Blockchain's coming to hospital to digitalize healthcare services: Designing a distributed electronic health record ecosystem

Roberto Cerchione[a,*], Piera Centobelli[b], Emanuela Riccio[c], Stefano Abbate[d], Eugenio Oropallo[e]

[b,d,e] Department of Industrial Engineering, University of Naples Federico II, Naples, Italy.
[a,c] Department of Engineering, University of Naples Parthenope, Naples, Italy.

(a) roberto.cerchione@uniparthenope.it; (b) piera.centobelli@unina.it; (c) emanuela.riccio@unibg.it; (d) stefano.abbate2@unina.it; (e) eugenio.oropallo@unina.it

***Corresponding author.**

Abstract

The technological revolution in blockchain achieved the healthcare sector and offered a significant opportunity to lead this digital transformation. A significant problem is that various healthcare organizations keep numerous and fragmented patient medical records. The proposed platform solves this problem by integrating electronic medical reports in a private and permissioned blockchain to create a distributed electronic health record (EHR) ecosystem. In this context, the information processing theory (IPT) allowed us to design and validate a blockchain-based EHR system enhancing the storage of medical records and data exchange among healthcare providers and reducing environmental uncertainty. The potential benefits of the implementation of our distributed network regard clinical outcomes (e.g., improved quality, reduced medical errors), organizational outcomes (e.g., financial, operational benefits), and managerial outcomes (e.g., improved ability to conduct research, improved population health, reduced costs). Future research directions concern the application of the proposed blockchain platform to a vast extent of healthcare services and organizations.

Keywords: blockchain design, digital transition, distributed ledger, electronic health record (EHR), health and medical sectors, health care and medicine, health 4.0, information processing theory (IPT).

1. Introduction

In the last decade, digital and smart technologies have become adequate to manage large data sets in real-time, allowing faster detection and identification of diseases and supporting healthcare ecosystems to rethink their global strategies (Bardhan et al., 2020; Cobianchi et al., 2020a; Cobianchi et al., 2020b; Dal Mas et al., 2020; Ienca et al., 2020; Keesara et al., 2020; Massaro, 2021; Shu Wei Ting et al., 2020; Yoo et al., 2010). Trends in healthcare 4.0 include digital enabling technologies such as blockchain, the internet of things (IoT), artificial intelligence, cloud computing, telemedicine and big data (Biancone et al., 2021; Elia et al., 2020; Kumari et al., 2018; Nambisan et al., 2020; Rippa and Secundo, 2019; Secundo et al., 2019; Sousa et al., 2019; Wang et al., 2020). Blockchain is defined as a distributed database containing a continuously expanding log of transactions in chronological order (Centobelli et al., 2021a). Through this structure, digital transactions, data records, and executables can be managed (Andoni et al., 2019). Nowadays, the application area of blockchain technology is significantly diversified as the advantages include improvements in traceability, transparency, privacy, and security of tangible and intangible processes. Several blockchains are adopted in various domains to facilitate new value processes (Mendling et al., 2018). For instance, the chemical and pharmaceutical industries use the blockchain to simplify machine-to-machine interactions and create new markets (Sikorski et al., 2017). Blockchain can improve the way organizations conduct transactions and track items within the value chain (Saberi et al., 2019). Blockchain technology is also used by energy supply companies, start-up, technology developers, financial institutions, national governments, and academic communities (Aggarwal et al., 2019; Andoni et al., 2019; Centobelli et al., 2021b, 2021c, 2021c; Dorri et al., 2017).

As for the health and medical domains, blockchain can improve health services for the patient and the entire ecosystem. It allows creating and managing an extensive distributed database to enhance medical records and data exchange storage. Hence, recently, the medical and health sectors have used this technology (Kuo et al., 2017). Considering the integration with other enabling technologies, it is expected that blockchain will also revolutionize the IoT. In fact, most IoT devices are constrained mainly to support blockchain technology directly (Novo, 2018), and blockchain can offer IoT a platform for distributing trusted data and information (Fernández-Caramés et al., 2018). Nevertheless, the integration of IoT and blockchain should be addressed (Reyna et al., 2018), taking into account security and privacy issues (Lin et al., 2017). There is still much misinformation on the blockchain, and people could still prefer traditional applications rather than distributed ones (Gatteschi et al., 2018).

