

## The Blockchain Technology: Benefits and Applications in Healthcare Information Systems

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### ABSTRACT

**Objective:** Healthcare information systems aim to provide high-quality healthcare services to ensure the security of patients' health information. They can also assist in safeguarding an encyclopedia of clinical data to make more informed decisions in a private environment. However, the majority of today's healthcare information systems are centralized and have great difficulty in providing indispensable information security and privacy, patient health records immutability, transparency, and flexibility to detect vulnerabilities and cyber invasions.

**Methods:** The current study has explored the striking benefits and opportunities for blockchain technology in the healthcare information systems sector. It has identified the key applications that blockchain technology offers to provide indispensable information security and privacy, the immutability of patient health records, transparency, and flexibility to detect vulnerabilities and cyber invasions.

**Results:** Blockchain technology as a regulatory technology can enhance healthcare information services by bringing high-quality healthcare services in a crystal clear view that is decentralized, immutable, tamper-resistant, flexible, traceable, and secure. It also enables clinical professionals to effectively detect vulnerabilities and cyber invasions related to patients' health information.

**Conclusion:** The practical deployment of blockchain technology in healthcare information systems takes years of research and experience to reach fruition. In order to enable the practical deployment of blockchain technology in healthcare information systems, a series of research will need to be conducted.

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## **Introduction**

The digitization and evolution of the healthcare environment present important needs to protect it against different security attacks (López Martínez, Gil Pérez, & Ruiz-Martínez, 2023; Matulevičius et al., 2022). In the healthcare environment, security is key for all Healthcare Information Systems (HISs) since these systems contain confidential and indispensable information on patients. It is thus critical to ensure that the HIS safeguards the security of patients' health information because the information is daily used and uploaded online by physicians, professional staff, and health specialists to establish high-quality healthcare and improve healthcare delivery. Several legal regulations by the EU and US have been created, such as General Data Protection Regulation (GDPR) and Healthcare Insurance Portability and Accountability Act (HIPAA), respectively, to safeguard HIS against vulnerabilities and cyber invasions (Alharbi et al., 2022; López Martínez et al., 2023; Sari, Handayani, Hidayanto, Yazid, & Aji, 2022). In fact, according to the IBM Security report, 44,993,618 healthcare records were stolen or exposed during data breaches that cost \$7.13 million (Foy, 2023). Thus, the security of HIS is required to make patients feel more comfortable and increase trust in its applications. HISs offer economic benefits, alleviate hospital overcrowding, prevent medical errors, and support healthcare providers and doctors in diagnosis. Conventional centralization is a significant impediment in current HIS that faces the risk of a central point of failure. In addition, information in existing HISs are prone to various major and minor threats compromising the availability and confidentiality of respective systems (Alharbi et al., 2022; Fatima & Colomo-Palacios, 2018; Luna, Rhine, Myhra, Sullivan, & Kruse, 2016; Matulevičius et al., 2022). Blockchain Technology (BT) can guarantee to address such potential problems. The promising BT follows a decentralized-distributed architecture to preserve Electronic Health Records (EHRs), validate patient information, pre-authorize payments, improve health outcomes, and deliver safer drugs among diverse participants (Kombe, Ally, & Sam, 2018; Negro-Calduch, Azzopardi-Muscat, Krishnamurthy, & Novillo-Ortiz, 2021). Providing the full ownership of health records by patients, exchanging health information of patients with their consent, monitoring patient's medical wearables to gather current body status from a distance, collecting temper-proof medical history of patients to improve drug prescriptions and recommendations for use by physicians, designing an interoperable HIS through a multi-institutional medical records database, and reducing third party risk, are among the key pitfalls that can be overcome by BT.

HIS as the repository and nervous system enables clinicians, medical institutions, and hospitals to remotely store, exchange, and analyze large masses of data by facilitating medical operational processes, thereby utilizing remote monitoring of patient's medical history, providing cost savings by reducing paperwork, and keeping patients at the heart of care—where healthcare professionals can securely access and interpret health information. Technological progress and digital transformation of HISs help both patients to confirm or deny any access to their information and

physicians to share DNA data or large medical images for better diagnosis and treatment (Leng, Tan, & Wang, 2021; Li & Kuo, 2021; Negro-Calduch et al., 2021; Shuaib, Saleous, Shuaib, & Zaki, 2019). The major benefits of current HISs are represented in Fig. 1 that illustrate respective systems have the potential to automatically safeguard the security of electronic records of patients without being compromised by unauthorized parties. Moreover, the integration of BT into current HISs can provide numerous opportunities to ensure the security of healthcare, such as prospectively storing and exchanging clinical data using cryptographic techniques, monitoring healthcare records, allowing patients to effectively control their data, preventing system threats when real data of patients are accessed from one sector to another, maintain patients' privacy via a decentralized identity management framework. Fig. 2 presents the key properties of BT, such as peer-to-peer (P2P) architecture, transparency, availability, and immutability of data.

