5th African International Conference on Industrial Engineering and Operations Management, Johannesburg/Pretoria, South Africa, April 23 - 25, 2024
Publisher: IEOM Society International, USA
Published: April 23, 2024 DOI: 10.46254/AF05.20240251

A Blockchain-based Patient Portal for Mental Health Management

Panashe Jhamba, Belinda Ndlovu and Sibusisiwe Dube
Department of Informatics and Analytics
National University of Science and Technology
Bulawayo, Zimbabwe
jhambapanashe01@gmail.com; belinda.ndlovu@nust.ac.zw;
sibusisiwe.dube@nust.ac.zw

Martin Muduva
Department of Information and Marketing Science
Midlands State University
Gweru, Zimbabwe
mmuduvah@gmail.com

Fungai Jacqueline
ICT and Electronics Department
School of Engineering Science and Technology
Chinhoyi University of Technology
Chinhoyi, Zimbabwe
fungaijacquelinekiwa@gmail.com

Kudakwashe Maguraushe
Department of Information and Communication Technology
Mangosuthu University of Technology
Durban, South Africa
maguraushe.kuda@mut.ac.za

Abstract

Mental health is an important aspect of well-being as it encompasses emotional, psychological and social well-being. The use of patient portals in mental health care has gained attention as a potential tool to improve access to care for individuals with mental illness. Patient portals may be vulnerable to unauthorized access if appropriate security measures are not put in place. This study leverages blockchain technology to create tamper-proof patient records. The proposed solution uses an on-chain database that stores hashes and the actual medical record of a patient as well as an off-chain solution that handles encryption of each user's medical record using their respective keys in a trustless manner before they are uploaded on-chain. A secure smart contract hosted on Ethereum and the Byzantine Fault Tolerance consensus algorithm was used to ensure patient privacy. The research employed the Comparative Analysis Research Methodology as the research methodology and the Kanban methodology as the software development methodology. The research project concludes that the proposed solution addresses the current security issues and data privacy concerns in patient data. The decentralized nature of blockchain ensures security, transparency, and tamper-

proof storage of information. Further research is needed for future advancements, like integrating blockchain-based patient portals with wearable devices and IoT.

Keywords
Blockchain, Patient portal, Mental health

1. Introduction
Mental illness is one of the highest contributors to the global disease burden, accounting for the greatest proportion of years lived with disability. American Psychiatric Association (2022) defines mental illness as a wide range of conditions that affect a person's thinking, mood, behavior, and overall mental well-being. To address these challenges, technological advancements in healthcare, such as online patient portals, have emerged as tools to enhance patient engagement and access to care. Otokiti (2020) defines online patient portals as web-based applications that give patients direct and secure 24-hour access to their electronic health records. Through such portals, patients can view information like medical history, patient notes, and many more. Despite the development of e-health in other nations, Zimbabwe has limited activity and the majority of the population lacks access to high-quality healthcare (Furusa and Coleman 2018). There is a lack of immediate access to medical records, especially in mental health institutions resulting from inadequate use of portals that cater to mental health. This results in the loss of patient records in the outpatient department and, a lack of patient involvement in their treatment. Data privacy, confidentiality, and security concerns are some of the major factors influencing the adoption of e-health in Zimbabwe (Furusa, 2018). This research is going to focus on portals for mental health institutions in Zimbabwe using blockchain technology to enhance security. Blockchain technology is described as a distributed ledger mechanism for database storage that uses encrypted blocks of data arranged in chains for access (Nakomoto 2018). The use of blockchain technology in the development of the portal will increase the privacy and security of patient data. Blockchain's distributed ledger technology enables the creation of tamper-proof records. Patient information stored on a blockchain can be securely recorded, preventing unauthorized modification (Zhang et al. 2018).

Objectives
To investigate the various implementations of blockchain technology in patient portals within mental health institutions
To devise an alternative methodology for evaluating the feasibility and effectiveness of integrating blockchain into a patient portal system within a mental health setting.
To assess the implications of implementing a blockchain-based patient portal on security, privacy, data integrity, and overall user experience in the mental health institution.

2. Literature Review
Patient portals are a type of personal health record connected to an electronic health record system, which provides patients with secure access to their clinical data while also facilitating patient-centered care and equitable, effective and quality health care delivery (Carini et al., 2021). Literature suggests that there has been a rapid growth in patient portal use especially in Europe and North America (Onyeaka et al.M2020). by Carini et al. (2021) reveals that patient portals have the potential to improve the doctor-patient relationship, raise health status awareness as well as increase adherence to therapy. Patient portals are not yet extensively adopted globally, particularly in situations related to mental healthcare, despite their benefits (Shin et al. 2023).