Smart contracts are IT protocols that facilitate, verify, or enforce the negotiation or execution. Starting from 2016, increasing attention has been paid to smart contracts (Macrinici et al., 2018). Smart contracts are expected to revolutionize many traditional industries (Wang et al., 2019). Besides, smart contracts in healthcare evaluate the information collected by patients based on personalised threshold values and perform real-time analysis so that transaction metadata can be recorded. Therefore, smart contracts are used in the healthcare field to perform real-time analysis and log transaction metadata for medical sensors (Griggs et al., 2018). Smart contracts, thanks to the architectural role of blockchain, can be used to improve the transparency of data management in clinical trials (Nugent et al., 2016). Furthermore, smart contracts allow automating complex multi-step processes or time-consuming workflows in new and unique ways (Christidis et al., 2016). There are many benefits to using blockchain in healthcare. A big challenge for healthcare data systems is collecting, storing, and analysing personal healthcare data without increasing privacy breaches (Yue et al., 2016). Moreover, blockchain enables data sharing securely and protect data privacy (Xia et al., 2017b). There is an innovative approach for handling electronic medical records (EMR). In fact, it is possible to provide audibility, interoperability, and accessibility via a comprehensive log (Azaria et al., 2016). However, challenges like achieving interoperability between different electronic health record (EHR) systems through nationally agreed standards, costs, privacy, security, and acceptance of electronic personal health records (ePHRs) need to be tackled. In contrast with EHRs that healthcare providers maintain, ePHRs reflect patient-related health records and are handled by the patient (Archer et al., 2011). The information in an EHR is compiled by healthcare providers and can only be accessed by medical professionals. Besides, only one healthcare provider can provide information for an EHR. On the opposite, people can maintain the influence of their ePHRs, including health information from different sources, such as various health care providers or the patient (Roehrs et al., 2017). The adoption rate by health consumers is low despite many advantages of ePHRs. To increase ePHRs' adoption, technical, individual, environmental, social, and legal factors should be managed (Alsahafi et al., 2018). According to Dubovitskaya et al. (2017), there is the possibility to develop a secure and trustable EHR data management and sharing system using blockchain. Many blockchain systems are based on an algorithm that allows scalability, robustness, and immunity, secure data sharing, and offers dependable data privacy (Hussein et al., 2018).

In this context, we use the information processing theory (IPT) to describe information management in healthcare organizations. Given the uncertainty of today's healthcare environment, the IPT is highly relevant for rapidly changing organizations as healthcare organizations. Therefore, this theory has been chosen for its potential insights into enhancing healthcare organisations' processing capacity and reducing environmental uncertainty. This theory's evidence is that organizational information requirements increase because workflows are increasingly diverse, unsettled, and interdependent (Bolon, 1998a). However, much of the clinical information on patients' treatment is still included in paper records or clinical databases. Consumers' ability to extract clinical details in a way that could be communicated to other systems, even highly modern computerized medical information systems, is restricted. Today, few products could import clinical information from external systems. Clinical practitioners are more and more required to have access to detailed and comprehensive health records to manage and share the information with and between care teams to provide a safe and efficient provision of complex and knowledge-intensive healthcare (Smith, 1996). Besides, patients also have access to their EHR to play an active role in managing their health. These needs are becoming increasingly important as healthcare progressively shifts from specialist centres to community settings and the patient's environment. The EMR is an evolution of the paper medical record. In other words, it is the tool for the organic and structured management of data referring to the clinical history of a patient in the hospital or outpatient clinics. It also guarantees the support of clinical (e.g. diagnostic-therapeutic) and assistance processes in individual episodes of care. It promotes patient care continuity between different episodes of care afferent to the same hospital structure by sharing and retrieving the clinical data recorded.

In this evolving scenario, this study aims to provide a new method for managing medical records and better sharing patient health data between healthcare facilities. More in detail, this paper aims to provide a conceptual framework for developing confidence, traceability, and transparency before and after blockchain technology implementation in healthcare processes. Research targets include the definition of a blockchain network framework, the design of a blockchain platform, and the evaluation of the potential added value. We designed a blockchain platform to prove its feasibility and demonstrate our model's validity for managing medical records among different healthcare organizations. Our prototype provides a proof-of-concept system, demonstrating how principles of private and permissioned blockchain architectures could contribute to more secure and interoperable EHR systems. With the implementation of our model, it is possible to achieve five main objectives: (1) support the planning and evaluation of care and preparation of the diagnostic-therapeutic assistance plan; (2) provide documentary evidence of the appropriateness of the standards care provided; (3) design communication tool aimed at facilitating operational integration between health professionals to guarantee continuity of care; (4) establish a data source for scientific studies and clinical research, training, updating health professionals, evaluating assistance activities and administrative-legal needs, and responding to cost-accounting needs; (5) support the legal protection of the interests of the several stakeholders to trace all the activities. It is a model that contains all the information necessary for the management of a diagnostic-therapeutic-care process, which usually includes clinical and nursing assessment information, physical examination, integrated clinical diary, medical reports, outpatient services, and other diagnostic-specialist tests (e.g., laboratory, radiologists), management of the drug cycle and nursing activities. Section 2 provides a theoretical background of blockchain implementation in the healthcare field. Section 3 presents IPT in healthcare based on trust, traceability, and transparency concepts. Section 4 presents the proposed conceptual framework using blockchain technology, with a system overview and entities. In Section 5, the technological environment has been thoroughly discussed and analysed. Section 6 reported the main phases of the EHR platform design. Section 7 addresses blockchain networks' effect on trust, traceability, and transparency in the healthcare network. Finally, Section 8 provides a comprehensive discussion, analysis, and implications of this study's result.

