beam et al., 2018).

Within the decentralized landscape of blockchain, an ever-expanding series of records, termed "blocks," interconnect through the mining process. Once the blockchain completes the information processing, all computers in the network synchronize simultaneously, establishing an enduring and unalterable digital record. The protocol of each blockchain system delineates the entities authorized to append new blocks to the chain and outlines the specific procedure for doing so (Beam et al., 2018; Haleem et al., 2021)

This technology holds the potential to usher in substantial improvements for data security and data sharing among stakeholders in the healthcare sector and their patients. Such advancements would coherently complement the Artificial Intelligence component of the proposal, creating a synergetic integration that enhances overall system efficiency and effectiveness (Tagde et al. 2021)

In the healthcare sector, blockchain technology is undergoing a conceptual shift, delivering substantial value to data management by enhancing efficiency, access control, technological innovation, privacy protection, and security (Supriya, 2021).

2.3.1. Data Security

The concerns surrounding data security and patient privacy have been intensifying by the rise of incidents related to security breaches affecting healthcare records. Statistics from Beazley, a leading global cybersecurity insurance company, reveals that in 2017, a staggering 45 percent of ransomware attacks specifically targeted healthcare organizations (Barkly 2018, as cited in Attaran, 2020).

Addressing these challenges, the integration of blockchain technology emerges as a key solution. When successfully incorporated into the data management chain, blockchain deploys robust encryption protocols that render healthcare data immutable and impervious to decryption (Barkly, 2018, as cited in Attaran, 2020; Liu et al., 2020; Yaqoob et al., 2022) This cryptographic security ensures that sensitive patient information remains safeguarded against unauthorized access or tampering.

Furthermore, blockchain transactions are authorized through private identification keys, exclusive to individual users and maintained with utmost confidentiality (Liu et al., 2020). This aspect not only increases the overall security of patient data but also empowers individuals with control over the sharing of their health information with selected service providers. The decentralized and transparent nature of blockchain ensures that patients can securely share their data while maintaining privacy and control (Attaran, 2020; Rahman et al., 2024; Yaqoob, I. et al., 2022)

Additionally, blockchain technology introduces the concept of proof of ownership for medical records, providing a verifiable trail of authenticity. This not only improves the integrity of healthcare data but also acts as a secure obstacle against counterfeiting or fraudulent activities within the healthcare ecosystem (Attaran, 2020; Yaqoob, I. et al., 2022)

Beyond the security and privacy dimensions, blockchain technology holds the potential to optimize interoperability within the healthcare sector. The decentralized nature of blockchain enables consistent and secure sharing of health records across disparate systems, fostering greater collaboration and efficiency (Mettler, 2016; Liu et al., 2020; Yaqoob, I. et al., 2022)

The integration of blockchain technology addresses critical issues of data security and patient privacy in healthcare. By leveraging its cryptographic mechanisms, private identification

keys, and proof of ownership features, blockchain not only solidifies the security of healthcare data but also empowers individuals in managing and selectively sharing their health information (Liu et al, 2020).

Its potential to improve interoperability positions blockchain as a transformative force in creating a more resilient and efficient healthcare data ecosystem.

2.3.2. Interoperability and Data Sharing

Blockchain technology represents a transformative force in healthcare, offering a secure and transparent environment for the access and sharing of patient data among diverse healthcare entities. Recent developments reference its potential to revolutionize data management in the healthcare sector.

Smart contracts, a key feature of blockchain, have emerged as powerful tools in automating consent management and data-sharing agreements (Attaran, 2020; Rahman et al., 2024). These self-executing contracts enable a dynamic and automated approach to consent, fostering a unified healthcare ecosystem. Patients, in particular, benefit from enhanced confidence and security in the system. The implementation of smart contracts empowers patients to control and specify the information they consent to share, thereby ensuring a more personalized and patient-centric approach to data management (Li et al., 2019; Khatoon, 2020)

Furthermore, smart contracts introduce innovative solutions for scenarios where obtaining patient consent may be challenging, such as critical health conditions. In situations where patients are incapacitated and unable to provide immediate consent for data sharing, pre-established smart contracts can trigger the sharing of critical health information. This predetermined agreement, previously accorded by the patient, ensures a timely and ethically sound approach to data accessibility in emergency scenarios (Rahman et al, 2024; Khatoon, A. 2020)

By automating consent management through smart contracts, blockchain not only increases the efficiency of data sharing but also ensures that the process aligns with patient preferences and ethical considerations. The ongoing evolution of blockchain technology in healthcare demonstrates a shift towards a more patient-centric, transparent, and secure data-sharing environment, promoting trust and confidence in the healthcare ecosystem.

2.4. Artificial Intelligence in Healthcare

The recognition of AI's potential in medicine dates to the mid-twentieth century, with researchers continuously investing in clinical decision support systems (Beam et al., 2018). Over the years, machine-learning algorithms have played a pivotal role in this area, categorized into supervised and unsupervised learning methods based on their task objectives (Beam et al., 2018).

The resurgence in AI's impact on medicine is notably attributed to the successful implementation of deep learning (Reparthi, M., et al. 2020). This approach involves training artificial neural networks with multiple layers, commonly referred to as 'deep' neural networks, using extensive datasets, particularly large sources of labeled data (Beam et al., 2018; Habehh, H., & Gohel, S. 2021 Alanazi, A. 2022)

In the context of supervised machine learning, the methodology entails accumulating a substantial volume of 'training' cases, including inputs such as fundus photographs, along with corresponding desired output labels (Castiglioni et al, 2021). On the other hand, unsupervised learning involves extracting inherent patterns within unlabeled data to uncover sub-clusters, identify outliers, or generate low-dimensional representations of the data (Beam et al., 2018; Habehh, H., & Gohel, S. 2021; Alanazi, A. 2022).

The impact of these algorithms is particularly noteworthy in the field of Diagnostic and Imaging. By increasing overall accuracy, AI algorithms contribute significantly to improving processes and results in medical diagnostics - They increase the precision of diagnostic tools, assisting healthcare professionals in making more informed decisions based on accurate and timely information (Feng, 2023; Açpwais, S. A., et al. 2023)

The evolving landscape of AI in medicine, especially in diagnostic and imaging applications, demonstrates the ongoing commitment of researchers to harness the potential of machine learning for improved patient outcomes and healthcare practices. The continuous innovation in this field promotes an improvement to the accuracy and efficiency of medical diagnostics, offering a positive outlook for the future of healthcare. (see annex 2.1.)

2.4.1. Diagnostic and Imaging

A Mayo Clinic's findings highlight a critical aspect of the potential benefits of AI in medical diagnostics. Diagnosis errors, which account for a significant portion of medical errors, have serious consequences, leading to an estimated 40,000 to 80,000 deaths annually in U.S. hospitals (Arsene, 2020, as cited in Lee & Yoon, 2020). Notably, machine learning algorithms exhibit a much higher accuracy rate (91%) compared to a trained human expert (69%) in diagnostic tasks (Lee & Yoon, 2020). This significant disparity emphasizes the potential of AI to significantly reduce diagnostic errors and improve patient outcomes.

The utilization of AI algorithms in medical diagnostics becomes even more promising when considering the vast amount of data available in hospital settings. Hospitals serve as rich repositories of diverse patient data, offering an excellent opportunity to train and optimize machine learning algorithms. The integration of AI into diagnostic processes can provide a significant use of this data, which in return would provide an enhancement in terms of precision and personalized medical diagnoses (Beam et al., 2018; Panayides et al., 2020)

The transformative potential of AI, particularly machine learning algorithms, in medical diagnostics is evident in the substantial improvements in accuracy and efficiency. As research and development in this field progresses, the integration of AI into diagnostic processes holds promise for reducing errors, enhancing patient outcomes, and employing the vast data resources available in hospital settings. This evolution underscores the ongoing commitment to harnessing the power of AI for the betterment of healthcare practices.

2.5. Integration of Blockchain and AI in healthcare

In this section, the analysis and development of the theoretical framework that this dissertation is based on will be verified. The provided tables will then be extended in the discussion.

2.5.1. Secure Health Data Sharing

The synergistic integration of blockchain and artificial intelligence technologies holds tremendous promise in reshaping healthcare by ensuring secure and interoperable health data

sharing and management. This transformative combination offers a multifaceted approach, decentralizing ledger systems for secure storage of patient records on blockchain, while AI applications leverage this data to enhance diagnostic accuracy and treatment planning (Alabdulatif et al., 2022).

Collaborative use of blockchain and AI introduces automation, intelligence, security, and cost-effectiveness, thereby constituting a cornerstone for the evolution of healthcare systems (Alabdulatif et al., 2022).