Blockchain technology can be used in patient portals to allay privacy and security concerns. It has the potential to revolutionize healthcare by enhancing the security, privacy, and interoperability of health data (Tavares, 2021). Blockchain technology has been used in many healthcare systems. BiiMed is a Blockchain framework that uses a private Ethereum blockchain to improve interoperability and data integrity in the context of EHR sharing within a Health Information System (HIS) (Jabbar et al. 2020). Hylock and Zeng (2019) and Chen et al. (2019) proposed a searchable encryption scheme for electronic healthcare records using blockchain. They designed an algorithm for indexing healthcare records and a two-part evaluation scheme for securing the EHR system using smart contracts.

They included the Hyperledger Fabric framework, to implement scalable healthcare data management applications. Hylock and Zeng (2019) highlight the use of redactable patient blocks, by way of chameleon hashing, introduced to minimize data fragmentation, allow for in-place editing, and reduce resource consumption. They proposed that future researchers must deploy the proof-of-concept client tool on a hosted, browser-based system. Chen et al. (2019)

proposed a searchable encryption scheme for electronic healthcare records using blockchain. They designed an algorithm for indexing healthcare records and a two-part evaluation scheme for securing the EHR system using smart contracts. They included the Hyperledger Fabric framework, to implement scalable healthcare data management applications.

Tanwar et al. (2020), Parekh (2020), and Evans (2020) leverage methods proposed by Chen et al. (2019). They used Hyperledger Fabric-based EHR sharing system and its related test environment was based on Hyperledger composer. Gebremedhin et al. (2019) adopted the Ethereum blockchain to provide a transparent and trusted environment for registration and exchange of information between participant nodes in a mental health setup. The study used DApp that allowed a user to enroll in the Ethereum network without authentication from a trusted third party. This study researchers adopted the method employed by Gebremedhin et al. (2019). Most of the studies reviewed by the researchers used Hyperledger Fabric, there is a need to develop more systems using Ethereum to enhance data security and privacy.

3. Methods

The study employed the Comparative Analysis research method as the research methodology and the Kanban methodology as the software development methodology. Comparative analysis research is a quantitative research methodology that involves comparing two or more objects, systems or approaches to identify similarities, differences and relative advantages as well as disadvantages. Prior studies have highlighted the need for comparing existing patient portals to blockchain-based systems in healthcare. The data collected in these studies goes on to highlight the implementation of blockchain and its opportunities in healthcare. The Comparative Analysis Research methodology aligns with the steps taken by these studies to come up with the systems. This methodology allows the researchers to evaluate its effectiveness and feasibility compared to existing patient portal systems. It is composed of five stages namely, defining research objectives, identifying and defining comparison objects, data collection, data analysis, and data reporting (Dovetail Editorial Team 2023).

i) Defining the Research Objectives

Objective: To compare the effectiveness of a blockchain-based patient portal (BCPP) with a traditional electronic health record (EHR) system in improving the security of data in patient engagement and data sharing.

Comparison criteria

Table 1. Comparison Criteria

Criteria	Features and Functionality	Ease of use	Data Security	Patient Engagement
Features	- Medication management - Lab results access - Appointment scheduling - Secure communication	- User interface design - Navigation - Overall usability	- Encryption standards - Access control mechanisms - Data privacy protocols	- Login frequency - Data sharing activity - Patient satisfaction with the system

ii) Defining the Comparison Objects

The research study used a blockchain-based patient portal and a widely used EHR system as its comparison objects.

iii) Data collection

The research study relied on data collected on a blockchain-based patient portal and an EHR system.

iv) Data Analysis and Comparison

Table 2. Comparison Table

Feature	Blockchain-based patient portal	EHR
Functionality	- Secure and transparent storage of medical records on a blockchain network (Jabbar et al., 2020). - Access control and granular permission management for medical records. - Automated workflows and smart contracts for medication reminders and other tasks. Integration with other healthcare applications and devices. - Patient-centric design with a focus on user experience and control over data.	- Comprehensive storage of medical records including demographics, diagnoses, medications, allergies, immunizations and lab results (Chelladurai et al., 2021). - Clinical decision support tools and alerts to improve care quality. - E-prescribing capabilities for streamlining medication workflow. - Reporting and analytics tools for population health management. - Interoperability with other healthcare systems to enable data exchange.
Ease of use	- User-friendly interface designed for patients with varying levels of technical expertise. - Mobile accessibility for convenient access to medical records on the go - Secure login and authentication mechanisms. - Educational resources and support are available to help patients understand their medical information (Fatokum et al., 2021).	- May require training and technical knowledge for healthcare providers to use effectively - User interfaces may be complex and difficult to navigate for patients - Limited mobile functionality for some EHRs (Fatokum et al., 2021).
Data security	- Tamper-proof and immutable records stored on a distributed ledger	- Centralized storage of data may be vulnerable to cyber-attacks and data breaches.