2. Theoretical background

2.1 Blockchain in healthcare

In the health sector, blockchain is being explored by various stakeholders to optimize processes, reduce costs, improve patient outcomes, enhance compliance, and enable better use of healthcare-related data (Mackey et al., 2019). Research on blockchain technology and its use in the healthcare sector is rising. Current trends indicate that it is mainly used for data sharing, medical records, and access control, but rarely for other scenarios, such as supply chain management or drug prescription management (Hölbl et al., 2018). The use of blockchain in healthcare systems plays a vital role in the current healthcare market. Thanks to its use, the health system can collect and verify data from various immutable sources in an automated manner and with a reduced probability of cybercrime (Tanwar et al., 2020). Healthcare data sharing is vitally essential for intelligence healthcare services, and it is possible by utilizing the blockchain platform as a storage system (Yue et al., 2016). Blockchain allows the medical data to be transferred within the healthcare system safely and shared (Wang et al., 2018). Furthermore, blockchain could facilitate patient-driven interoperability, like digital access rules management, data aggregation and availability, patient identity, and immutability (Gordon et al., 2018). According to Khezr et al. (2019), blockchain technology is an indispensable tool for pharmacists and healthcare professionals to authenticate legitimate drugs' flow and delivery promptly and adequately to patients. An exciting advantage of the blockchain is that it is inexpensive to verify a single transaction's integrity. All information is always available to the entire network and can still be verified in real-time (Dimitrov, 2019). Blockchain can be used together with big data and cloud storage as a complete solution to the problem of sparse, poorly maintained, and unorganized patient records to improve interoperability and availability of medical records (Dhagarra et al., 2019). Most blockchain platforms have similar characteristics and specialized in different technical features, such as improving the speed of transactions, improving users' privacy or anonymity, and supporting authorized or private blockchain networks (Kuo et al., 2019). Furthermore, one of the blockchain uses is to secure management and analysis of big healthcare data (Dwivedi et al., 2019). The most substantial potential of blockchain technology in healthcare is its applications such as security, integrity, continuous availability, and authentication principles due to the general ledger and block related infrastructure (McGhin et al., 2019). Furthermore, blockchain can respond to the healthcare sector's request to have high privacy and data security standards (Mamoshina et al., 2018). Patients have always been concerned about access to the medical record archive. Blockchain technology's emergence brings a new idea to solve this problem (Chen et al., 2018). Moreover, blockchain ensures constant privacy due to the stamp of medical records so that no one can tamper with them after joining the distributor's register. Patients will have the right to decide who can and cannot access their data and for what purpose (Khezr et al., 2019). Additionally, blockchain technology is also used to manage health data's secure storage (Omar et al., 2019). Blockchain allows a unique link between patients, hospitals, health offices, and health communities allowing a complete and continuous exchange of health data and the review of medical records (Wang et al., 2018).