Several key areas have been identified, where the integration of these technologies showcases notable improvements, such as:

1. Blockchain Applications (see annex 2.2):

a. Human Organ Supply Chain Management: Blockchain provides transparency and traceability in the organ supply chain, reducing the risk of errors and ensuring the authenticity of organ transplants (Alabdulatif et al., 2022; Hawashin et al., 2022)

b. Privacy in Bioinformatics: The decentralized nature of blockchain enhances the security and privacy of bioinformatics data, addressing concerns related to the sensitive nature of genetic information (Alabdulatif et al., 2022; Balakrishnan et al., 2023)

c. Streamlining Care and Preventing Costly Mistakes: Blockchain streamlines care processes by providing a secure and accessible record of patient history, reducing the likelihood of errors and improving overall care coordination (Alabdulatif et al., 2022; Yaqoob et al., 2022)

d. Drug Traceability and Safety: Blockchain ensures transparent drug traceability, reducing the risk of counterfeit medications and enhancing overall drug safety (Alabdulatif et al., 2022; Musamih et al., 2021)

e. Secure Electronic Health Records (EHR): Blockchain enhances the security and privacy of EHRs, safeguarding patient information against unauthorized access or tampering (Alabdulatif et al., 2022; Oladele et al., 2024).

2. AI Applications (see annex 2.3):

a. Clinical Decision Support: AI applications assist healthcare professionals in making informed decisions by analyzing vast datasets and providing relevant insights (Alabdulatif et al., 2022; Wang et al, 2023)

b. Patient Lifestyle Advice: AI-driven systems offer personalized lifestyle advice based on patient data, promoting preventive healthcare practices (Alabdulatif et al., 2022).

c. Patient Stratification: AI aids in patient stratification, categorizing individuals based on risk factors, enabling targeted interventions and personalized care plans (Alabdulatif et al., 2022; Giordano et al, 2021)

d. Predictive Analysis: AI's predictive analytics capabilities enhance the early detection of potential health issues, allowing for proactive intervention and prevention (Alabdulatif et al., 2022; Alowais et al, 2023)

e. Improving Diagnosis: AI algorithms contribute to improved diagnostic accuracy, ensuring timely and precise identification of medical conditions (Alabdulatif et al., 2022; Feng et al., 2023)

These annexes demonstrate the processes, tasks and applications related to AI and Blockchain that the healthcare sector presents. These come with challenges, which will need the alignment of the various participants of these processes to attempt their nullification and optimize their strengths.

The collaborative integration of blockchain and AI technologies serves as a catalyst for a comprehensive transformation in healthcare, addressing key challenges and enhancing various facets of the traditional healthcare system. These advancements showcase the potential for a more efficient, secure, and patient-centric healthcare ecosystem.

2.6. Challenges associated with novel technologies

Blockchain and Artificial Intelligence are powerful technologies promoting innovation across industries, yet their integration brings a unique set of challenges. These challenges must be

carefully considered to ensure effective implementation and to harness their full potential. Addressing these issues is essential for a successful fusion of Blockchain and AI in diverse applications, securing a more transparent, and efficient digital future.

2.6.1. Challenges associated with Blockchain

Blockchain can present certain challenges in terms of their applicability and scalability (Yaqoob, et al., 2022; Mylavarapu et al., 2023) The scalability of the use of these technologies is not a certain, as there has been cases of different blockchains having wide ranges of simultaneous use, this can be verified with the examples of or example Visa being process more than 1700–2000 transactions per second, while Ethereum blockchains are far behind in terms of transaction speeds as they can only process approximately 20 transactions per second (Yaqoob et al., 2022; Mazlan, et al., 2020)– This would present an issue, as there would be a large of number of healthcare workers that would need to have access to this information simultaneously.

To fully harness blockchain technology's potential in healthcare, it is crucial to tackle interoperability challenges. Interoperability is essential for enabling effective interaction between different blockchain networks. While the lack of standardization provides flexibility for developers, it also creates significant communication challenges due to limited interoperability (Yaqoob et al., 2022; Househ et al., 2020) - This could present an issue with the verification of different blockchain technologies across different sectors. Tokenizing healthcare data has the potential to revolutionize the industry and address this issue, by creating digital representations of healthcare information with specific usage rights for certain services - This approach enables users to securely access and retrieve their healthcare data without the need for decryption or re-encryption, enhancing both accessibility and privacy (Yaqoob et al., 2022).

Most of the existing healthcare data registries contain inaccuracies due to various reasons (e.g., price discrimination, insurance market competition, human and administrative errors, avoiding for tax purposes, among others) - The need for a cleaning and verification of their information would be needed, which is quite an extensive task, due to the irregularities in their information. (Yaqoob et al., 2022).

Adopting blockchain technology in the healthcare sector requires a cultural shift. Most current healthcare systems rely on manual, centralized structures, making them vulnerable to data breaches and single points of failure. Furthermore, there is a shortage of skilled professionals capable of managing the complexities of decentralized, peer-to-peer blockchain networks. (Yaqoob et al., 2022; Aljaloud & Razzaq, 2023).

2.6.2. Challenges associated with AI

Implementing information technology in healthcare comes with a variety of challenges, and AI is no exception. These obstacles emerge across all stages of AI adoption: from data acquisition and technology development to clinical integration, as well as ethical and social considerations. (Ting et al., 2021; Khayru, 2022).

The first barrier is data availability. Machine learning and deep learning models require large datasets to accurately classify or predict various tasks. Industries with substantial datasets have seen significant advancements in ML due to the ability to develop more complex, precise algorithms. In healthcare, however, data availability presents a unique challenge. Health data is costly, and there is often reluctance among hospitals to share data, as it is typically viewed as proprietary, with each institution managing its own patients' information independently. (Ting et al., 2021; Khayru, 2022)

AI-based interventions are still limited in prospective clinical trials. Empirical research is sparse and mostly focuses on AI's impact on the general workforce rather than on patient outcomes. Most research on AI in healthcare remains at a preclinical stage, often conducted in controlled or simulated environments, making it challenging to generalize the findings to real-world settings. (Ting et al., 2021; Khayru, 2022)

AI has faced ethical concerns and protests since its inception. Beyond issues of data privacy and safety, the primary concern is accountability. In healthcare especially, poor decisions can have serious consequences, and there is an expectation that a specific person be held responsible. However, AI is often seen as a "black box," making it difficult to understand how the algorithm arrived at a specific prediction or recommendation. (Ting et al., 2021: Khayru, 2022)

A longstanding concern about AI in healthcare is the fear that it will replace jobs, making healthcare workers obsolete. This threat often leads to distrust and resistance toward AI-based

interventions. However, this belief largely surges from a misunderstanding of AI's role and capabilities. Even setting aside the many years it would likely take for AI to advance enough to fully replace healthcare workers, the introduction of AI is not about job elimination but rather about job transformation and re-engineering. (Ting et al., 2021; Khayru, 2022)

Chapter iii: Methodology

One of the main goals for this dissertation is to identify processes that take place in the healthcare system of Portuguese hospitals, which these novel technologies could improve. To achieve this, qualitative research, through semi-structured interviews was used as the chosen method collection process (DeJonckheere & Vaughn, 2019). In contrast to large-scale epidemiological studies, or even surveys, a family medicine researcher can conduct a highly meaningful project with interviews with as few as 8–12 participants (Kotera, Y., et al. 2022)

For this dissertation, interviews were conducted with healthcare professionals across different hospitals and different locations to understand their experiences, understanding in relation to the current services and these novel technologies. To respect the participants' privacy and anonymity, some interviews were not recorded. The information presented is based on notes and the responses provided by the participants in a separate document.

The implementation of these technologies seeks the improvement of healthcare services, especially for diagnosis and data management. Topics like the processes of gathering patient's information and medical history were discussed, considering the challenges more frequent associated with these, with the specification of the type of data that the participants believe to be the crucial, especially the ones needed the instance the doctors start their processes.

These interviews allowed for an understanding and perspective that were vital for the elaboration of the implementation plan, in terms of processes and information.

The selection criteria for the interviews were:

1) Specialization of the doctors, with a wide variety being the goal, in order to obtain a broader understanding of the different processes and stages that the healthcare field presents, thus, to analyze the different advantages that these technologies could provide;
2) Different age groups, to provide a wider range of years of experience and insights, these doctors could present not only in the field, but also literacy in the novel technology subject.

The participants from Hospital Santarém were obtained with the approach in their workplace, with the help of an acquaintance in common, while the remaining ones were obtained through volunteering when the interview was proposed through an acquaintance in

common.

The interviews themselves had a mix of participants who asked to stay anonymous and participants who accepted their information being shared for this analysis. The interviews were split between online and presential, with a direct link between non-anonymous participants having them being conducted online and the anonymous participants having them in-person. The average duration of the interviews was 20 minutes, with key information (all with the original words from the participants) being taken from them. The language in the interviews was in Portuguese and later translated verbatim directly to English by a native speaker.

The interviews were successful in terms of achieving data saturation and obtaining the answers for the pre-established general topics, with the total number of interviews collected being 12. The data analysis method chosen was content analysis (Zhang and Wildermuth, 2009).