	- Strong encryption and cryptography protocols to protect patient data - Fine-grained access and audit trails to prevent unauthorized access. - Data breaches are less likely due to the decentralized nature of the blockchain (Sonkamble et al., 2021).	- Security protocols and access controls may not be as robust as blockchain-based solutions - Potential for data silos and lack of interoperability, making it difficult to share data securely (Sonkamble et al., 2021).

v) **Reporting and Interpretation**

Blockchain-based patient portals offer several advantages over traditional EHRs, including improved data security, patient control over data, and increased transparency. They also have the potential to be more user-friendly and accessible to patients. Blockchain technology is still evolving and some challenges need to be addressed before these solutions can be widely adopted. EHRs, on the other hand, are a mature technology that is widely used in healthcare settings (Ratwani, 2018). They offer a comprehensive set of functionalities and are well-integrated with other healthcare systems. However, they can be complex to use and may not provide the same level of data security and patient control as blockchain-based patient solutions. Patients using blockchain-based patient portal reported greater ease of use, convenience, and satisfaction with the system compared to the EHR system. The blockchain-based patient portal offered advanced data security features and improved control over patient data access (Taherdoost 2023).

The Kanban Methodology employed in this study is an agile project management methodology that focuses on continuous flow and limiting work in progress. It uses a visual board to track tasks and manage workflow. The research methodology increases efficiency and productivity. Focusing on a limited number of tasks reduces multitasking and promotes focused work. The methodology also provides improved visibility and transparency. The visual board provides a clear overview of the workflow and task progress (Parson, 2022). There are four stages to be followed in undertaking this methodology, which are, visualizing workflow, limiting work in progress (WIP), managing the workflow actively, and continuous improvement.

i) **Visualizing workflow**

In this first stage, the central element of Kanban, a visual board with columns representing different stages of the workflow, is created. Tasks are represented by cards that move across the board as they progress through the workflow (Wrike Team 2023). In this case, a digital tool was used, the Trello visual board. The researchers included tasks such as designing the user interface, implementing smart contracts on the blockchain, integrating with external systems, and conducting testing and quality assurance.

ii) **Limit Work In Progress (WIP)**

In this stage, the researchers set WIP limits for each stage of the workflow. The limit 'In Progress' was set to four (4) tasks to ensure focused work and prevent bottlenecks. Management of the flow of tasks by pulling new tasks into 'In Progress' only when capacity allows, was done. Monitoring the board regularly and adjusting the WIP limit as needed was done to optimize the flow.

iii**) Managing the workflow actively**

In this stage, the researchers used Kanban to manage tasks related to blockchain integration, such as smart contract development, data encryption and security testing. Visualization of the workflow for these tasks is monitored and the researchers ensure smooth integration with other development processes. At this stage, the researchers also monitor the progress and address any challenges related to blockchain integration efficiently.

iv) Continuous improvement

The researchers reflect on the process regularly and make adjustments to optimize efficiency and effectiveness. Analyzing metrics like lead time, cycle time and throughput to identify areas for improvement, is also done at this stage.
The diagram below shows the activity diagram for the system architecture of the proposed system.