2.2 Types of health records

Healthcare 1.0 has been characterized by a lack of digital systems. Similarly, biomedical machines have not yet been developed and incorporated into networked electronic equipment. Paper prescriptions and reports in healthcare organizations have been used widely during that period, contributing to higher costs and time. Between 1991 and 2005, the Healthcare 2.0 age had been observed and, health and information technology were merged to create healthcare systems. Visual monitoring was implemented at this point, and physicians were given imagery systems to analyse patients' wellbeing. Healthcare providers started developing online information-sharing, data-storing communities for cloud-based servers, and providing access via mobile devices to documents and patient records, allowing providers and patients to have all-around access. The introduction of Healthcare 3.0 coincided with the Web 3.0 definition to customize the distribution of patient information. User interfaces were made more comfortable and tailored to streamline and personalise the interactions. EHR and wearable and implantable systems have also been implemented to monitor patient healthcare in real-time (Tanwar et al., 2020). We have been through the Healthcare 4.0 period from 2016 to today. This period derived from Industry 4.0 paradigm, where high-tech and high-touch technologies are implemented to design blockchains enabling real-time access to patients' clinical data by using cloud computing, fog and edge computing, big data analytics, artificial intelligence and machine learning (Kumari et al., 2019). The primary objective of this period is to develop virtualization and allow customized medical care in real-time. The emphasis is now on teamwork, coherence, and integration, improving and personalizing healthcare (Tanwar et al., 2020). There are three main types of health records: 1) EMR, 2) EHR, and 3) ePHRs. EMR advantages are many, such as having unlimited patient data available, ensuring privacy, and reducing the amount of paper used. Another benefit could be a positive financial return on investment to the health care organization (Wang et al., 2003). The effective use of EMR could eventually save more than $81 billion annually (Hillestad et al., 2005). Furthermore, EMR offers many benefits, especially to primary care. There must be a plan or standard for using EMR that any insurer could promote to improve and digitize hospitals (Bates et al., 2003). Another possible benefit of EMR is identifying the causes of many conditions, including infectious diseases, non-communicable diseases and acute events, and psychological states (Ford et al., 2016). A full-text search engine can retrieve medical information from medical and electronic records (Hanauer et al., 2015). The success factors for implementing the health system are IT skills and adaptation of the system to the culture and organizational processes (Ludwick et al., 2009). Failure to use computerization can lead to missed opportunities in public health, such as providing preventive care and services (Bates et al., 2003). The introduction of EMR into the healthcare system is a significant change and involves complimentary adjustments and the innovation of practices and culture (Boonstra et al., 2010). Before investing in new information systems, doctors and their staff must discuss possible concerns about efficiency, quality, responsibility, and security (Ludwick et al., 2009). There are various obstacles to EMR adoption, which can be simply solved by avoiding the failure to use computerization can lead to missed opportunities in public health, such as providing preventive care and services (Bates et al., 2003). There are two costs associated with EMR implementation: system costs and induced costs. The first one is the cost of the software and hardware, implementation, maintenance, and support. The second one is the cost of transitioning from a paper to an electronic system, such as the temporary decrease in provider productivity after implementation (Wang et al., 2003). EMR has positive and negative impacts on the entire health ecosystem. The positive effects are the advantages over traditional methods on primary care outpatient practices regarding readability and accessibility. Positive results are time requirements for learning and training and a budget of initial costs associated with implementation (Holroyd-Leduc et al., 2011). Removing technical, financial, and legal barriers is not enough to have widespread use of the EMR. There are also psychological, social, time, organizational, and process change barriers (Boonstra et al., 2010). The main reason for using EHRs is to carry out further research on medical records or complete epidemic surveillance of infectious diseases (Ford et al., 2016). Through EMRs, clinical and social factors are available within hours of hospital presentation. Data can be analysed quickly to identify patients at risk of readmission or death within 30 days (Amarasingham et al., 2010). The use of EMR leads to improved patient care provision and greater access to clinical data and ensuring quality or manage the population's health (Hanauer et al., 2015). The information extracted from the EMR text, using algorithms, can identify various conditions of sensitivity and specificity (Ford et al., 2016). Hybrid methods have been developed to quickly extract clinical information from EHRs (Cheng et al., 2019). Besides, Feng et al. (2020), by analysing the EMRs of patients with lung cancer over the age of 65, developed a comorbidity model for the most frequent types such as pneumonia, cerebral infarction, and hypertension. Furthermore, the main reason for using EHRs is to carry out further research on medical records or complete epidemic surveillance of infectious diseases (Ford et al., 2016). Patients generally appreciate the potential benefits that computers can offer, such as sharing, integrating, and evaluating information when used for their direct care. However, many patients are concerned about open access to electronic databases (Perera et al., 2011). If patient data security is ensured, hospitals may be more inclined to adopt EMR. In this way, hospitals can easily exchange patient information (Miller et al., 2009). Patients can share their health data with EMR but, at the same time, require different types of privacy and so granular privacy control (Caine et al., 2013). The digitally stored EHR of the healthcare system aims to facilitate quality of treatment, education, and study to guarantee confidentiality. The EHR is an instrument to support the continuity of care and, therefore, the consistency, access, and efficiency of healthcare service (Iakovidis, 1998). Improved transactions involving medical records, insurance billing, and smart contracts have led to breakthroughs in blockchain technology based on EHR that enables the security of the data and transmitting transactions. A critical benefit of implementing blockchain technology in the health sector is that it can reform healthcare databases' interoperability, enhance access to medical patient records, monitor devices, and insert drug databases (Tanwar et al., 2020). Moreover, EHR systems help users retrieve information quickly, interact easily with others, and improve user performance (Iakovidis, 1998). A variety of EHRs are currently being created to arrange the clinical content. They are different in terms of interoperability, content structure, access services, multimedia support, and protection (Eichelberg et al., 2005). These different EHR have in common the access to patient data, reliability, data integrity, consistency in agreed-upon format and for a given period, accessibility and versatility, providing the details generally in few seconds and assuring security and suitability (Iakovidis, 1998). With the introduction of EHR, there have been benefits for doctors and patients. Analysing EHRs made it possible to identify, predict, and classify different diseases as acute myocardial infarction (Coloma et al., 2013). It is not difficult for any healthcare provider to evaluate the immediate advantages of using EHR and the usability, comparability, collaboration, and confidentiality of administrative and clinical data (Iakovidis, 1998). ePHR refers to an electronic program in a personalized, safe and confidential environment where patients visualise, exchange, and maintain their health information (Pagliari et al., 2007). ePHRs have been developed to improve the use and interoperability of EHRs. Although EHR systems support medical professionals' knowledge needs, ePHR systems serve patients and medical professionals. Health technologies with ePHRs now play a vital role when tracking data, such as dietary information, blood markers, gait, stress, sleep patterns, and tremors, in patients' preparation, recovery, and monitoring. They also help users record their intake of medicines (Koumaditis et al., 2018). It can be helpful because we never analyse our body and behaviour (Lupton, 2013). With vast medical data sets generated by mobile, patient-oriented ePHR infrastructure, every day reveals new insights and provides new therapies and methods to enhance patient well-being (Dohan et al., 2014). In exploring ePHR literature, different fundamental designs can be differentiated for ePHRs with variances in architecture and functionality (Kaelber et al., 2008). Detailed medical data from mobile patient infrastructure stored in ePHR infrastructures every day show new knowledge and pave the way for new therapies and approaches to improve patient's well-being (Dohan et al., 2014). Today, paper on ePHRs is still used daily, even if there is the availability of digital media. By comparison, tethered personal health records act as a digitized and automated framework that incorporates EHR and ePHR mechanisms to enable patients to access their health information stored on their medical providers' systems. The ePHR system may also contain additional features that allow patients to apply for appointments and recruitment renewals, even interact with clinicians or expert systems in tethered or connected configurations (Koumaditis and Hussain, 2018).