Participants	Hospital	Area of expertise	Years of Experience
1	District Hospital of Santarém	General Medicine	>15
2	District Hospital of Santarém	General Medicine	>15
3	District Hospital of Santarém	General Medicine	>10
4	District Hospital of Santarém	Pediatrics	>15
5	District Hospital of Santarém	General Medicine	>10
6	District Hospital of Santarém	Orthopedics	>10
7	Hospital CUF Tejo	Nutrition	<5
8	Hospital CUF Tejo	Nutrition	>5
9	USF Alma Mater, na ULS Amadora Sintra	Emergencies	<5
10	Unidade Local de Saúde (ULS) - Nordeste	Family Medicine	<5
11	Braga Public Hospital	Family Medicine	<5
12	Unidade Local de Saúde de Matosinhos	Family Medicine	<5

Table 1: Information about the participants involved in the methodology

Source: Created by the author

The goal of centers on expanding the theoretical framework. This can achieved while showcasing the literacy level of the participants about these novel technologies, and simultaneously obtaining the correlation between the advantages, information and steps vital for their processes. Then, demonstrating how technologies could provide an improvement, while also verifying if these are already present in their processes. This is vital for the research, as the

conditions that the participants have for the adoption of these technologies, while being informed on how these operate, on a basic understanding. As presented above in the literature review, there are substantial concerns about the implementation of these technologies from the healthcare force, with considerable distrust about them and their use. This research aims to provide the steps recommended to tackle such concerns, in order to have the trust of the future users of these technologies, in order to ensure a smooth transition and use of them.

To build trust among future users of these technologies, it is vital to establish transparent communication channels and provide robust training programs tailored to the specific needs of healthcare workers. Engaging them early in the implementation process and seeking their feedback can also promote a sense of ownership and confidence in these technologies. Ultimately, this research strives to create a framework that not only facilitates the integration of innovative technologies but also ensure that they are met with acceptance and enthusiasm from the healthcare workforce, paving the way for a smoother transition and more effective utilization in the long term.

Chapter iv: Findings

Based on the interviews conducted, the following insights and observations were obtained.

4.1. Expertise and Adoption of Emerging Technologies

As was found, the expertise of the participants in relation to these emerging technologies is low, as these are quite recent—this was verified across specialties and years of professional expertise. Despite this, there is a clear intent and understanding of their potential and multiple advantages, if there is an ethical approach to their implementation and use. Blockchain and AI would not only provide an advantage in terms of better results for their processes but also improve the different stages of the diagnostic process, from the information gathering to the diagnostic associated of this sector. Currently, participant feedback indicates that the systems and processes for information storage and sharing are quite outdated and slow, as indicated by Participant 5: *"Still very delayed to what it should be"* and Participant 8: *"Very slow and sometimes lacking information"* when addressing the current level of presence and quality of the technological development in their processes. Participants believe that these novel technologies can help address such issues and are open to their implementation. Furthermore, their limited expertise spans not only these emerging technologies but also general technological competencies across various levels of healthcare professionals. Nonetheless, they have shown a strong commitment to learning, adopting, and adapting to these technologies.

This could be seen as a barrier to the use of blockchain and AI. However, participants expressed interest in using and learning about these technologies, considering that they receive proper training, and the focus is on making their use as dynamic as possible. This interest was reflected in the comments of Participant 3: "*Real practice and intuitive medical IT advancements, where the use of these technologies would not be complicated and would improve with experience, especially for professionals who are not as comfortable with technology. This has been observed for both experienced and novice healthcare professionals."* Similarly, Participant 7 remarked: *"Having a common system across hospitals with all patient information that is fast and easy to use, featuring more symbols and less text."*

4.2. Diagnostic Process Needs and Technological Potential

The gathering and access of information are vital to the diagnostic process. Blockchain represents a significant advancement in obtaining, storing, and securing information, while also contributing to the development of AI by providing a rich and secure data source for its development. The current technological landscape in healthcare is underwhelming, as indicated by feedback from participants, highlighting the need for a detailed and timely implementation plan. Despite this, the adoption of these technologies is increasingly seen as a question of "when" rather than "if," as they have the potential to address and optimize common challenges in the healthcare sector.

This becomes more evident when analyzing the methods and sources used by participants to obtain information. When discussing their approaches to information gathering, it was noted that some participants need to obtain information directly from patients, as was mentioned by Participants 1: “Patient interview and medical history” and, occasionally, from their families, as noted by Participant 6, “By the patient and family; information from attending doctors and emergency and consultation records.”. It is inevitable for healthcare professionals to establish contact with patients and conduct interviews. However, the information-gathering process could be improved to be more efficient and reliable, a topic that will be further explored in the discussion.

4.3. Dissatisfaction and Entrepreneurial Spirit Among Healthcare Professionals

A key point raised during the interviews was the dissatisfaction and entrepreneurial spirit within the healthcare workforce concerning the current level of technology. For instance, Participant 11 remarked, *“The tech systems are very slow, and the equipment is also cumbersome to use”* while Participant 6 observed, *“The technological state of healthcare is still far behind where it should be.”* This discontent has prompted some healthcare professionals to develop independent solutions to compensate for the lack of technological progress, such as systems for recording and transcribing conversations between doctors and patients or tools for managing patient information. As Participant 10 noted, *“There were colleagues who, in collaboration with other professionals in fields like medical engineering, began developing technologies for use in their processes, although these have not been approved yet.”* Similarly, Participant 11 mentioned, *“I had a colleague who started working on a "Patient Passport" aimed at storing as much information as possible about the patient.”* These initiatives, while not yet officially approved, reflect significant frustration with the slow pace of innovation and development in healthcare processes.

This discontent showcases a need for state and hospital support to improve the doctor's experience when using these systems.

4.4. Challenges in Patient Information Accuracy

A challenge identified during the interviews was the occasional lack of ethics displayed by patients when describing their symptoms and their severity. Participant 10 noted, *"Patients often exaggerate their symptoms to receive priority treatment, especially in emergencies"* while Participant 5 added, *"Patients sometimes provide inconsistent and confusing information due to medical illiteracy or a desire for priority treatment."* Participant 2 further emphasized this issue, stating, *"Incomplete or inaccurate information from patients is a major challenge in diagnostic processes."* This behavior, often driven by long waiting times in emergency rooms or for urgent consultations, presents a significant challenge not only for doctors but also for AI systems, which may struggle to detect exaggeration and adjust diagnostic conclusions accordingly.

Current waiting times in emergency rooms, especially in metropolitan cities, often extend to around 8 hours. This leads some patients to exaggerate their symptoms in an attempt to receive higher priority. However, another factor contributing to the apparent long waiting lists is the inaccurate information about patients waiting to be attended. Participant 9 highlighted this issue, stating, *"We have cases where a patient enters the emergency room but ends up leaving due to the long wait times. Despite their departure, our system still shows them as waiting to be attended. We sometimes have to inform incoming patients about this to provide context for the long waiting lists and to prevent discouraging them, which could cause them to leave as well."*

This lack of real-time information reflects a significant area where blockchain technology could provide improvement, by ensuring more accurate and up-to-date patient data.

4.5. Patient Independence Through Technology

Regarding the potential changes Blockchain and AI could introduce, a key discussion point was the increased independence patients could achieve through their use, when discussing the evolution of the healthcare professional and patient dynamic. Participant 10 suggested, "*We could give patients more responsibility and independence. For example, they could use a smartphone app, or platform, to input requested data, which would be particularly useful for those requiring regular supervision and regulation."* Participant 5 noted, *"The relationship between patients and doctors*

is becoming more IT-based, which could offer several benefits." Participants pointed out that certain processes, such as monitoring for diabetic patients—especially those with serious conditions requiring frequent checks—could be streamlined. These patients could conduct their analyses at home, upload the results to an app connected to their doctor, and have the data monitored online. Consultations could also be conducted virtually when necessary. This approach would significantly reduce the time patients spend on these processes and offer them greater autonomy, as indicated by Participant 11: *"Telemedicine would improve significantly with the integration of these technologies, as it would enable more processes."* Participant 7 added, *"I believe teleconsultation could benefit from easier access and communication through these technologies."* This solution also addresses an important issue raised by Participant 6 regarding patient transfers between hospitals: "*More and more, the focus is on transferring patients and shifting responsibilities, often without prior notice, which creates a bad experience,"* in which it would mitigate a negative aspect as well from the transferring of patients between the public and private sector that the doctors are responsible for.

4.6. Reducing Bureaucratic Burdens

One of the main complaints from participants was the burden of bureaucratic tasks. When discussing the goals associated with the implementation of these technologies, Participant 11 stated: *"The development of tools that assist with bureaucratic processes, which take time away from patient care."* Participant 12 echoed this sentiment: *"There is a need to facilitate bureaucratic tasks, which these technologies could address, giving doctors more time to attend to patients and providing better overall care."* Participant 8 also called for a *"faster and more intuitive system to help with our tasks."* The considerable time spent daily on activities such as code registration, diagnostic documentation, and note-taking reduces the time available for patient care. Currently, no tools facilitate these processes, especially code registration, which often requires detailed research due to the specificity involved. The introduction of a tool or program to assist with these tasks could significantly reduce the workload for healthcare professionals, allowing them more time for patient care or personal use, as some doctors are currently forced to complete these tasks during their free time due to heavy workloads.