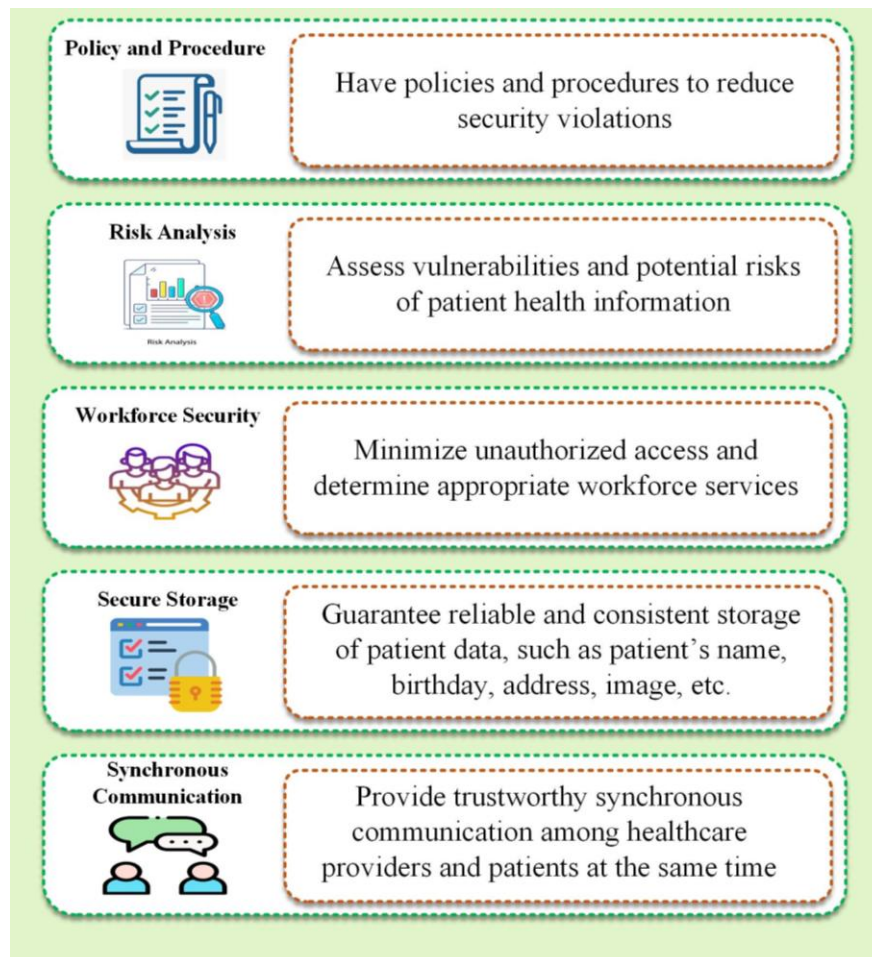
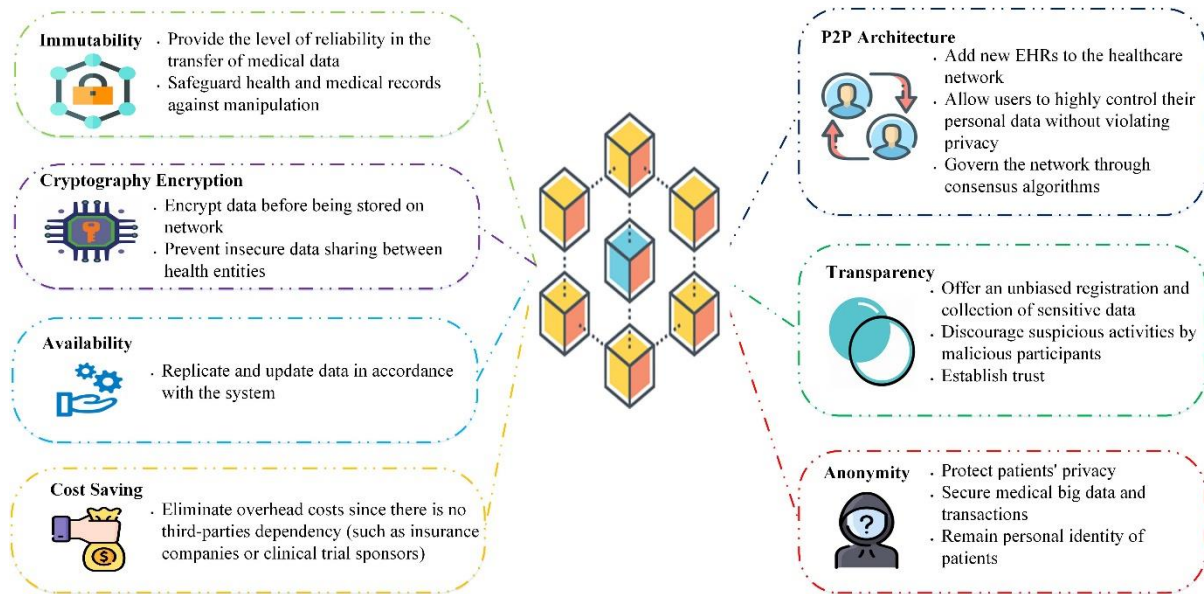


Figure 1. Benefits of HISs services.