3. Information processing theory in healthcare

Information Processing Theory's roots are centred on how organisation structures knowledge and how it is used (Galbraith, 1973). Galbraith analysed organizational variations focused on using knowledge to minimize tasks ambiguity. In the context of organizational decision-making, information processing was described as selecting, interpreting, and summarizing information (Tushman et al.,1978). The theory of information processing complements blockchain's understanding of the healthcare field. The care standard consists of detailed, tangible findings that are objectively assessed as a set of binary responses to whether patients genuinely achieve to receive particular evidence-based care (Gardner et al., 2015). Blockchain is essentially an information technology; hence, the IPT supports the knowledge of the effects of blockchain on processes (Martinez et al., 2019). There are three sources of task instability in the healthcare field, typical of hospital conditions (Tushman et al.,1978). First, task features include the variety of tasks and interdependence of tasks within units. Second, external and static vs dynamic environmental controls define the sub-unit task environment. Third, the inter-unit role interdependence is the sub-unit's ability to interact with other units to share and organize information. In organizations, ambiguity can be minimized by an iterative cycle where management evaluates situations with increasingly detailed questions and then form their behaviour based on answers. The IPT focuses on connecting environmental uncertainty (cooperation and sharing of information in healthcare), information processing (analytical capability), and organizations adaptation requirements (organizational flexibility) (Zhu et al., 2018; Srinivasan et al., 2018).

3.1 Information sharing

Information sharing is considered an essential component of the organization since it promotes enhanced performance. The knowledge and sharing of health data allow continuous monitoring of patients and helps prevent diseases, thus improving the patient's quality of life. It links individuals, technology, and processes to improve healthcare through knowledge management (Myllärniemi et al., 2012). With the growth of communication technologies, today's geographical gap cannot prevent the exchange of information and knowledge transfer (Shi et al., 2020). Information sharing in the health sector can start using cloud technology, enabling EMRs. Undoubtedly, cross-institutional electronic patient records' security and privacy protection are critical, particularly for exchanging health information (Guo et al., 2012). Systems such as mobile social health networks have grown as a promising next-generation health system to enhance quality significantly. However, updated privacy policies are needed before personal health information is shared with other parties (Jiang et al., 2015). Efficient knowledge sharing management can improve organizational productivity through investments in new technologies. In creating new knowledge through teams, exchanging information based on experience is essential. The dialogue required for team decision-making enables the implicit articulation of knowledge and provides the chance to generate new knowledge (Quinlan, 2009). Exchange of know-how includes learning and organizational skills, error reduction, high team cooperation, more significant technical resources, a high level of support, and lower costs (El Morr et al., 2010). Professionals must be open-minded in their choice of tactics, be versatile in supplying information. The desire to build should rest on the team's social responsibility, share their recent experience, and explore new and better solutions. More probable healthcare professionals willing to share knowledge are more likely to innovate (Radaelli et al., 2014). Managers must also establish and implement programs to respect other team members' input and improve autonomy and knowledge sharing. Knowledge management and information exchange are essential to improve patients, doctors, staff, and healthcare managers' lives and understanding (Van Beveren, 2003). The digital transition is transforming, in particular, the way healthcare professionals access data, handle information and manage knowledge through the adoption of 4.0 enabling technologies (Centobelli et al., 2021). Singh et al. (2018) suggest that when medical professionals share their expertise externally, it is not a matter of earning prizes, such as financial rewards, but benefiting others. As hierarchical structures vary from the sharing of tasks, error discipline, individual recognition, or award programs, creating knowledge-sharing practices is tricky for organizations. Hospital directors and managers must have an environment where results can be easily communicated and any errors improved (Kim et al., 2012). The development of the contact network and the knowledge exchange, while growing socialization, are increased through horizontal and vertical integration in healthcare firms.