4.7. Blockchain for Secure Information Storage

In terms of information storage and access, blockchain offers a secure format for storing sensitive data, with real-time access available to both patients and the healthcare workforce. The security and ethical implications of these processes were highlighted in the interviews, where participants expressed concerns about how these technologies would address such issues, when discussing these technologies and their impac, such as Participant 4: *"Currently we do not have these technologies in my processes, but I believe the possible ethical side would need a deep investigation and analysis before implementing"* and Participant 3: *"I have not formed an opinion yet. However, I think we should be cautious. AI can be a "double-edged sword", especially considering the ethical and human perspective that would need heavy consideration"*. As discussed in the literature review, blockchain could be an effective solution for managing the storage of information across systems. This would include data input by patients from analyses and procedures, whether in the public or private sector, as well as information recorded by doctors, such as notes, recordings, and codes. With the support of AI, doctors could shift to a role more focused on reviewing this information.

4.8. Ethical Considerations in Information Sharing

The aspect of information sharing discussed with the participants emerged as another important topic, especially regarding the ethical considerations they raised. Certain types of information would require specific requirements and hospital approval before being shared, as referenced in the findings, as highlighted by participant 4: *"For certain medical exams, the hospital board would need to approve a requirement made before making certain medical exams and information available to the patient"* . Smart contracts could facilitate these processes by enabling patients, doctors, and hospitals to establish agreements that are pre-approved for scenarios and conditions, thereby streamlining the process and reducing associated bureaucratic tasks. This approach would also minimize the time needed to review each patient request, allowing for faster access to information. However, participants expressed concerns about ensuring that the healthcare workforce reviews the information first to determine the most appropriate method for sharing it with the patient, such as Participant 12: *"Obtaining easier patient consent would be a benefit, as long as the doctor has access to the information prior to sharing with the patient, in order to analyze and verify which would be the ideal way to reveal the news and/or results first. Certain*

information needs a delicate delivery from the doctor, due to the nature or gravity of the results and this is something that I believe our training and input is very important." – This further emphasizes the need of establishing the relationship between doctor and AI as one that sees AI playing an auxiliary role to the healthcare worker.

4.9. Collaboration and Training for Technology Implementation

A key topic that emerged from the interviews was the importance of collaborating with the healthcare workforce to determine the best approach for implementing Blockchain and AI. When discussing these technologies and their impacts, significant points about their concerns in relation to these technologies, and their implementation, were raised by participants. Like this, Participant 6 stated, *"It will have a positive impact, but only if accompanied by human clinical judgment,"* and Participant 3, who remarked, *"I have not formed an opinion yet. However, I think we should be cautious. AI can be a double-edged sword."* In response to these concerns, the suggestion to involve healthcare professionals in the planning and implementation of these technologies was seen as a way to address safety and acceptance issues. This collaboration would include providing educational training to help healthcare staff understand how the technologies work and how they can be optimized, especially given the current low level of literacy in this area. By equipping the workforce with foundational knowledge, they would be better prepared to contribute to the integration of these technologies, with their skills and understanding continuing to improve over time. This approach would ultimately enhance the effective and safe use of the technologies in clinical practice.

4.10. Cross-sector Information Sharing Challenges

In terms of information management and sensitivity, the conditions for time management in the healthcare workforce are not ideal when assessing the status of information sharing between the public and private sectors. Currently, there is no platform that allows healthcare workers to access information from both sectors, resulting in a time-consuming task for doctors, who must contact colleagues in the other sector to explain or provide details about a patient's case.

Participants highlighted several areas where they would like to see changes driven by AI. A common theme was the need for more reliable and easier access to information, as illustrated by their goals for technological improvements:

- Participant 2**:** *"Speed in equipment; a more comprehensive data platform; and the ability to view patient history from both hospitals and professional clinics."*
- Participant 6*: "AI in consultation records, hospitalization, and discharge notes."*
- Participant 7: *"A common system among all hospitals that allows fast and easy access to all patient information, using more symbols and less text."*
- Participant 10: *"Patient passport, …"*

The current state of information sharing between public and private healthcare sectors creates significant inefficiencies in time management for healthcare professionals, especially when patient information is not accessible across systems. Participants expressed a strong desire for AI-driven solutions that would improve access to comprehensive patient data, reduce redundant communication, and ultimately improve the speed and quality of patient care. Their suggestions—including faster equipment, integrated data platforms, and a unified system that simplifies patient history access—highlight a clear need for AI to bridge the gap in information management across healthcare sectors. Addressing these gaps with AI could lead to more efficient workflows, enhanced collaboration, and ultimately, better patient outcomes.

4.11. Comparison with other areas of healthcare

Despite a low overall literacy rate among healthcare workers regarding Blockchain and AI, there is a recognition of their basic aspects and the areas where their presence is being more heavily explored, particularly in comparison to diagnostics. When discussing the influence of these technologies on the diagnostic process in recent years, some participants acknowledged their awareness that these technologies have been implemented in other areas, even though their actual use in diagnostics remains limited. For example, Participant 10 stated, "*I had already observed in lectures that there are aspects of these technologies that could enable doctors to carry out processes completely. Blood coagulation tests are a good example of this. I was fascinated when I saw this, particularly regarding robotics. I recognize that there are various purposes and objectives that AI can serve in this sector."* Similarly, Participant 1 noted, "*We've seen the development of better tools for complementary means, especially for test elaboration and patient care for more complex procedures."*

This understanding highlights a recognition of the advantages of these technologies, despite participants' low literacy about them and their current lack of use in existing processes.

This recognition can facilitate a smoother promotion of the implementation of these technologies in their areas, as participants can see that these technologies have already provided advantages to others in the industry.

4.12. Key Findings

By reviewing the interviews, an analysis of the questions separately and then the overall process was the preferred method. The key conclusions of these interviews were the following:

1. The typical steps involved in the interview processes revolve around gathering the most reliable information possible to access the case and proceed with the correct steps. Medical history, clinical and complementary exams, and the information provided by the patient (such as precedents, family history and symptoms, for example) are key information for the process, independently of the patient and area.
2. Hospital's public systems and the records provided by the patient are the general sources of information. There is not currently a platform that stores both the information of the private and public sector from a patient.
3. As the dependency in information is very high for the diagnostic process, the unreliable and/or outdated information can harm it. Also, it's important to highlight that the symptoms that patients have can be verified across different diagnoses, showcasing the possibility of multiple differential diagnoses and the need of the authentication of the accuracy of the patient's symptoms and their levels.
4. Every participant informed that these emerging technologies have not been implemented in their processes.
5. The participants recognized the value of these technologies and their potential for their fields of expertise processes. Despite this, it was highlighted in a significant amount the need of follow-up by the human eye and their verification, especially for ethical purposes. The complementary exams were the common reference of the process that would highly benefit from these emerging technologies. In order to address this issue, the common practice suggested by the participants was the agreement between the healthcare workers and the patients in terms of how and when these technologies would be used – An example of this would be the approval of the healthcare worker in terms of when and how certain exam results would be shared with the patient

6. From the perspective provided in relation to the information relative to the diagnostic process, there is information that will be needed independently of the area of expertise, but every piece of information is key for this process. Due to the similarities between symptoms across different diagnosis, small pieces of information can be the main differentiator diagnoses.
7. The feedback in terms of their experience in relation to the doctor-patient relationship is being heavily influenced by technological innovation. This influence can be classed as positive or negative, depending on how the patients use these technologies, with examples such as use of misinformation or lack of reliable sources in the choice process. As these technologies provide an evolution of the relationship, more possibilities of patient's information gathering process and care are verified, which could provide a more personalized service by the healthcare workers.
8. The feedback in terms of transitions between hospitals was negative. Although there has been a considerable evolution over the years, there's still a good amount of dependency in certain outdated processes, like the sharing of information, for example, which is centered in direct communication between the healthcare providers from the public and private sectors and information shared by the patient, which is prone to be incomplete. These outdated processes also influence in a negative aspect the amount workload and attention time related to patient.
9. Despite the verification of the lack of knowledge and proficiency by some participants, which was expected, the suggestions in relation to these emerging technologies are related to improving the complementary tests process, in which the assistance of AI could provide an easier and more accurate process, and patient history and information, for the information gathering and storing of critical information, which is quite extensive according to feedback from the participants, needed for the diagnosis, and overall care, process of the patient.

Chapter v: Discussion

This research takes into consideration multiple areas of concern from healthcare workers regarding Blockchain and AI. As previously discussed, there are concerns about ethics, job replacement due to AI and process optimization. The articles analyzed for the elaboration of this dissertation focus on the advantages and implementation of these technologies but fail to address the concerns and suggestions from healthcare workers regarding AI implementation and success have been documented (Jennath et al., 2020; Jabarulla & Lee, 2021).