**Figure 2. Representation of intrinsic elements and characteristics of BT for HISs.**

The P2P architecture property builds a tamper-proof medical data-sharing (Matulevičius et al., 2022; Rghioui, Bouchkaren, & Khannous, 2022) and avoids the central point of failure; this reinforces the data storage of HISs against cyber-attacks or accidental events (Ahmad et al., 2021; Matlebjane & Ndayizigamiye, 2022; Mnyawi, Kombe, Sam, & Nyambo, 2022). Moreover, the consensus algorithms ensure the common agreement on the current state of a ledger to maintain trust and efficiency among HISs participants (Kombe et al., 2018) and enable them to control the status of their data (Shuaib et al., 2019). The immutability property of health records is maintained due to asymmetric cryptography key, which makes the transactions in the network extremely unchangeable or alterable. The distinguishing features and advantages of leveraging BT to HISs are mentioned in Table 1. The internal requirements of the healthcare environment, such as broadcast updates of data on the chain and connecting patients, healthcare providers, hospitals, pharmacies, and insurance companies together (Shuaib et al., 2019), real-time data sharing with someone who resides in a foreign country to obtain better medication (Bazel, Ahmad, & Mohammed, 2022), low-cost system, eliminate duplication, lack human capacity, and recommend as a solution for low-to-middle-income countries (Rghioui et al., 2022), decrease the need for doing the repetitive laboratory test with a high risk of radiation (Bazel et al., 2022), can be achieved by BT. Besides, using blockchain for improving lab reports, prescriptions, and X-ray reports at the point of care can lead to revolutionizing the healthcare environment and help to community's health needs (Khubone, Tlou, & Mashamba-Thompson, 2020; Singh et al., 2023). Hyperledger fabric as a permissioned BT is a mature toolset that can be used in the HISs. A hyperledger fabric is an open-source blockchain that attracts the attention of industry and academia nowadays. Due to its key features such as fine-grained access control, permission management, and high transaction

performance, hyperledger fabric can strengthen the reform of HISs. Hyperledger fabric is suitable for controlling EHR as it creates a confidential and scalable infrastructure solution, which allows specific authorized users to access certain data (Stamatellis, Papadopoulos, Pitropakis, Katsikas, & Buchanan, 2020).

**Table 1. Comparison between centralized and blockchain-based HISs**

	Centralized HISs	Blockchain-based HISs
Financial & Cost	Low	Low
Central Point of Failure	Yes	No
Patient Waiting Time	Low	Low
System Response Time	High	Low
Data Provenance	No	Yes
Medical Data Management	Low	High
Decentralized Data Analysis	No	Yes
Documentation	Yes	No
Energy Consumption	Low	High
Audit Trails	No	Yes
Reliability & Integrity	Low	High
Validity & Authenticity	Low	High
Transparency	No	Yes

Hyperledger fabric has been extensively used in respective systems that are developed to digitize the healthcare sector (Leng et al., 2021). More specifically, the current works have widely focused on transaction efficiency (Kombe et al., 2018; Leng et al., 2021; Mnyawi et al., 2022; Rghioui et al., 2022; Uddin et al., 2021), fine-grained access control (Antwi et al., 2021; Merlo, Pio, Giusto, & Bilancia, 2023), scalability (Agbo, Mahmoud, & Eklund, 2019; Castillo, 2022), self-sovereign identity (Purohit et al., 2021; Uddin et al., 2021) (), and remote patient monitoring (Merlo et al., 2023). The blockchain-based healthcare information management systems presented in (Daraghmi, Daraghmi, & Yuan, 2019; Fan, Wang, Ren, Li, & Yang, 2018; Yaqoob, Salah, Jayaraman, & Al-Hammadi, 2021; Zaabar, Cheikhrouhou, Jamil, Ammi, & Abid, 2021) have maintained the security and privacy of EHRs. In (Merlo et al., 2023), the authors investigated in detail the striking applications of blockchain in the real-world healthcare environment. The authors also presented that BT facilitates up-to-date and accurate sharing of EMRs (Electronic Medical Records) and EHRs in emergency and non-emergency health services. Another study proposed in (Uddin et al., 2021) has leveraged hyperledger fabric to secure and improve EHRs systems in the P2P architecture of different healthcare ecosystems. The blockchain-based security architecture merge with the Government of Tanzania HIS presented in (Mnyawi et al., 2022) enables secure storage of data concerning confidentiality, integrity, and availability. The hyperledger fabric platform introduced in (Alshalali, M'Bale, & Josyula, 2018) allows all participants, such as doctors, researchers, and healthcare agents to communicate with the blockchain anytime from anywhere. According to this paper, all the participants can interact meticulously with one another without



worries. Table 2 summarizes and compares the related works that have reviewed the benefits of blockchain-based healthcare systems in several healthcare domains. It also shows that none of the current works has fully explored the benefits of BT in HISs, except our work. The significant contributions of our work are summarized below:

- We review and highlight the plethora of benefits that BT can offer to current HISs by strengthening their significant weaknesses in terms of availability, accessibility, transparency, traceability, data provenance, immutability, trust, and security.
- We update recent discussions on the applications of BT related to health systems.
- We try to explore new applications of BC in HISs in terms of infectious disease surveillance systems, durable medical equipment, chronic disease management strategies, health coverage, and patient satisfaction.