3.2 Information processing as analytical capability

Information processing capability is an organisation's capacity to collect, analyse, and synthesize information efficiently that facilitates decision-making (Tushman and Nadler, 1978). The capabilities analysis are continually learned and improved before operating routines in a specific context and become dynamic capabilities. There are three operational routines: learning mechanisms, accumulation of experience, information articulation and codification (Zollo et al., 2002). Today's highly networked world offers organizations the possibility to capitalize and compete for their information processing capacity through integrated technologies that produce vast data quantities (Sahay and Ranjan, 2008). Analytical capability refers to analytical techniques typically used in a big data analytics system to process data with a considerable volume, variety, and velocity via a single data storage technology (Chen et al., 2012). Analytical capability in healthcare can detect care patterns and identify associations from extensive medical records, giving a broader view of clinical practice based on evidence. Healthcare analytics provide solutions that satisfy an increasing need and allow healthcare companies to manage large amounts of data in parallel, manipulate in real-time or near real-time, and record all visual data or medical data of patients. The information processing (the analytics capability) of an organization is accompanied by organizational flexibility (Martinez et al., 2019), and it is correlated positively with collaboration and operational performance (Iyer, 2011). Industry 4.0 technologies can facilitate the information processing capability process, especially in healthcare. In fact, through the cloud, it is possible to collect information, which is patient health data in a medical case. The data can come from two different sources. The first one is automatically stored for devices with wearable sensors that continuously monitor the patient's vital data. Data monitoring can enhance communication and knowledge between the patient and the health specialist using body sensors or specific applications. According to Pramanik et al. (2020), many people, devices, and sensors are linked across digital networks, which generate massive data. The second one is done manually by the doctor after evaluating the patient's health status and then entering the medical record electronics.

Moreover, healthcare information and communication, support for informed choices, EHRs, practical societies, and advanced healthcare planning are numerous change opportunities in the healthcare field (Shahmoradi et al., 2017). The data analysis process is facilitated by big data analysis technology. The big data analysis system can then send health data to personalize healthcare, health predictions, and statistical evidence on strategic government planning (Jiang et al., 2016). According to Wang et al. (2018), different big data analytical competencies have been found, such as analytical capabilities for care models, analytical capability for unstructured data, capacity for decision support, prediction, and traceability. Big data analytics have been developed to help companies use information (Chen et al., 2015) to gain a competitive edge in organizational readiness and data protection as a specific information processing capacity (Dutta and McCrohan, 2002). While broad data analysis methods, frameworks, and software are realized in different fields, they have yet promising research directions for the health care organization to incorporate and deliver new solutions in possible healthcare applications (Palanisamy et al., 2019). The use of blockchain technology facilitates analytical capability. Furthermore, blockchain is a promising technology to drive organizational efficiency and create new revenue models for competitive advantage (Martinez et al., 2019). Blockchains allow clinical data to be accessed in real-time by cloud and big data analytics (Kumari et al., 2019). This technology is used to exchange information about health among patients, hospitals, health providers, and healthcare groups (Wang et al., 2018). Blockchain is seen as an organization's ability to program and process information involving intrinsic analytic skills (Martinez et al., 2019). Moreover, blockchain enables patients to continuously exchange and track their medical data securely without any privacy breach. The continuous safety cycle changes the whole health system through this technology (Yue et al., 2016).