Current literature often lacks a comprehensive examination of the managerial perspectives necessary for the optimal implementation and success of technologies like blockchain and artificial intelligence in healthcare. While much focus has been placed on the technical capabilities and potential benefits of these innovations, there is a significant gap in understanding how effective management strategies can improve their integration into existing healthcare systems. Successful implementation requires not only a clear vision of technological capabilities, but also a deep understanding of the organizational culture, stakeholder engagement, and resource allocation necessary to support these changes.

It is vital to recognize that there is no singular approach to implementing blockchain and AI technologies (Khan et al., 2023). The diverse nature of healthcare environments means that implementations must be tailored to fit specific organizational needs, patient populations, and regulatory frameworks. Factors such as available resources and the existing technological infrastructure all play critical roles in determining the most effective strategies for deployment. However, despite the variability in potential implementations, there are general steps and best practices that can guide healthcare administrators in this complex process.

The recommendations for these steps are drawn from the literature review and insights gathered from interviews with healthcare professionals from multiple areas and their knowledge provided about their different processes. These discussions highlighted the importance of aligning technological advancements with the broader goals of the organization, ensuring that the implementations serve to improve patient care and operational efficiency. Additionally, the need for ongoing training and support for staff was emphasized, as well as the importance of fostering a culture of innovation that embraces change.

By synthesizing insights from both academic literature and practical experiences, the following sections will outline key steps that healthcare administrators should follow to navigate

the complexities of implementing blockchain and AI. These recommendations aim to bridge the gap between technology and management, ensuring that healthcare organizations can leverage these powerful tools effectively while adapting to their unique circumstances.

5.1. Role of Technology

Despite being very effective and accurate, AI and blockchain will play an auxiliary role for healthcare workers, and their input is crucial to achieving optimal results. Additionally, the AI discussed in articles like Alabdulatif's does not expand on how it would assist in collaboration with healthcare workers. These technologies cannot, at the time of writing, function independently in the healthcare sector, especially when used together, as there are still significant gaps, particularly in diagnosis, patient treatment, data management, and storage, as outlined by Ameen et al. (2023). These gaps can be filled by healthcare workers. This perspective emphasizes the need for collaboration between healthcare workers and technology developers to ensure optimal development and implementation (Xie et al., 2021).

Current literature emphasizes the capabilities of blockchain in storing and securing patient information but often falls short in detailing which specific pieces of information should be stored and the methodologies for efficient retrieval. Moreover, while the AI technologies referenced in these articles suggest potential applications, they do not adequately address how these systems would facilitate collaboration with healthcare professionals, which would be vital to promote the implementation of these technologies to the healthcare professionals

Additionally, managers should create wide-ranging teams that include IT specialists, healthcare professionals, and administrators. These teams can work together to identify best practices for integrating AI and blockchain into existing workflows, ensuring that the technologies are used in ways that enhance rather than disrupt patient care (Shiden et al., 2024). By facilitating cross-functional collaboration, managers can promote a deeper understanding of how these technologies can support various aspects of healthcare delivery.

5.2. Process Optimization

Process optimization is a key focus for these technologies, and a significant insight from the interviews was the prevalence of outdated practices still used in the sector. One example cited by participants was the labeling of diagnostics in internal reporting tools. The process of assigning codes, which requires specifying symptoms and their severity, is time-consuming. Participants expressed interest in finding solutions to streamline this task. In this case, these technologies could automate data sorting and generate a final code for the healthcare worker to review and verify against their notes. This would reduce the time spent on administrative tasks, allowing healthcare professionals to allocate more time to patient care. This aligns with what Božić (2022) stated regarding AI-powered tools being able to assist healthcare workers in overcoming barriers to digital literacy, including limited time, resources, and training. For instance, AI-driven chatbots can deliver on-demand support for queries related to electronic health records (EHRs), while AI-enabled virtual assistants can automate administrative duties. This allows healthcare professionals to allocate more attention to patient care.

To effectively integrate blockchain and AI technologies in healthcare, it is crucial to develop tiered training programs that accommodate the varying levels of technological expertise among staff. This involves designing a structured curriculum with multiple tiers: a basic level for those with minimal tech experience, covering foundational concepts in blockchain and AI; an intermediate level focusing on practical applications in daily workflows; and an advanced level for experienced users that delves into troubleshooting and ethical considerations. Including interactive components such as hands-on practice sessions and scenario-based learning will help engage staff, and assessments can reinforce knowledge and encourage progression through the tiers.

In addition to tiered training, establishing a culture of continuous learning and updates is essential. Regularly scheduled learning sessions with industry experts can keep healthcare teams informed about the latest advancements in AI and blockchain. Providing access to an online portal or library with resources, tutorials, and case studies allows staff to explore topics at their own pace. Promoting peer learning opportunities encourages experienced professionals to share insights and best practices, further enhancing the knowledge base. It is also important to include updates on compliance and regulatory changes, ensuring that staff remain informed about ethical practices in technology use.

To foster an environment of innovation, implementing iterative feedback loops is vital. This involves creating real-time feedback channels where staff can share their experiences and report issues with the new systems. Regular check-in meetings can facilitate open discussions about what's working and what needs improvement. By utilizing this feedback, managers can make necessary adjustments to technology features and workflows, ensuring that solutions are aligned with user needs. Transparency is key, so sharing summaries of feedback and subsequent improvements with the team reinforces that their input is valued.

Running controlled pilot programs is another effective strategy. By selecting specific departments where the technology will have the most impact, managers can test AI and blockchain solutions in a small, controlled environment. Clearly defining measurable goals for the pilot—such as data retrieval time and user satisfaction—provides a solid basis for evaluation. Monitoring usage metrics and collecting feedback during the pilot phase allows for documentation of both successes and challenges. This data can then be used to refine technology features and training materials before implementing the system across the organization.

Establishing collaborative standards is essential for creating consistency in data storage and sharing across healthcare institutions. Collaboration with representatives from various departments and other healthcare organizations can lead to the development of standardized data formats and protocols, ensuring compatibility and ease of data exchange. High standards for data security and compliance with regulations must also be established to protect patient information and foster trust among stakeholders. Documentation of these standards, along with training for staff, will ensure optimal compliance and better interoperability in patient care.

Lastly, encouraging early adopters and showcasing the benefits of these technologies to patients can significantly enhance buy-in across the organizations. Identifying staff members who are enthusiastic about adopting new technologies and providing them with additional resources or mentoring can empower them to master these technologies. Creating ambassador roles for these early adopters will help them facilitate training and encourage their peers. Highlighting tangible improvements in patient care, such as reduced diagnostic wait times and streamlined care coordination, will further motivate staff to embrace the changes. Visualizing positive outcomes through data, testimonials, or real-world examples from early adopters can illustrate the impact of the technologies, reinforcing commitment to their implementation.

5.3. Perspectives of Job Replacement

The interview participants did not express a significant fear of being replaced by technology. Instead, they recognized the potential benefits of implementing AI, believing that it could address a major issue related to the current level of technology in their systems. Despite a general lack of familiarity with AI, they highlighted concerns about the technological shortcomings in existing processes, feeling that an issue is being overlooked in terms of technology development in their already existing processes. The current state of certain hospitals and health centers, in terms of technological development, raises concerns about the possible implementation of these technologies. When discussing this concern, Islam (2021), cited by Ekwueme et al. (2023), provides excellent context, noting that intelligence is being used more extensively in hospitals worldwide as it aids in addressing medical challenges such as monitoring patients' health conditions and assisting doctors in diagnosing illnesses and developing effective treatment plans.

In light of these developments, the integration of AI in healthcare is likely to redefine traditional roles rather than replace them. While some may fear that technology could displace jobs, the reality is more nuanced. The relationship between AI and traditional healthcare workers can be viewed as collaborative rather than competitive.

AI can improve the capabilities of healthcare professionals by automating routine tasks, allowing them to focus on more complex aspects of patient care. For instance, nurses may spend less time on administrative duties and more time interacting with patients, leading to improved care and patient satisfaction. Similarly, physicians can leverage AI to analyze large datasets and receive decision support, ultimately improving diagnostic accuracy and treatment plans.

Furthermore, as healthcare systems become more data-driven, traditional roles will likely evolve to include a greater emphasis on data interpretation and application. Healthcare workers will need to develop skills that complement AI technologies, such as understanding algorithmic outputs and integrating these insights into clinical decision-making. This shift can lead to a more informed and efficient healthcare workforce, where professionals act as interpreters of AI-generated data.

As new technologies emerge, opportunities for collaboration between AI systems and healthcare providers will expand. This collaboration could foster a team-based approach to care, where AI acts as a supportive tool, enhancing the expertise of traditional healthcare workers. For instance, radiologists could utilize AI algorithms to highlight anomalies in imaging, allowing them

to focus their expertise on interpreting findings rather than sifting through images alone.