**Table 1. Comparison of current works on blockchain-based healthcare systems.**

Article	EHR/PHR Management	Clinical Trials	Health Coverage	Patients Satisfaction	Disease Management	Pharma/Drugs Supply-Chain	Durable Medical Equipment
(Ghosh, Chakraborty, Hasan, Rashid, & Siddique, 2023)	✓	✓	✗	✗	✗	✓	✗
(Baysal, Özcan-Top, & Betin-Can, 2023)	✓	✓	✗	✗	✗	✓	✗
(Merlo et al., 2023)	✓	✓	✗	✗	✗	✓	✗
(Rahman, Islam, Uddin, & Stea, 2022)	✓	✓	✗	✗	✗	✓	✗
(Mamun, Azam, & Gritti, 2022)	✓	✗	✗	✗	✗	✗	✗
(Elangovan et al., 2022)	✓	✓	✗	✗	✗	✓	✗
(Leng et al., 2021)	✓	✓	✗	✗	✗	✓	✗
(Xie, Zhang, et al., 2021)	✓	✓	✗	✗	✗	✓	✗
(Ahmad et al., 2021)	✓	✗	✗	✗	✗	✓	✗
(Hasselgren, Krlevska, Gligoroski, Pedersen, & Faxvaag, 2020)	✓	✓	✗	✗	✗	✗	✗
Our Study	✓	✓	✓	✓	✓	✓	✓

## Blockchain Benefits in Healthcare Information Systems

The overall arrangement of this section is to comprehensively discuss the striking benefits brought by BT in HISs to build trust among healthcare providers, as illustrated in Fig. 3.

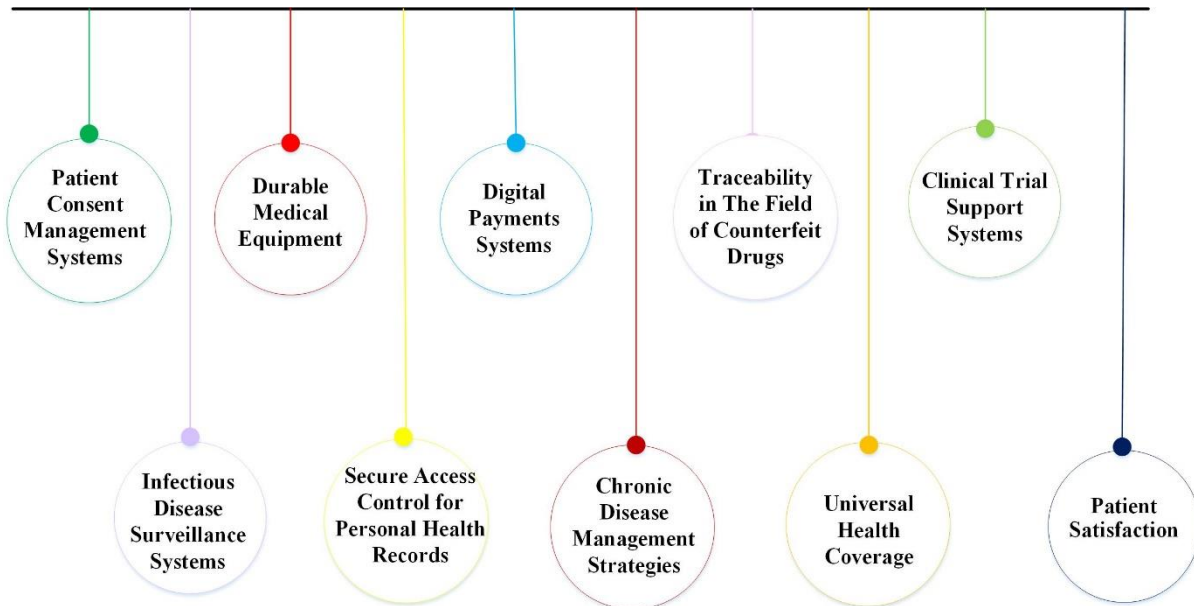


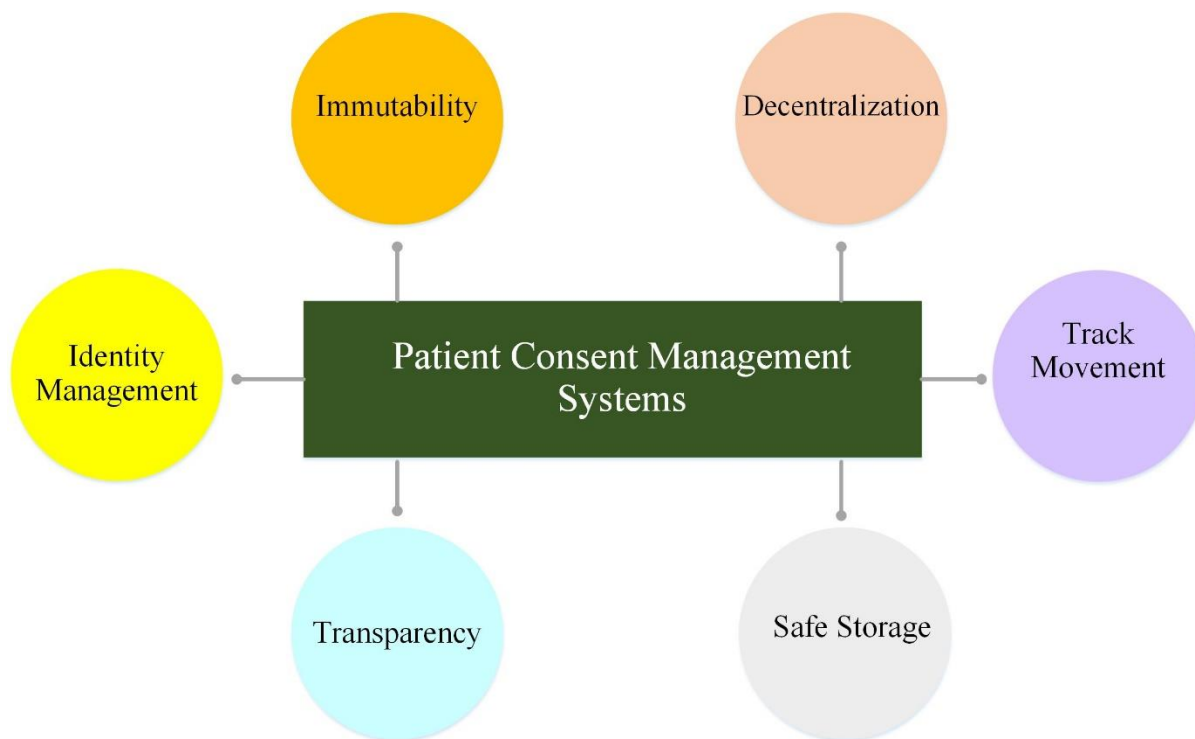
Figure 3. Striking benefits of BC in HISs.