3.3 Organizational flexibility as trust, traceability, and transparency

IPT is related to operational efficiency, in which organizational flexibility integrates an organization's analytical capacity. The basis for analytical capacity is transparency and demand visibility (Srinivasan and Swink, 2018; Zhu et al., 2018). An organization is flexible when adapting to its environment in several ways. Since the transition between reactions requires cost set-up, versatility can damage performance. However, organizations have to take care of agile responses (flexibility) and productivity in an environment of globalization and fast-changing organizations (Phillips and Tuladhar, 2000). A flexible structure and organization in healthcare are not straightforward. According to Van Rossum et al. (2016), the versatility of workforces, an operational culture should be developed to allow people from various units or disciplines to collaborate without obstacles. It stimulates the multidisciplinary work needed and optimizes the whole process flow. Organizational versatility is considered a means of adapting rapidly to new or changing environments. This topic received much attention from researchers and managers to help organizations survive and succeed in turbulent, uncertain environments (Sopelana et al., 2014). Theoretical discussion of how flexibility can be achieved includes developing dynamic capacities, maintaining multiple options, and supporting horizontal communication and teamwork (Englehardt and Simmons, 2002). Blockchain technology's high degree of flexibility is one of its main advantages. It also improves the versatility and openness of organizational capability. Below, we discuss blockchain technology's role in creating trust, traceability, and transparency in healthcare processes. Trust demonstrates an exchange of partner expectations on which the other party can rely, comply, and act reasonably (Nakamoto, 2008; Glaser, 2017). Trust is one of the main features of blockchain technology (Notheisen et al., 2017). In healthcare, there is always a large flow and exchange of data between hospital members. Big data in healthcare are collected from several sources, including clinical research, electronic records, patient databases, and imagery. All this data comes in a wide variety of formats and from various data streams. For patients' benefits, the data must be analysed and interpreted promptly (Karafiloski and Mishev, 2017). However, physicians need new ways to monitor, share, track data to provide instant input for specific patients. Furthermore, blockchain enables all patient data histories, including structured medical records, mobile apps, and wearable sensors, to be shared (Karafiloski and Mishev, 2017). Simultaneously, the distribution of medical information poses several dangers to patients' privacy because malicious acts seriously damage the integrity and finances of all parties involved in the data, directly and indirectly. Blockchain protocols are distinguished by an immutable record of transactions, which incorporating a distribution basis with chronological and cryptographical references through decentralized consensus mechanisms (Nofer et al., 2017). In line with Xia et al. (2017a), much research tackles the issue of exchanging medical data in a trustless world using blockchain technology. Organizational trust is an increasingly critical factor in assessing workers' success and engagement in today's healthcare work environments. It is essential to study the impact of corporate trust and empowerment on two forms of corporate involvement (Laschinger et al., 2000). Blockchain-based, trust-free systems enable the revolution of interactions that demand great trust, typically facilitated by third-party providers (Hawlitschek et al., 2018). Blockchain is a progressive solution to current technical problems such as decentralization, trust, identification, data ownership, and decision-making based on data (Karafiloski and Mishev, 2017). Moreover, blockchain offers a shared and open history of all transactions to create credibility, accountability, and transparency applications. The use of this technology offers an exceptional opportunity to build a safe and reliable EMR information management and sharing system (Dubovitskaya et al., 2017). Traceability is the ability to monitor production data from any IT aspect of the system in all service units of the organization. Medical data, such as behaviour and cost data, clinical data, pharmaceutical research and development data, patient behaviour, and emotions are typically gathered in real or nearly real-time from medical and non-medical stakeholders (Groves et al., 2016). On the other hand, big data analytics algorithms allow approved users to enter major national or local data pools and simultaneously collect patient information from various healthcare systems or devices. This eliminates tension between healthcare industries and reduces challenges in connecting the data to the process optimization workflow. The primary purpose of traceability is to make data reliable, accessible, and easily analysed (Wang et al., 2018). A traceability system enhances service levels in combination with the restructuring processes (Bendavid et al., 2012). Via tracking all the data sets generated by different systems and devices, the traceability of medical services allows monitoring connections between patients' needs and potential solutions. The addition of information from RFIDs in big data analysis systems also helps hospitals take swift steps to optimize medical supplies usage and minimize patient flow delays (Wang et al., 2018). The RFID traceability of medical goods can significantly improve the health supply chain (Bendavid et al., 2012). Transparency is the third goal of the blockchain. It is the degree to which both the counterparty and the observer can quickly obtain information (Bai and Sarkis, 2020). Therefore, transparency is an essential parameter in evaluating healthcare efficiency, given the emerging security environment. Transparency in healthcare aims at growing healthcare comprehensibility and quality through creative IT. It is essential to keep track of the collection of consents through blockchain technology, demonstrate the data's integrity and consistency from the perspective of the involved parties, and allow them transparency, accountability, and power (Benchoufi et al., 2017). As an emerging technology, blockchain has several useful features, including confidence-free, transparency, pseudonymity, democracy, automation, decentralization, and security (Xie et al., 2019). According to Jaffe et al. (2006), transparency enhances decision-making and improves performance measures. Blockchain technology introduces a paradigm change from a more general and forward-looking perspective to the entire field of clinical science (Benchoufi et al., 2017). Dubovitskaya et al. (2017) offer a standard, permanent and open record of all transactions to create applications with trust and transparency. The purpose of the blockchain is to introduce a mechanism that requires informed consent obtained from patients, subject to procedure examinations, storing and tracking consent, and to allow the exchange of this information in real-time in a safe, non-falsifiable, and publicly verifiable manner (Benchoufi et al., 2017). Blockchain mitigates adopting of a centralized authority to certify information integrity and ownership and mediate and exchange digital assets while allowing for secure and direct interaction agreements. Technology has essential features, such as immutability, decentralization, and transparency, which may address important healthcare issues like incomplete care records and demanding access to patients' health information (Zhang et al., 2018).

4. Conceptual framework for blockchain technology in healthcare

4.1 System overview

Figure 1 is a general scenario for user-centric personal health data sharing and includes five central nodes, including patients, wearable technologies, healthcare providers, the cloud database, and the blockchain network. The patient can grant, deny, and revoke consent to his data to doctors and medical wearable devices. Doctors have access to patient data, store it with cloud technology, and share it with other healthcare facilities using blockchain technology.