5.4. Automation and Information Management

When considering these aspects, it becomes evident that these technologies could significantly enhance the healthcare workforce, patient care, and overall processes. As discussed in the literature review, these technologies offer a high degree of automation that could improve processes by enabling the healthcare workforce to review information derived from their own notes and recordings. This would save a substantial amount of time and optimize the quality of the processes as well.

AI has the potential to boost human intelligence in much the same way the internet transformed access to information and shared knowledge. As AI research moves from the lab into practical, everyday use, it's paving the way for tools that can better compile, process, and make sense of complex data. This means that insights and information will be available in real time, helping healthcare professionals make smarter, more informed decisions quickly and effectively (Chaudhary et al., 2021).

Much like the internet's role as an "information platform" AI offers an excellent source of insights that makes data-driven decisions easier and faster. By doing so, AI does not just optimize workflows; it becomes a powerful intellectual partner, helping healthcare providers navigate complex cases with confidence and precision. Paired with Blockchain, which could lower the costs of economic transactions and make data-sharing smoother, these technologies are set to reshape healthcare into a system where informed decisions and exceptional patient care are the norm, leading to significant improvements in health outcomes (Chaudhary et al., 2021).

5.5. Economic Considerations

Recent analyses highlight significant concerns regarding global health spending. "Global health spending per person is excessive, and it is evident that system flaws — such as incorrect disease diagnoses, insufficient care services, unnecessary procedures, and exorbitant treatment costs — are the primary contributors. However, by harnessing the power of data to enable faster diagnoses, appropriate treatments, and more informed decision-making, artificial intelligence technologies have the potential to create an ecosystem that can address these issues. Research on artificial intelligence in the medical field demonstrates its ability to facilitate early and accurate

diagnosis, appropriate treatment, and studies that guide clinicians in making optimal choices, thus helping to prevent the root causes of high medical expenses" (Mammadov et al., 2020, cited by Ekwueme et al., 2023). The same trend is being observed in other industries, such as security, particularly cybersecurity. As a result, it is impossible to detect, analyze, and protect against such threats without the use of threat intelligence, big data, and machine learning techniques (Ekwueme et al., 2023).

Moreover, the integration of these technologies leads to substantial resource management improvements and cost savings (Chaudhary et al., 2021; Toivonen et al., 2021). By employing AI-driven analytics, healthcare providers can optimize operations, reducing the burden of administrative tasks and minimizing the likelihood of errors. For example, predictive analytics can improve patient scheduling and resource allocation, ensuring that staff and equipment are utilized efficiently. This not only optimizes patient care but also significantly lowers operational costs.

In addition, AI's ability to analyze vast amounts of data allows for the identification of patterns that can inform preventive measures, by reducing the incidence of costly medical interventions. By investing in these technologies, healthcare systems can significantly reduce long-term expenses associated with chronic conditions and emergency care.

In cybersecurity, the proactive use of machine learning algorithms to analyze threat patterns can prevent costly breaches before they occur. The early detection capabilities can save organizations millions in recovery and compliance costs, showcasing that initial investments in advanced technologies are offset by significant savings in the long run.

Overall, while the initial investment in AI and related technologies may be substantial, the long-term financial benefits—through increased efficiency, reduced errors, and prevention of costly incidents—demonstrate a clear case for their adoption across various sectors.

5.6. Broader Applications of AI

Artificial intelligence is already being applied in various fields such as education, healthcare, sports, and law-making. While AI will not replace doctors in the near future, it will assist them in making more accurate diagnoses and treatment decisions. Some technologies will replace certain tasks performed by workers, while others will complement their roles (Atkinson, 2019). Regarding job loss in certain industries, it is also important to recognize that the implementation and advancement of these technologies have created new jobs and opportunities. AI is reshaping the

structure of skills and employment by replacing some previously valued roles and skills while simultaneously generating demand for new ones (Acemoglu et al., 2022), a trend that would be verified in this case discussed here.

The impact of AI extends beyond healthcare, with significant implications across multiple industries. In education, AI-powered platforms are revolutionizing personalized learning experiences, allowing educators to tailor their approaches to meet individual student needs - This shift is not about replacing teachers but rather empowering them to focus on mentorship and fostering critical thinking skills (Ghorashi et al., 2023; Ghamrawi et al., 2024)

In sports, AI is being used to analyze player performance and develop training programs that enhance athletic capabilities - Coaches and athletes are leveraging data-driven insights to refine strategies and improve outcomes, demonstrating how AI can augment human expertise rather than replace it (Rajšp & Fister Jr, 2020)

Moreover, the legal industry is experiencing transformation through AI-driven tools that streamline document review and case research, enabling lawyers to focus on complex legal reasoning and client interaction instead of routine tasks (Contini, 2020). These advancements demonstrate a broader trend where AI technologies improve productivity across various sectors.

While concerns about job loss in certain industries are valid, it is also vital to recognize that the implementation and advancement of these technologies have created new jobs and opportunities. For example, the rise of AI has led to increased demand for data scientists, AI ethicists, and machine learning engineers (Johnson et al., 2021). AI is reshaping the structure of skills and employment by replacing some previously valued roles and skills while simultaneously generating demand for new ones. This trend is evident in the discussed case, where technology not only alters the job landscape but also prompts a reevaluation of the skills that are becoming essential in the modern workforce.

In summary, the integration of AI across various industries serves as a powerful reminder of its potential to enhance human capabilities and create new opportunities. While it may disrupt certain roles, the broader picture shows a transformation that fosters innovation, efficiency, and skill development across the board.

5.7. Issues with information Sharing

The outdated process of sharing information presents significant issues in urgent cases, as patients often have to relay information to healthcare workers themselves. Although independence in this aspect is present, it is not advantageous here; there needs to be efficiency and transparency in communication between hospitals. This would ensure accurate information sharing, avoid the need for healthcare workers to double-check whether patients are providing all necessary information, and reduce the risk of incorrect diagnoses and prescriptions.

5.8. Comparison with other areas of the healthcare industry – Laboratory

The current level of innovation and technological development in healthcare diagnostics, particularly in laboratory settings, highlights a significant development compared to other processes within the healthcare sector. Laboratory diagnostics have embraced cutting-edge technologies such as automated analyzers and next-generation sequencing, which enable rapid and precise testing for a wide array of conditions, from infectious diseases to genetic disorders. This transformation has led to faster reduced times for results, allowing healthcare providers to make more informed decisions swiftly.

In addition to advanced technologies, the integration of artificial intelligence in laboratory diagnostics has further enhanced data analysis capabilities. AI algorithms assist in interpreting complex test results, increasing accuracy and minimizing human error. This is particularly vital in a field where precise diagnostics can directly impact treatment procedures, reflected by the different possible diagnostics can be verified from inaccurate test results. The rise of point-of-care testing has revolutionized how diagnostics are conducted, enabling immediate results at the site of patient care, which is critical in emergency scenarios.

When examining these advancements in terms of management, it becomes evident that the laboratory sector is often better equipped to leverage technology compared to other areas of healthcare. The implementation of these innovative tools requires efficient management strategies to ensure optimal use of resources, such as trained personnel and laboratory space. By embracing automation and AI, laboratory managers can have optimized workflows, reduced operational costs, and improved overall efficiency.

In contrast, other processes within healthcare, such as patient consultations and care coordination, may still rely heavily on traditional methods and human-driven workflows. This

disparity suggests that while laboratory diagnostics are at the forefront of innovation, there is significant room for improvement in how other healthcare processes are managed. By adopting similar technological advancements and management strategies, the healthcare sector could optimize patient care, reduce costs, and improve outcomes across all levels of service. Ultimately, the success seen in laboratory diagnostics serves as a model for how innovation and effective management can transform the entire healthcare landscape.

5.9. Implications and Proposals

Based on feedback from interviews and the analysis conducted, especially taking into consideration the vital access to the patient's information and data, the following two proposals were made for the implementation and use of these technologies:

1. **Universal Profile** – A universal profile, which would store and provide access via blockchain technology for both healthcare workers and patients' usage. This profile could also utilize smart contracts to provide authorizations for accessing information in specific scenarios, such as a patient's unconsciousness. The profile would store key information and categorize it for easy access and interpretation by both AI and doctors, improving the accuracy and effectiveness of the diagnosis process. It would also facilitate data transfer and access between different hospitals, particularly between the public and private sectors. Improved access for patients, with doctor approval, would also be highly beneficial, enabling family members to assist with simple procedures (e.g., collecting prescriptions for elderly patients). Ensuring transparency, with security as a key priority in managing this information, would improve overall healthcare outcomes.

The proposed universal profile stored on blockchain technology offers significant advantages from a managerial perspective, enhancing operational efficiency and improving patient care.

First, the use of a centralized, secure platform for health information fosters streamlined communication and collaboration among healthcare teams. Managers can facilitate better coordination of care across different departments and facilities, minimizing delays in accessing critical patient data. This interconnectedness not only improves response times in emergencies but also enhances the overall workflow, allowing healthcare workers to focus more on patient care rather than administrative tasks.