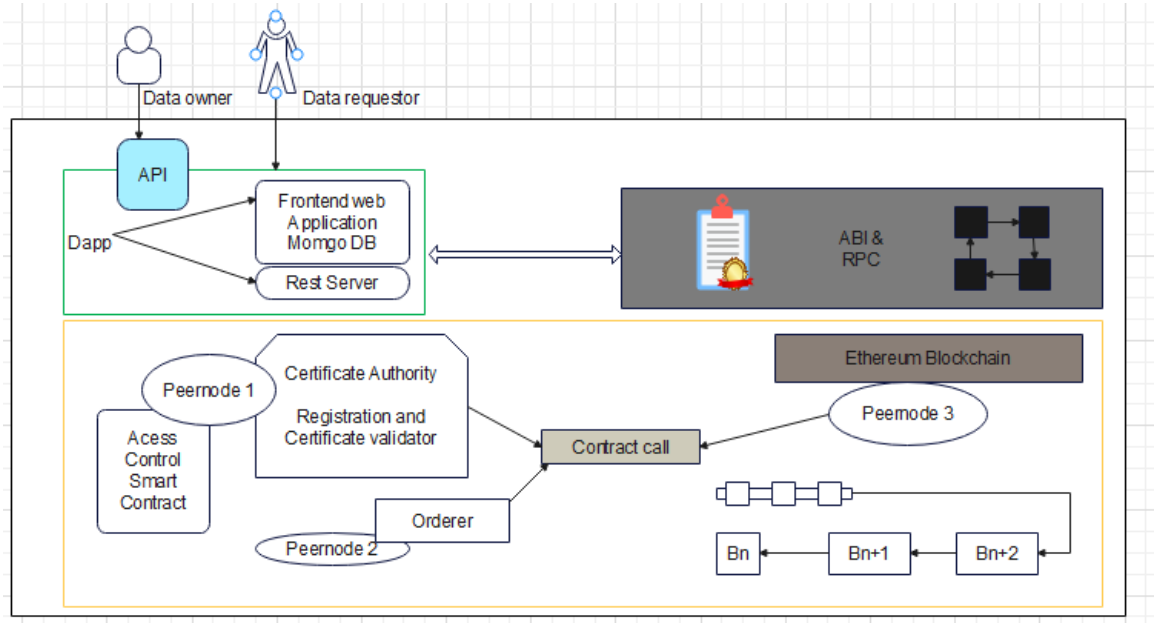

Figure 1. Activity diagram for the system architecture

Blockchain is a peer-to-peer, decentralized network in which each user keeps a copy of a shared ledger containing digitally signed transactions. This ledger cannot be changed, it can only be appended to. A consensus process is used by participants in a blockchain to maintain this ledger's synchronization (Ncube et al. 2022). A patient may be considered the data owner when they interact with the frontend, all requests are sent through the Rest Server to the backend, which then makes calls to the Blockchain. Ethereum blockchain uses rocksDB for its management of records. Both the data hash and the real data are stored on-chain (Marx 2018). At the Ethereum Blockchain level, certain nodes are in charge of adding a block known as validators to the chain, which ensures that accurate and synched data is shared around all the peers.

The proof of authority consensus algorithm was utilized to add data to the blockchain, hence, it will operate more quickly than the proof of work consensus process (Cryptopedia Staff 2023). For any network validator to validate incoming data, they must possess an authority certificate. This is achieved via channels where all validators screen each other's work, in other words, if data is not signed by a validator, it will be rejected and not added to the blockchain (Walgenbach, 2024). The user will communicate directly with the front end, all requests, such as granting the prescriber access to a personal prescription, will take place here. This request is forwarded to the backend, which then carries out all the labor-intensive tasks like locating the public key of the designated physician, comparing it with the one provided, and carrying out some cryptographic operations to temporarily shift prescription ownership from the user to the prescriber. Following completion of all computations, the output will be sent to the Blockchain module, which will store the data in the form of transactions on the blockchain indefinitely. The IPFS module, which is in charge of storing the data permanently, will also be responsible for sending and receiving data to and from the blockchain module. After completing all the steps, the recognition is granted.

4. Data Collection

In this stage, there is the collection of relevant data from various sources like technical documentation, literature review, expert interviews, case studies, surveys, and benchmarking studies (Dovetail Editorial Team, 2023). The researchers collected data on a blockchain-based patient portal and an EHR system through a literature review. To find existing literature on blockchain-based patient portals and EHR systems, the researchers developed a search string

which was: ('blockchain-based patient portals') AND ('EHR systems'). The researchers used this search string across several scholarly databases which included Science Direct, Research Gate, and Google Scholar to find relevant research studies published from 2019 to the current year. The researcher read all identified studies and carefully applied the inclusion and exclusion criteria to ensure that the most relevant studies were selected for further review. The researchers then conducted selected research studies to identify emerging themes and introduce solutions to address the research problems. Overall, what the researchers discovered from the literature review was that blockchain technology in patient portals increases data security and interoperability compared to an EHR that does not leverage blockchain technology (Taherdoost, 2023).

5. Results and Discussions

The blockchain-based patient portal is made up of several components that include a frontend user interface, backend and Ethereum blockchain which will be glued to the frontend via the backend. The following sections show the results of the implemented work.

5.1 Numerical Results

The results of the conducted literature review indicated an interest in the application of patient portals and blockchain technology in healthcare across different parts of the world. Seven (7) of the reviewed studies were conducted in North American countries (USA and Canada), while four (4) in Asian countries (India, Iran, Qatar, Japan), six (6) in Europe (UK, Netherlands, Portugal, Norway), two (2) studies were conducted in Africa (South Africa and Tanzania) and one

(1**) in Australia.**

Five (5) of the chosen studies investigated the use of patient portals in mental healthcare. All of the five studies concluded that patient portals are still not widely used in mental health settings. Eight (8) of the studies investigated the use of blockchain technology in healthcare. Of the eight, four (4) authors used smart contracts in Ethereum to establish an iterative, secure, accessible, and decentralized healthcare ecosystem. Three (3) authors investigated the use of the Hyperledger Fabric Framework to develop electronic health systems. One (1) study used a different framework which is the hybrid off-chain blockchain system framework to secure patient data. Four (4) studies investigated other technologies used in patient portals. These studies presented technologies like machine learning, AI, wearable devices, and customized Functionally Authorized Facet (FAF).