### *Patient Consent Management Systems*

The performance of health monitoring and the progress of the healthcare environment is based on the crystal clear integrity of the EHRs. EHRs as a part of HISs include a longitudinal picture of a patient's medical history, wellness, problem lists, treatment and outcome plans, progress notes, medications, immunizations, vital signs, laboratory reports, and radiology data. Thus, HISs virtually cover all aspects of this information and allow patients and healthcare providers to access EHRs electronically through patient portals. The EHRs are the extra-sensitive and precious asset of healthcare systems, which needs to be regularly shared among different stakeholder groups, such as health officials, health regularity authorities, hospitals, and pharmacies to keep a patient's information up to date (Ahmad et al., 2021; Henry Mathews Odiango, Silvanice Abeka, & Samuel Liyala, 2022). The health legislation for HIS has enabled patients to dynamically monitor and manage their past, present, or future personal information by setting information access restrictions and usage permissions rules. In other words, patient consent management systems are a novel process that empowers patients to control back dynamically (i.e., agree/deny, access, view, and update) their personal information against skeptical information consumers. However, the conventional consent management systems create multiple challenges, such as difficulty in sharing EHR with healthcare professionals in a transparent manner and confined trust on the third-party

platforms that developed patient consent management platforms. These multiple challenges create in traditional consent management systems due to being dynamic healthcare systems. BC can help to strengthen trust as no centralized architecture exist and no third party is involved in the network. Through BC, the patient consent management systems can maintain immutable, transparent, and flexible (Kakarlapudi & Mahmoud, 2021; Velmovitsky et al., 2020).

It also makes the operations of systems, such as searching, storing, processing, consulting, and erasing more trustworthy for the patients (Merlec, Lee, Hong, & In, 2021). Moreover, the striking accountability, traceability, and reliability features of blockchain can be used to leverage consent management systems. Smart contracts are another feature of BC that can also be leveraged to capture whether the consent management process is compliant with ethical and legal purposes across territories (Velmovitsky et al., 2020). Ultimately, with these features of BC, it will be simpler to agree/deny, access, view, and update consent. Fig. 4 shows the features brought about by blockchain-based patient consent management systems.



**Figure 4. Blockchain-based patient consent management system.**

### *Infectious Disease Surveillance Systems*

HISs are extremely valuable assets for the early detection of disease outbreaks, especially outbreaks of emerging and re-emerging infectious diseases, threats of pandemics, or even bioterrorism. The potential of HISs are to improve the efficiency, quality, and productivity of infectious disease



surveillance systems in hospitals. Last JM defined it as a “Systematic, ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that the action can be taken” (Last, 2001, p. 174). Surveillance systems identify both chronic communicable and non-communicable infectious diseases by HISs. These surveillance systems are needed to prevent outbreaks of epidemics and to monitor future disease patterns early (Chattu, Nanda, Chattu, Kadri, & Knight, 2019; Hasselgren et al., 2020). In existing surveillance systems, independent health agencies are unable to manage clinical and infectious data during a pandemic due to their centralized systems. This is a key challenge for them to keep the data flow attainable, up-to-date, and accurate. To overcome this key challenge, BC assists in the decision-making of health agencies by efficiently tracking data in unexpected emergencies, such as opioid misuse (Chattu et al., 2019). The transparency and safety reporting of critical data (e.g., deaths from infectious diseases) is guaranteed due to decentralized-distributed architecture, which overcomes the limitations of centralized systems.

### *Durable Medical Equipment*

Durable medical equipment assists patients in facilitating their healing process in clinical and non-clinical situations. Durable medical equipment as a reliable and high-fidelity HIS (Sinhasane, 2022) includes hospital beds, power wheelchairs, surgical devices, oxygen equipment, and similar supplies. The combination of this equipment is often used for life-saving treatments, illness, or injury. Medical equipment are considered reusable and no disposable equipment (Jacobs & Lee, 2014) and the majority of adults and users with specific health conditions can benefit from it. One of the significant effects of the COVID-19 pandemic has been a severe shortage of medical equipment for both patients and healthcare providers in many hospitals. Although there is significant progress in the medical equipment supply chain to move medical equipment from producer to consumer in pandemic times, today’s medical equipment supply chain faces several challenges. These several challenges include centralization, time-consuming, high cost, lack of transparency, traceability, mistrust, and visibility from reputed manufacturers. For such challenges, BC can be used to transparently and spontaneously distribute medical equipment between untrusted parties. It can also facilitate automatic payments and increase medical equipment supply chain visibility. By integrating BC with the medical equipment supply chain, medical equipment, and similar supplies can be electronically ordered from manufacturing to consumption. As a result, the adoption of BC reduces geographic limits and strengthens medical equipment management. Besides, a blockchain-based approach can be helpful for healthcare providers, patients, and hospitals to trace and track medical equipment during a pandemic.