Additionally, the incorporation of smart contracts for access authorization aligns well with

compliance and regulatory requirements. Managers can ensure that data access protocols align with the legal standards, eliminating risks associated with unauthorized information sharing. This proactive approach to governance not only protects patient privacy but also increases the organization's reputation by demonstrating a commitment to ethical data management.

From a resource management standpoint, the universal profile could lead to cost efficiencies. By reducing unnecessary tests and procedures through improved data sharing, healthcare organizations can lower operational costs while providing higher-quality care. Moreover, the ability to harness AI for predictive analytics can optimize resource allocation, allowing managers to make informed decisions based on real-time data insights.

Empowering patients and their families to access certain aspects of their health information promotes a culture of patient engagement. Managers can leverage this increased involvement to improve adherence to treatment plans and foster better health outcomes. Family members and/or legal guardians, powered with up-to-date information of health conditions, can play a supportive role in managing care, which can lead to fewer hospital visits and lower overall healthcare costs.

Lastly, the transparency provided by blockchain technology supports accountability within the healthcare system. Managers can utilize immutable records to track data access and changes, ensuring that all stakeholders are held responsible for their interactions with patient information. This transparency not only increases trust among patients but also encourages a culture of responsibility among healthcare workers, ultimately driving improvements in the quality of care delivered.

2. **Diagnosis Assistance App** – In conjunction with the universal profile, this public app would assist patients with the diagnosis process and possible treatments between the onset of symptoms and hospital visits. It could provide reliable information based on anonymized data from patients with similar physical builds and health conditions, offering possible solutions and treatments before visiting the hospital. This app would not replace doctors but would communicate symptoms and relevant information to healthcare platforms, leading to a quicker diagnosis process

From a managerial perspective, this app can significantly improve patient engagement and education, which are critical components of effective healthcare delivery. By providing patients with reliable information about their symptoms and potential next steps, healthcare administrators can foster a proactive approach to health management, potentially reducing the volume of non-

emergency visits to hospitals. This could lead to a more efficient allocation of healthcare resources and a decrease in wait times for patients requiring immediate attention.

Additionally, the app acts as a communication bridge between patients and healthcare providers. By facilitating the collection and transmission of relevant symptoms and health information to healthcare platforms, the app enables more accurate and comprehensive patient profiles. This information can help healthcare professionals prepare for visits, leading to a more optimized and effective diagnosis process. Administrators can then leverage this technology to improve patient flow and optimize care coordination, ultimately improving the overall patient experience.

Furthermore, the integration of this app with the universal profile can provide valuable insights into population health trends, allowing managers to identify common symptoms and treatment efficacy across various demographics. This data can inform public health initiatives and resource planning, enabling healthcare organizations to respond proactively to emerging health issues.

The app also reinforces the importance of data security and patient privacy, aligning with regulatory compliance and ethical standards. By ensuring that patient data is anonymized and securely handled, managers can build trust with users, encouraging wider adoption of the app and its features.

In summary, this public app complements the universal profile by increasing patient education, optimizing communication with healthcare providers, and providing valuable insights for managers. By promoting a more informed and engaged patient population, healthcare organizations can improve care outcomes and operational efficiency while maintaining high standards of privacy and compliance.

5.10. Extension of the Framework

The following extension is proposal in relation to these novel technologies:

Artificial Intelligence:

Inputs	Processing	Tasks	Applications	Common Challenges	Solutions for Common Challenges	Managerial Aspects and Topics
Text (Clinical Reports, Lab Reports, Handwritten Notes, Other Documents)	Data collection, cleaning, natural language processing (NLP), feature extraction, monitoring, model deployment	Extracting important information, text classification, summarizing text	1. Analyzing clinical data	Data quality issues (e.g., errors, incomplete info), privacy concerns, inconsistent formats	1. **Data Standardization**: Creating uniform data formats and language standards	**Data Governance**: Implementing rules and policies for managing data effectively
			2. Converting data to a usable format		2. **Privacy Solutions**: Implement data anonymization	**Compliance**: Ensuring all data handling follows legal and regulatory requirements
			3. Supporting clinical decisions		3. **Automated Data Cleaning**: Use AI for identifying and fixing errors	
			4. Identifying urgent cases			
			5. Classifying diseases			

Inputs	Processing	Tasks	Applications	Common Challenges	Solutions for Common Challenges	Managerial Aspects and Topics
Images (X-Ray, CT, MRI, Ultrasound, Videos)	Feature extraction, processing layers (e.g., convolution, pooling), image segmentation, enhancement techniques	Object detection, classification, localization, and image analysis	1. Radiology and oncology	Bias in models, lack of trust in AI decisions, high cost and time needed for annotating data	1. **Addressing Bias**: Use diverse datasets and fairness-aware algorithms	**Investment in Technology and Training**: Allocating resources for data annotation and training AI systems
			2. Cardiology		2. **Building Trust with Explainability**: Provide transparent model explanations	**Risk Management**: Developing strategies to ensure model reliability
			3. Dermatology		3. **Data Augmentation**: Expand datasets with synthetic images	
			4. Eye exams (fundoscopy)			
			5. Patient monitoring			
Audio (Coughing, Breathing, Heartbeats, Other Sounds)	Feature extraction, signal processing, audio analysis (frequency, time-domain), machine learning	Detecting and classifying sounds, analyzing audio spectrum	1. Diagnosing respiratory issues	Noise interference, data privacy, limited access to large and diverse datasets	1. **Improving Signal Quality**: Use advanced noise reduction techniques	**Collaboration Across Disciplines**: Engaging clinicians, data scientists, and engineers to enhance AI integration

Inputs	Processing	Tasks	Applications	Common Challenges	Solutions for Common Challenges	Managerial Aspects and Topics
			2. Detecting heart diseases		2. **Secure Data Sharing**: Apply federated learning to avoid sharing raw data	**Change Management**: Preparing staff for new workflows and technologies
			3. Assessing pain in infants		3. **Data Partnerships**: Collaborate with other organizations to access larger datasets	
			4. Identifying mental health conditions			
Wearable Sensor Data (Heart Rate, Activity, Glucose Levels)	Signal processing, data fusion, time-series analysis, machine learning	Monitoring activity, detecting anomalies, predicting health trends	1. Continuous health monitoring	Data quality (sensor errors), calibration issues, battery life constraints	1. **Self-Calibrating Sensors**: Implement calibration algorithms to improve accuracy	**Resource Management**: Balancing processing power and battery life for wearables
			2. Early detection of chronic diseases		2. **Edge Computing**: Perform local data processing to extend battery life	**Compliance with Health Standards**: Ensuring wearable data meets quality and accuracy standards
			3. Fitness tracking		3. **Data Integration**: Merge data from multiple sources for better reliability	

Inputs	Processing	Tasks	Applications	Common Challenges	Solutions for Common Challenges	Managerial Aspects and Topics
Genomic Data (DNA Sequences, Gene Expression Data)	Sequence analysis, variant detection, statistical modeling, data integration	Identifying mutations, analyzing gene expression, personalizing medicine	1. Predicting disease risks	High data complexity, privacy concerns, interpreting large-scale genomic information	1. **Data Simplification Techniques**: Use dimensionality reduction to handle large datasets	**Data Security and Compliance**: Handling sensitive patient information securely
			2. Tailoring drug treatments (pharmacogenomics)		2. **Blockchain Security**: Secure sensitive data with blockchain technology	**Data Integration**: Combining genomic data with other medical data for comprehensive analysis
			3. Cancer research		3. **Visualization Tools**: Employ interactive dashboards to aid interpretation	

Table 2: Extension of the theoretical framework for AI

Adopted from: Shinde, R., Patil, S., Kotecha, K., Potdar, V., Selvachandran, G., & Abraham, A. (2024). *Securing AI-based healthcare systems using blockchain technology: A state-of-the-art systematic literature review and future research directions*. *Transactions on Emerging Telecommunications Technologies, 35*(1), e4884.

Blockchain:

Blockchain Properties	Blockchain Components	Applicability in Healthcare Applications	Related AI Aspects	Managerial Aspects and Topics
Immutable	Time-stamped cryptographic linkage within blocks, distributed ledger	1. **Medical Data Integrity**: Ensures no alterations to patient records.	Explainability and Trust: Keeps XAI insights traceable.	**Data Integrity Management**: Strategies to maintain accurate records.
		2. **Audit Trails for AI**: Logs corrections to AI predictions.		**Compliance Assurance**: Ensure records meet legal standards.
		3. **Secure Diagnostic Data**: Stores trusted, unaltered diagnostic data.		
Decentralized	Peer-to-peer network	1. **Access to Diverse Datasets**: Enables collaboration without central data sharing.	Federated Learning: Supports decentralized AI model training.	**Collaboration Models**: Establish agreements for data-sharing.
		2. **Federated Learning**: Facilitates secure AI training across institutions.		**Resource Coordination**: Efficiently manage data across organizations.