5.2 Graphical Results

The patient portal is comprised of three screens that the patients, doctors, and pharmacists interact with.
The login screen prompts the user to enter their credentials and gives feedback if the credentials are incorrect.

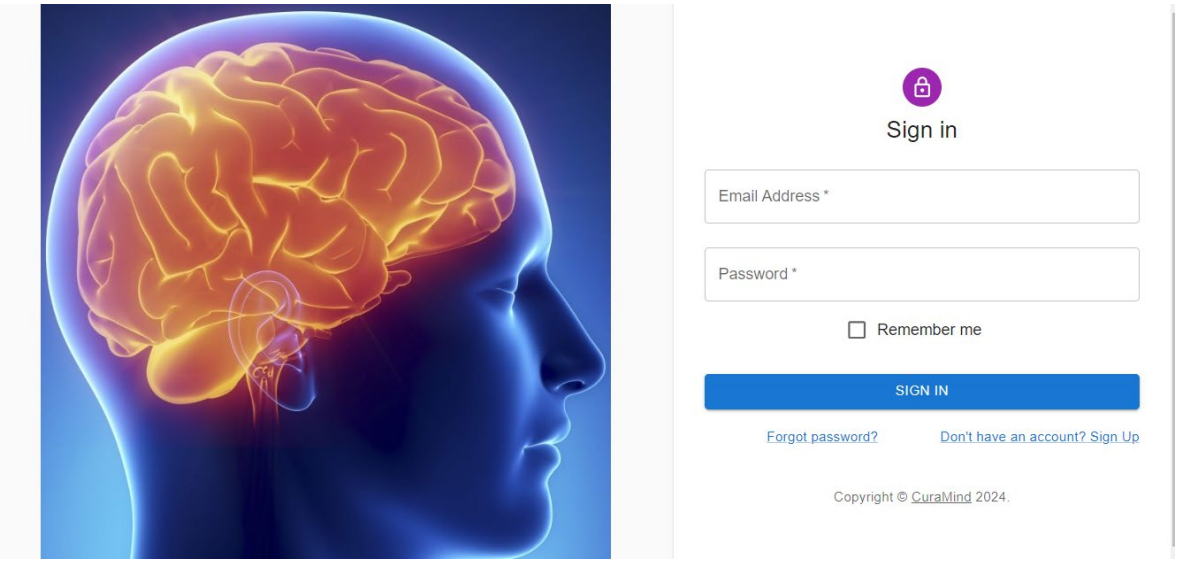

Figure 2 . Login screen

Patient screen

The patient screen allows patients to retrieve their medical records, schedule appointments and view their prescriptions from the doctor. The patient also grants permission to doctors to access their medical records prescribe medication or revoke access to their medical records. Pharmacists also require permission from the patient to access patient prescriptions.