### *Secure Access Control for Personal Health Records*

Personal Health Records (PHRs) refer to an individual's health information including wellness, personal development, welfare, exercise, and diet information related to the patient. As PHRs are in line with the patient-centric strategy, they enable patients to have a 360° view of their lifestyle information. PHR comes from different sources — from the patient via entering information manually, or from EHR via monitoring device. Unlike the EHR, which is controlled by health organizations, the information of the PHR is controlled and managed by the patients (Wager, Lee and Glaser, 2017, p. 80). Despite the benefits of PHR, they are often based on traditional cloud computing platforms, which makes some drawbacks related to secure access to health information. Most cloud computing platforms are less trustworthy and reliable as they are controlled by a single untrusted entity. In simple terms, traditional cloud computing platform hinders patients to have a 360° view of their health information and compromises the integrity of PHR. For example, if a patient's information is hacked or attacked, they are not able to track the changes in their information. To alleviate these drawbacks, blockchain striking features enable patients to have comprehensive control over their health information. They also provide emergency access control through hyperledger fabric for patients when they are not able to give consent to healthcare providers (Merlo et al., 2023). Besides, cryptographic hashes in BC keep the integrity and confidentiality of the PHR. The value of the blockchain assists patients to become more engaged, more healthy, and more informed about the content of their health records.

### *Digital Payments Systems*

The existing HISs often implement centralized intermediary services to transfer payments and credits among peers, such as patients, healthcare organizations, insurance companies, and healthcare providers for using hospital and physician services. Centralized intermediary services make price and quantity commitments. However, today's centralized payment methodologies and structures are relatively slow and particularly vulnerable to intermediary party error and hacking. Moreover, they either do not provide flexible micropayments paradigm or support an inordinately expensive micropayments paradigm. To provide flexible micropayments paradigm in the healthcare environment, the blockchain offers tokens or virtual currencies between peers without requiring intermediary services. Tokens are defined as a carrier of assets, which allow peers to pay values from one sector to another. Hence, the direct exchange of tokens or virtual currencies to the wallet of peers provides an immutable and secure system across the globe (Till, Peters, Afshar, & Meara, 2017). As there are no central intermediary services to manipulate the whole payment, the payment disputes will be resolved. Moreover, BC can create a cash delivery service to minimize fraud and corruption. Smart contracts directly check the transactions and exchange the tokens according to predefined rules. As a result, BC enables secure, fast, and cheap cross-border payments and allows peers to receive optimized health services without paying high fees.

### *Chronic Disease Management Strategies*

Technological progress and innovation such as artificial intelligence, wearable medical device, and the Internet of Things can assist the HIS to support a patient's health status in chronic disease management through the power of biomedical sensors and devices — from wearable to ingestible (Bardhan, Chen, & Karahanna, 2020; Xie, Lu, et al., 2021). Biomedical sensors and wearable medical devices are attached to the patient's body at anytime and anywhere, to collect physiological data which are received from the tape of the pelvis, thigh, and shank ( Marschollek et al., 2012; Zhao, Wang, Wang, Wang, & Mu, 2022). Biomedical sensors and wearable medical devices as ubiquitous parts of the future and integral parts of patient-centric healthcare delivery (Marschollek et al., 2012) enable healthcare providers and caregivers to remotely communicate, transmit data, make decisions, and receive warnings, thereby monitoring the patient's chronic disease status and predicting the onset of chronic diseases (Bardhan et al., 2020). The physiological data are related to indicators, such as respiration, blood pressure, and heart rate. However, the old and inaccurate data received from a malfunctioning biomedical sensor can lead to diagnostic errors. To satisfactorily overcome this problem, blockchain-based smart contracts can verify the access control of biomedical sensors to collect health information on the distributed ledger (Griggs et al., 2018). To support a significant problem, smart contracts can quickly pass alerts and reminders to caregivers and healthcare centers. Sensor-based HISs can improve chronic disease management by integrating artificial intelligence-assisted blockchain systems (Xie, Lu, et al., 2021).

Figure 5 shows biomedical sensors and devices that utilize blockchain-based smart contracts for supporting a patient's health status. Blockchain-based smart contracts guarantee that unauthorized users are unable to access health information without the patient's consent.