Blockchain Properties	Blockchain Components	Applicability in Healthcare Applications	Related AI Aspects	Managerial Aspects and Topics
Enhanced Security	Privacy-enhancing technologies (homomorphic encryption, zero-knowledge proofs)	1. **Data Privacy**: Keeps patient information confidential.	Privacy-Preserving AI: Protects sensitive data during AI processes.	**Risk Management**: Address potential data security vulnerabilities.
		2. **Secure AI Computation**: Allows AI models to process encrypted data.		**Compliance with Privacy Laws**: Meet legal standards for data protection.
Highest Uptime	Peer-to-peer network	1. **Continuous Availability**: Ensures medical services stay online.	Robust AI Systems: Keeps AI available even with node failures.	**System Reliability Strategies**: Minimize downtime.
		2. **Avoiding Single Points of Failure**: Maintains AI applications' uptime.		**Disaster Recovery**: Plan for continuous service availability.
Collective Decisions	Consensus algorithms	1. **Collaborative Diagnosis**: Involves multiple experts in AI-driven decisions.	AI Validation: Uses decentralized consensus for model verification.	**Engaging Stakeholders**: Involve relevant parties in decision-making.
				Consensus Mechanisms: Implement collaborative governance models.

Blockchain Properties	Blockchain Components	Applicability in Healthcare Applications	Related AI Aspects	Managerial Aspects and Topics
Trusted Transactions	Smart contracts	1. **Audit Trails for Data Use**: Ensures traceability of AI-related data.	Explainability and Auditing: Provides clear records for compliance checks.	**Access Control Management**: Use automated systems for data access.
		2. **Automated Access Control**: Uses rules to manage data and model access.		**Transparent Auditing**: Maintain logs for regulatory purposes.
Autonomous	Smart contracts	1. **Automated AI Workflows**: Triggers actions when diagnostic criteria are met.	Automated Workflows: Allows self-executing AI tasks based on conditions.	**Workflow Automation**: Optimize tasks and processes.
				Performance Monitoring: Track the effectiveness of automated processes.

Table 3: Extension of the theoretical framework for Blockchain

Adopted from: Shinde, R., Patil, S., Kotecha, K., Potdar, V., Selvachandran, G., & Abraham, A. (2024). *Securing AI-based healthcare systems using blockchain technology: A state-of-the-art systematic literature review and future research directions*. *Transactions on Emerging Telecommunications Technologies, 35*(1), e4884.

Chapter vi: Conclusion

In summary, the integration of novel technologies such as blockchain and artificial intelligence provides potential for optimization of the healthcare sector. Blockchain's ability to secure, decentralize, and streamline health data management promises an optimization of the data integrity and patient privacy, while AI contributes to diagnostic accuracy, personalized medicine, and administrative efficiency. As these innovations continue to evolve, they bring unprecedented opportunities to address long-standing challenges in healthcare, from optimizing resource allocation to improving patient outcomes and reducing costs.

However, the successful implementation of these technologies depends not only on the technical development verified in the hospitals, but also on the insights and feedback of healthcare professionals who will ultimately use these systems. The perspectives of physicians, nurses, administrators, and other staff are invaluable to design user-friendly and effective technological solutions. Engaging these stakeholders early in the development and deployment process can help identify practical challenges, ensure smooth integration into clinical workflows, and foster broader acceptance among healthcare workers and patients alike.

Moreover, alongside blockchain and AI, other emergent technologies, such as the Internet of Medical Things and telemedicine, continue to reshape healthcare delivery. Together, these tools can enable more proactive and preventive care models, expand access to rural or underserved communities, and improve remote monitoring capabilities, which provide benefits for both healthcare workers and patients, especially in the independence and availability for both. Nevertheless, for these benefits to be fully realized, there must be ongoing investment in training and support for healthcare workers, clear regulatory frameworks, and mechanisms to continually assess the impact of these technologies on patient care and clinical outcomes.

This training is already being verified in certain universities, with the implementation of new learning models that already include the use of systems/programs that include Artificial Intelligence and/or Blockchain. Soon, fresh-graduated students will already be familiar with the

functionality and uses of these technologies, making the hospitals that already have them inserted and with close-to optimal use have an edge in talent attraction.

In relation to ethical and social concerns, it's important to note that these will be associated with these technologies before and after their implementation and normalization. It will heavily depend on the management of the hospitals to ensure the compliance and improvement of the processes associated with these, as to not only develop the care processes associated with the patients, but also to promote a secure environment for the healthcare professionals, in order to continuously increase the adherence and support related to these technologies.

In this research, the communication and feedback-seeking verified through the study demonstrate the correct initiative for assessing and verifying the technicalities of processes presented by healthcare workers. However, the study would benefit from a larger sample size, as this research should ideally be conducted in every hospital due to the unique aspects each one has. This gets further emphasized due to the lack of current literature that discusses the implementation of these technologies.

The proposals provided in the discussion serve as valuable first steps for hospitals in adopting these technologies. Despite the cost-related challenges of implementing new technological infrastructure, the economic and social landscape is increasingly shifting towards their adoption across industries and processes. This trend suggests that the question is not "if" but "when" these technologies will be implemented—especially given that many issues reported in healthcare literature and by participants can be mitigated through their use. The topics discussed already highlight the benefits and considerations necessary to address the challenges associated with these technologies, highlighting the importance of involving healthcare workers in their early development and implementation stages and proactive management of the ethical and social aspects.

In conclusion, while blockchain and AI provide a promising pathway to future-proofing healthcare, the active involvement of healthcare professionals is vital to ensure that these innovations are effectively tailored to meet the sector's unique demands. Future research should continue to explore these professionals' evolving needs and perspectives, helping to guide

technology developers toward solutions that are not only innovative but also practical, secure, and widely adopted and embrace the professional's feedback and suggestion for an optimal implementation.

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Annexes

2.1.

Sl. No	Applications	Examples	Technology
1	Medical Imaging Diagnosis	The goal of skin image analysis is to find skin cancer	Computer vision using deep learning
2	Smart Health Records	OCR recognition is based on machine learning and document categorization techniques that employ vector machines. Handwriting detection technique based on Google Cloud Vision API or Matlab machine learning	Handwriting detection technique based on Google Cloud Vision API or Matlab machine learning
3	Identifying Diseases and Diagnosis	Therapeutic treatments in oncology. Watson Genomics is a product from IBM that combines cognitive computing with genome-based tumor sequencing	IBM Watson Genomics
4	Crowdsourced Data Collection	IBM, in conjunction with Medtronic, developed a platform for understanding, collecting, and real-time exchanging diabetes and insulin data. Apple's Research Kit gives consumers access to interactive programs that employ machine learning to cure Asperger's syndrome and Parkinson's illness	Machine learning
5	Drug Discovery and Manufacturing	Biomarker discovery or validation. Deep Genomics uses artificial intelligence, especially deep learning, to help decipher the genome's meaning	Deep learning, artificial intelligence

Sl. No	Applications	Examples	Technology
6	Better Radiotherapy	Medical image analysis. DeepMind Health is assisting UCLH researchers in developing algorithms to distinguish between healthy and malignant cells	Deep learning algorithms
7	Tools for Risk Identification	El Camino Hospital researchers developed a method for forecasting patient falls by combining EHRs, nurse call data, and bed alarm data. Anomaly detection systems can anticipate catastrophic consequences, including strokes, heart attacks, and sepsis	Anomaly detection systems
8	Outbreak Prediction	Networks can aid in interpreting data and predicting severe infectious disease epidemics, such as malaria. BlueDot is a specialized tool for tracking epidemics	Data interpretation networks
9	Personalized Medicine	Based on patients' clinical history and available genetic information, evaluate the risk to the patients. Improved medical technology to spot genetic mutations	Genetic risk evaluation technology
10	Natural Language Processing	Review management and sentiment analysis. NLP-enabled systems detect and categorize words and phrases using algorithms	NLP algorithms

2.2.

Blockchain Properties	Blockchain Components	Applicability in Healthcare Applications
Immutable	Time Stamped Cryptographic Linkage within Blocks, Distributed Ledger	1. Medical Data Validation 2. An XAI-Corrected Version of Extracted Features 3. XAI Generates a Non-Corrupted Version of the Records for Diagnosis
Decentralized	Peer-to-Peer Network	1. Heterogeneous Medical Dataset 2. Federated/Distributed Learning
Enhanced Security	Privacy Enhancing Technologies like Homomorphic Encryption, Zero Knowledge Proof	1. Patient Profile Privacy 2. Medical Data Confidentiality
Highest Up Time	Peer-to-Peer Network	1. Resource Sharing 2. Eliminate Single Point-of-Failure
Collective Decisions	Consensus Algorithm	1. Collective Decision on Diagnosis
Trusted Transactions	Smart Contract	1. Data and User Provenance 2. Access Control Rules for Data and Model
Autonomous	Smart Contract	1. Automated Execution of Activities in Healthcare Fraternity

2.3.

Blockchain Properties	Blockchain Components	Applicability in Healthcare Applications
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