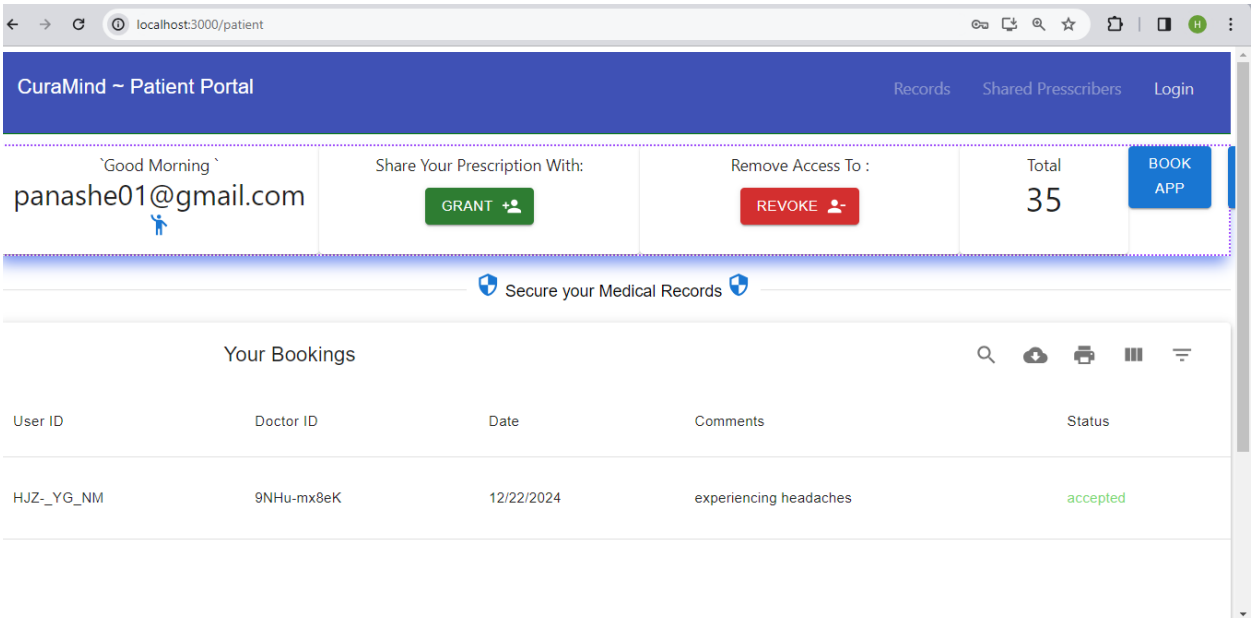

Figure 3 . Patient screen

Doctor screen

The doctor's screen enables the doctor to create, retrieve medical records and prescribe medication to patients. The patient will be able to view the record as soon as it is created and ownership will be instantly transferred to their account.

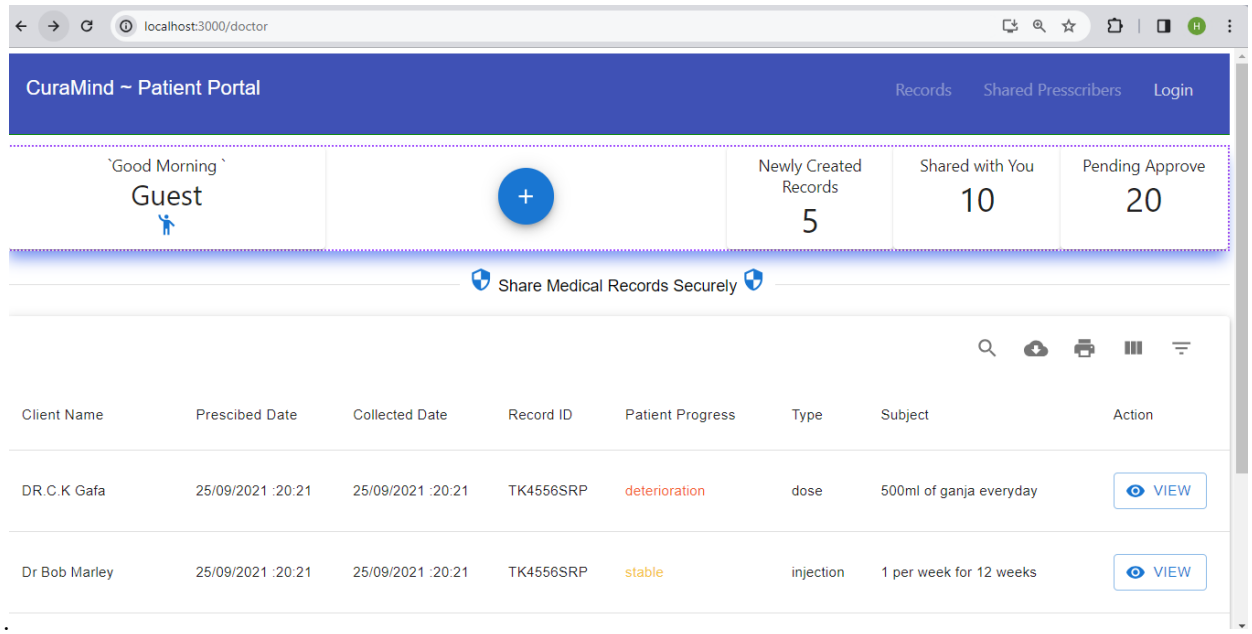

Figure 4. Doctor screen

Pharmacist screen

The pharmacist can view patient prescriptions they have access to. Along with the prescribed drug and date, it shows the name of the doctor from whom the prescription was obtained. The pharmacist can also verify whether the patient has collected the drug or not. The pharmacist can look up a patient's medical history by using the search bar.