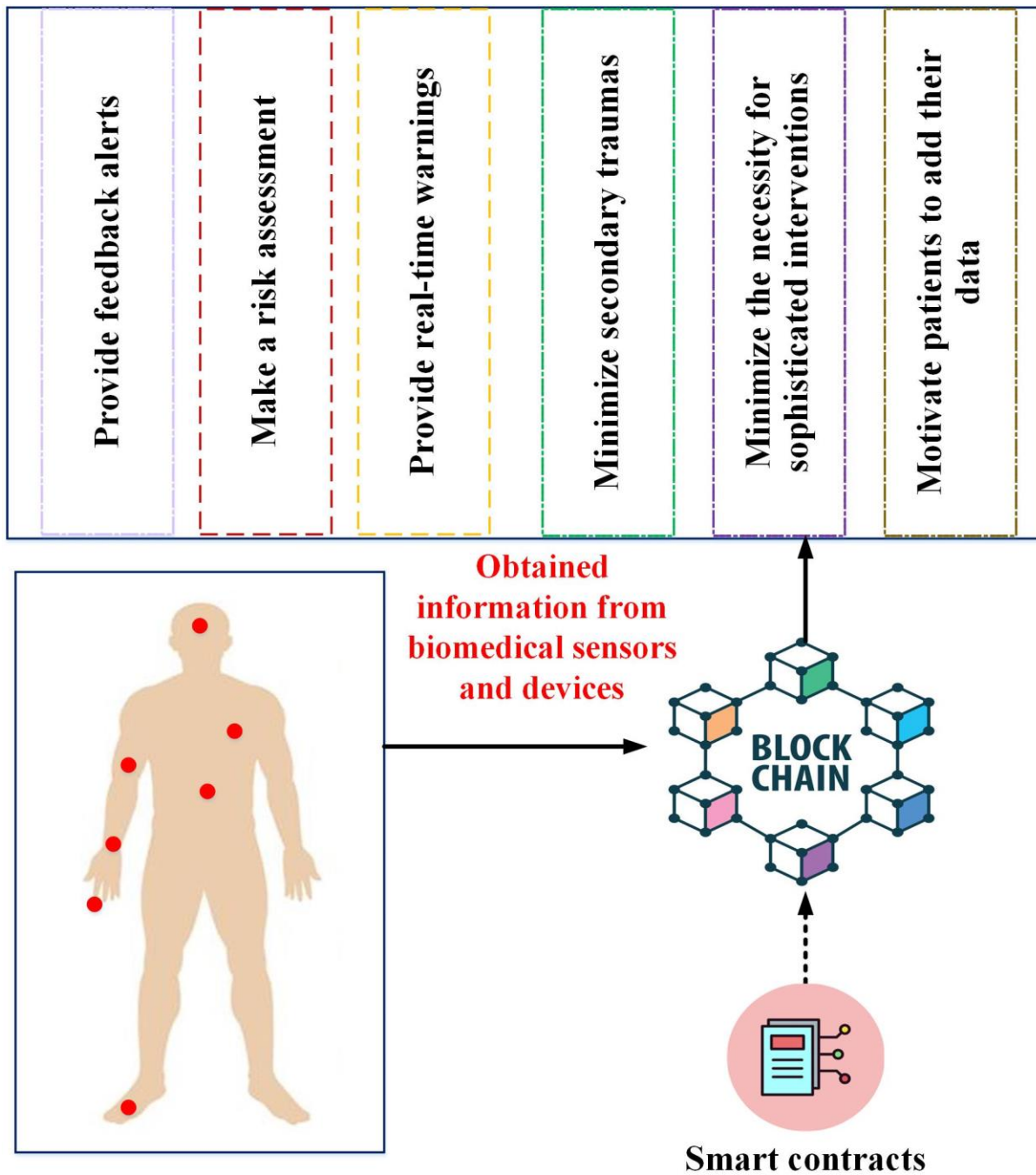


Figure 5. Blockchain-based smart contracts in chronic disease management.

### *Traceability in the Field of Counterfeit Drugs*

The pharmacy department is a subsystem of HIS that can cover comprehensive information on dispensing drugs, inventory control, and medication ordering to name a few. The pharmacy systems can minimize admissions, overcome medication issues, and strengthen electronic prescribing (e-

prescribing) across smart hospitals. Although the current pharmacy systems function well, they are controlled by various third-party sources, which increases the risk of tampering. Moreover, an illegal third-party source may enter counterfeit drugs or expired medicines into the health market and endangers the lives of innocent patients. For such a situation, BC hinders third-party involvement and maintains clarity and privacy of all assets. Blockchain-based traceability and immutability features address counterfeit drug problems in the healthcare supply chain by utilizing smart contracts on the Ethereum (Rai, Srivastava, & Arora, 2023). Interestingly, BC not only allows current pharmacy systems to trace unambiguously and reliably different drugs but also builds online trust and confidence in the HIS (Bhatt, 2023). Through the hyperledger, BC provides secure sharing of drugs in the healthcare environment and verifies the identity of sources to communicate with one another safely (Leng et al., 2021). It also eliminates abuse of prescriptions and prevents entering fraudulent drugs into the health market. Blockchain-based pharmacy systems can spontaneously provide an electronic prescription refill order when pharmacists and patients demand urgent medicine. Pharmacy fulfillment problems can be resolved through the authentication and validation of prescriptions by smart contracts.

### *Universal Health Coverage*

A robust HIS should monitor health priorities, improve high-quality services, address sustainable development goals, and achieve universal health coverage (WHO, 2021). Generally, universal health coverage can be regarded as systems that ease financial risk protection, ensure high-quality services (e.g., diagnosis, treatment, and prevention) are available to all ages, and provide urgent vaccines and medicines for all populations at greatest risk (United Nations, 2015; World Health Organization, 2023). The key point is that universal health covers all populations of all ages. Refugees and immigrants are part of this population that due to some worldwide challenges such as armed conflicts, economic pressures, human rights abuse, and violence have moved to their county. However, it remains a dream for HISs to provide migrant health data and to achieve universal rights (Corte-Real, Nunes, Santos, & Rupino da Cunha, 2022; Karim, Islam, & Bonhi, 2023). Consequently, the HISs opt for inappropriate data collection, storage, and dissemination that can lead to social injustice or ethical issues. The features of the BC are well suited to overcome today's universal health coverage challenges. To overcome these challenges, private or consortium blockchains can potentially revolutionize universal health coverage by offering secure storage of data and enabling inside and outside interoperability for health systems. Blockchain-based health system fosters interoperability as no protocols or mechanisms are needed to transfer the health data. It can also adopt on-chain and off-chain storage, which leads to better keeping migrant health data. Thus, BC improves communication and addresses health coverage gaps.