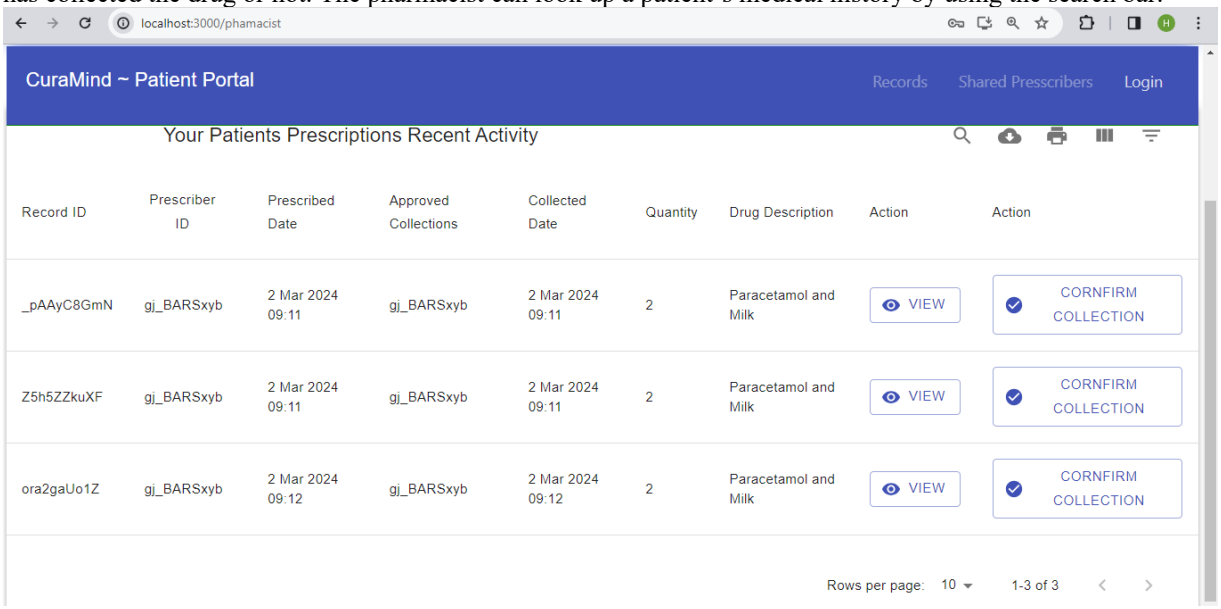

Figure 5. Pharmacist screen

5.3 Proposed Improvements

The system was a web-based application that supports mostly desktop environments. An improvement would be in developing mobile applications that show features that the patient portal implements. Further research is needed for future advancements like integrating the blockchain-based patient portal with wearable devices that monitor admitted patients, patients on a leave of absence, or those who are recovering at home. Another improvement would be the facilitation of secure video conferencing and communication channels between patients and healthcare providers.

5.4 Validation

The use of patient portals in mental health is beneficial to patients and healthcare providers. A pilot study involving 52 psychiatric patients who gained web-based access to their medical health records discovered that 82% of the patients felt more in control of their treatment because they read their treatment plans and medical notes and knew what to expect during their care process (Van Rijt et al., 2021). Chen et al. (2020) highlight that systematic reviews have revealed that telepsychiatry is highly satisfied by users and is equally effective as traditional in-person therapies for a variety of mental disorders and patient demographics. The implementation of blockchain technology in such portals increases the adoption rates of patient portals in mental health settings as data privacy and security are ensured.

6. Conclusion

This study shows how a patient portal designed for mental health institutions leverages blockchain technology to secure patient records and give patients control over their medical records. The first objective of the study was achieved by creating a secure on-chain database, where patient medical records are stored and retrieved by the patient, the authorized doctor, and the pharmacist. The second objective was achieved by creating an option to book a doctor on the patient's screen to facilitate the secure scheduling of appointments. The third objective was achieved by facilitating doctors to be able to prescribe medication to patients. The prescribing option shown on the doctor's screen enables authorized doctors to make prescriptions to patients. All these activities occur on-chain in a secure environment that ensures data privacy and security. All these features resulted in the successful implementation of a blockchain-based patient portal for a mental health institution.

References

American Psychiatry Association, DSM-5., *Diagnostic and statistical manual of mental disorders: DSM-5*, 5th ed, American Psychiatry Publishing Inc, 2022.

Carini, E., Villani, L., Pezzullo, A., Gentili, A., Barbara, A., Ricciardi, W., Boccia, S., The impact of digital patient portals on health outcomes, system efficiency, and patient attitudes: Updated systematic literature review, *Journal of Medical Internet Research*, vol 23(9)., 2021.

Chen, J., Chung, W., Young, S., Tuttle, M., Collins, M., Darghouth, S., Longley, R., Levy, R., Razafsha, M., Kerner, J., Wozniak, J., Huffman, J., Covid-19 and telepshychiatry: Early outpatient experiences and implications for the future, *General Hospital Psychiatry*, vol 66., pp. 89-95., 2020.

Cryptopedia Staff., Blockchain consensus mechanisms beyond PoW and PoS, 2023.

Dovetail Editorial Team., Kanban vs Scrum: Which agile methodology is right for your company, 2023.

Fatokun, T., Nag, A., Sharma, S., Towards a blockchain assisted patient owned system for Electrical Health Records, *Electronics*, 2021.

Furusa, M, and Coleman, A., Factors influencing e-health implementation by medical doctors in public hospitals in Zimbabwe, *SA Journal of Information Management,* vol 20(1)., 2018.

Gebremedhin, T., Lamo, Y., Svein., Lillehaug, I., Blockchain as a technology to facilitate privacy and better health record management., 2018.

Hylock, R. and Zeng, X., A blockchain framework for patient-centered health records and exchange (healthChain): Evaluation and proof-of-concept study., *Journal of Medical Internet Research*, vol 21(8)., 2019.

Jabbar, R., Krichen, M., Barkaoui, K., Adopting formal verification and model-based testing techniques for validating a blockchain-based healthcare records sharing system, pp. 261-268., 2020.

Marx, L., Storing data on the blockchain: The developers guide, 2018.

Ncube, N., Mutunhu, B., Sibanda, K., Land registry using a distributed ledger, *IST-Africa Institute and IIMC*, 2022

Otokiti, A., Williams, K, and Warsame, L., Impact of digital divide on the adoption of online patient portals for self-motivated patients, *Healthcare Informatics Research*, vol 26(3)., pp. 220-228., 2020.

Onyeaka, H., Ajayi, K., Muoghalu, C., Eseaton, P., Azuike, C., Anugwom, G., Oladunjove, F., Aneni, K., Firth, J., Torous, J., Acess to online patient portals among individuals with depression and anxiety, *Psychiatry Research Communications*, vol 2(4)., 2022.

Shin, H., Durocher, K., Lo, B., Chen, S., Ma, C., Wiljer, D., Strudwick, G., Impact of a mental health patient portal on patients' views of compassion: a mixed-methods, *BMC Digital Health,* vol 1(1)., 2023.

Sonkamble, RG., Phansalkar, S., Potdar, VM., Bongale, A., Survey of interoperability in Electronic Health Records management and proposed blockchain-based framework: MyBlockEHR, 2021.

Taherdoost, H., An overview of trends in information systems: Emerging technologies that transform technology industry, Cloud computing and data science, 2023.

Tanwar, S., Parekh, K., Evans, R., Blockchain-based electronic healthcare records system for healthcare 4.0 applications, *Journal of Information Security and Application*, 2020.

Van Rijt, A., Hulter, P., Weggelaar-Jansen, A., Ahaus, K., Pluut, B., Mental health care professionals' appraisal of patients' use of web-based access to their electronic health record: Qualitative study, *Journal of Medical Internet Research,* vol 23(8)., 2021.

Walgenbach, S., Blockchain nodes: Ensuring integrity in decentralized networks, 2024.

Zhang, Z., Citardi, D., Xing, A., Luo, X., Lu, Y., He, Z., Patient challenges and needs in comprehending laboratory test results: Mixed methods study, *Journal of Medical Internet Research,* vol 22(12)., 2020.

Biography

Panashe Jhamba is a Research Student in the field of Informatics for the National University of Science and Technology (NUST). She worked as an intern at Ingutsheni Central Hospital in Bulawayo, a mental health institution, under the department of Health Information and also the department of ICT. Her research interests are in the field of blockchain technology in healthcare.

Belinda Mutunhu Ndlovu is a PhD in Information System student at UNISA. She holds an MSc in Computer Science. She is a seasoned software developer and an academic. She has published several papers in fields of Data Analytics, Health Informatics, ICT 4D and 4IR.

Sibusisiwe Dube is an experienced lecturer of Information Systems and Computer Science courses. She holds a PhD in Information Systems, MSc in Computer Science and BSc in Information Systems. She has been lecturing since 2004. She is also an active researcher and supervisor of Postgraduate dissertations and undergraduate students' projects.

Fungai Jacqueline Kiwa holds a DPhil in Cultural Heritage and IT from Chinhoyi University of Technology, complemented by a PGDHE, MSc in Information System, BTech in CIT, Advanced Diploma in CIT and an MSc in Mechatronics and AI.

Martin Muduva is a PhD at from Chinhoyi University of Technology. He holds an MSc in Innovation and Entrepreneurship, a Masters in Mechatronics and AI, Master of Leadership and Corporate Governance, MSc in BDA, B. Tech (Hons) in Information Security and Assurance, Diploma in Corporate Safety Risk and Security Management and a Certificate in Higher and Tertiary Education.

Kudakwashe Maguraushe is an experienced lecturer in multiple computing-related modules. He holds a PhD in Information Systems, an MSc in Information Systems and a BSc (Hons) in Computer Science. He has supervised many students at both undergraduate and postgraduate levels. He has research interests in information privacy and security, healthcare systems, emerging technologies (artificial intelligence, machine learning and social media) and digital transformation.