### *Clinical Trial Support Systems*

Clinical trial support systems are important software systems that collect medical, surgical, or behavioral information from the subject at intervals to evaluate their intervention or side effects (Barenji & Hariry, 2023). They are the primary way that assists researchers to ensure the safety and efficacy of a new treatment, such as a new drug, vaccination, or medical device in people. Through several trial phases, preclinical testing is undergone by human participants to evaluate the effects of an experimental drug. Due to the different purposes of each phase, different numbers of human participants are divided from small groups (10-150) to large groups (1000 or more) to undergo the preliminary efficacy of therapy over long periods (Rohilla, Singh, Sharma, Keshari, & Kushnoor, 2013). However, existing clinical trial support systems have various challenges in obtaining informed consent from a group of participants and preserving subjects' rights. BC seems to address these challenges—and more. As an innovative and emerging distributed ledger technology, BC can manage patients' consent in a transparent manner and build trust in clinical studies (Hang, Chen, Zhang, & Yang, 2022). It employs an access control mechanism implemented on the hyperledger fabric to make it easier for patients to authorize any access to their personal data. Besides, smart contracts on the Ethereum BC can also be used to ensure transparency in the consent management process (Agbo et al., 2019; Castillo, 2022) and to raise patients' awareness.

### *Patient Satisfaction*

In the clinical realm, the qualification of healthcare outcomes and organizational performance depends on patients' satisfaction, which minimizes medical malpractice claims and improves patient retention. Patient satisfaction is a common factor, which has become an interesting area for consumers, providers, and accrediting organizations to quantify how satisfied a patient is with the treatment plan (Kazley, Diana, Ford, & Menachemi, 2012). Besides, it plays a vital role in involving patients in decision-making because it correlates with improvement in symptoms. Thus, questionnaire surveys are used by hospitals to assess patient satisfaction when implementing HISs. Although questionnaire surveys are used as a metric to gauge patients' tendencies to implement HISs, they can be non-transparent and biased, which leads to dissatisfaction. The need for third parties is another challenge that not only increases overhead costs but also can lead to patient confidentiality concerns. The decentralized nature of BC appears as a safe solution to promise a tamper-proof, unbiased, and transparent collection of data (Evangelatos, Özdemir, & Brand, 2020) and preserve the confidentiality of data by employing pseudonym-based encryption. Hash functions, digital signatures, public key cryptography, and symmetric key cryptography are among the cryptographic protocols which provide confidentiality and security of data. Moreover, as it eliminates the involvement of third parties, this massively reduces costs.

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## Conclusion

In this work, we began by focusing on leveraging BC for HISs by discussing its striking benefits to improve high-quality healthcare services in a crystal clear view that is decentralized, immutable, tamper-resistant, flexible, traceable, and secure. We have explored and identified the plethora of benefits offered by BC for HISs that can assist healthcare providers and physicians to improve healthcare services effectively and enhance disease diagnosis and treatments. We presented several benefits that require further research to acquire the capabilities of the current blockchain-based HISs to provide high-quality healthcare services. The summary of our major scientific findings on a blockchain topic is discussed below:

- BC can play a pivotal role in securing health data against cyber-attacks using hyperledger fabric by utilizing fine-grained access control in patient consent systems.
- The real-time monitoring of future epidemics and disease patterns requires a decentralized-distributed system to manage infectious data during a pandemic. Thus, leveraging BC in the existing surveillance systems can create unprecedented opportunities for tracing critical data in unexpected emergencies.
- The traceability feature of BC empowers patients and healthcare providers to accurately track durable medical equipment and reduces geographic limits for moving medical equipment between un-trusted parties.
- Blockchain-based smart contracts can improve chronic disease management by passing alerts and reminders to healthcare centers.
- The high security and privacy of blockchain-based health systems build trust and overcome HIS threats.

### What was already known on the topic?

- BC has diverse applications in many areas, including but not limited to the health sectors, financial industries, government, law, and energy supply.
- HISs reduce security threats against vulnerabilities and cybercrimes.
- Conventional centralization is a significant impediment in current HIS that faces the risk of a central point of failure. Besides, information in existing HISs are prone to various major and minor threats compromising the availability and confidentiality of respective systems.

### What did this study add?

- Blockchain-based applications can foster improvements in HISs by strengthening their significant weaknesses in terms of availability, accessibility, transparency, traceability, data provenance, immutability, trust, and security.

- Blockchain offers a majority of benefits such as infectious disease surveillance systems, durable medical equipment, chronic disease management strategies, health coverage, and patient satisfaction.

### Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used Conceptualization, F.M. and A.N.; writing—original draft preparation, F.M.; writing—review and editing, A.N.; visualization, F.M.; supervision, A.N.; project administration, A.N.

All authors have read and agreed to the published version of the manuscript.

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### Ethical considerations

The authors avoided from data fabrication and falsification.

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### Conflict of interest

The authors declare no conflict of interest.

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