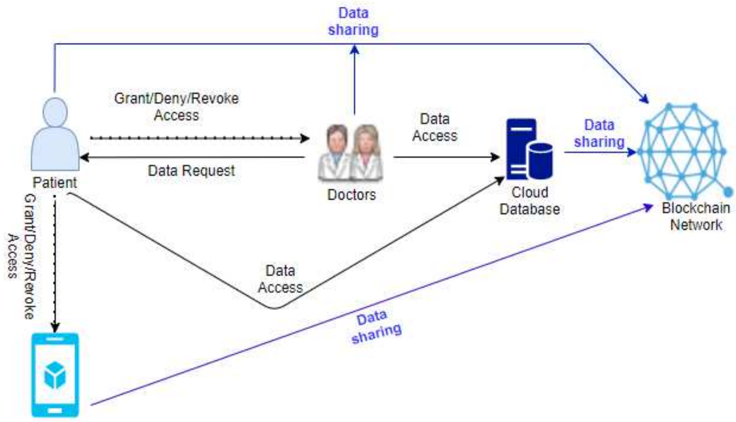

Figure 1 Personal health data sharing

4.2 System entities

Users are all people who can access the patient's health data. The new healthcare paradigm will help providers work efficiently and keep patients linked to wearable devices and other monitoring tools. Furthermore, the patient offers his approval to visualize and share the data collected by wearable devices or medical visits at health facilities. The patient has a complete view of privacy, and if the treatment is finished, can revoke access to health data at any time.

With *technological devices*, original health information is translated into the readable human format, and data is then synced into an online account by the user. A variety of wearable devices and medical devices are connected to each account. Wearable sensors can be built into wearable items or directly with the body to monitor and provide clinically relevant healthcare information. With wearable device sensors, real-time health data can be continuously uploaded into the integrated ePHR database. Wearable sensors will transmit the health data collected to a gateway for real-time transmission to an integrated ePHR database server.

The healthcare provider collects and stores data in a more patient-controlled information management system. Physicians and nurses are responsible for protecting patients' health and safety, risk assessment, and health surveillance inside the health structures. After the patient's medical examination, all the patient's health data is uploaded to the blockchain network to be seen by other health facilities with access to it.

Blockchain network is used for more factors. The first is to collect health data; each hashed data entry is submitted into the blockchain integrity security network from wearable equipment and healthcare providers. The second is to obtain the data owner's permission with a decentralized permission management protocol. The access by healthcare providers to patients' health data should be processed for data access requests. The access control policies should be stored on the blockchain in a distributed way to ensure stability. Besides, each permission request and access operation should be registered on the blockchain for further auditing or investigation.

Cloud database stores data related to users' health, data access, and data control policies. Data entry is responsible and traceable. Data can be directly entered automatically by wearable devices or by doctors. The data is always accessible and available and can be removed, if necessary, at any time.

5. Technological environment

The blockchain is technology-based upon the distributed database logic. The data is stored on many interconnected and distributed nodes, not on a centralized server. The blockchain enables the current data management to be innovated through a mechanism that links distributed cryptographical primitives, guaranteeing identity protection and traceability. The key benefit of distributed networks is that knowledge is accessible on all network-related devices. Two critical processes that ensure the correct operation and minimize the amount of information lost to zero are the basis of this database type:

- *Database replication*: software for detecting logical internal changes to the database, which can then reproduce changes to all devices linked to the medical network.

- *Duplication:* This ensures that the same data are accessible on any device linked to a medical network. This process enables a master database to be established as a model duplicated on the other network machines.

The blockchain operates based on the following components:

- *Knowledge and data exchange*: The logical care unit that coincides with patient data and medical knowledge sharing and exchange

- *Node:* a single blockchain actor is portrayed, and a server is physically constituted

- *Block:* a logical unit representing the unification of a series of transactions to be reviewed, accepted, and archived grouped

- *Ledger:* master book with documents, orders, and sequent orders of all transactions

- *Hash:* an uninvertible algorithmic feature that enables a single line with a predefined length to represent a text and numeric string of variable size.

Blockchain is a new technology, and in this sense, the block is defined by the collection of linked transactions, which must be verified, endorsed, and stored by the nodes in the network. Therefore, the block may be viewed as a transaction container, and within, there is helpful information to recreate the blockchains shaped temporarily and spatially. Each block contains a hash in its header, which registers its information in position "n". The information concerning the block in position "n-1" the whole chain of blocks can be constructed on that principle. The hash or fingerprint is the product of an algorithm called the hash function. Two key features of the hashes are the following: 1) the functions are characterized by a string with arbitrary input and a given length (output); 2) the functions are irreversible, and it is not possible to trace and produce the start string from the knowledge of the output string. One example is the SHA-256, one of the most popular hash features used to get a 64-character-long alphanumeric string regardless of the arbitrary starting string length. The hash allows developing a spatial cartogram for the whole blockchain, which is continuously modified with new blocks. The hash allows the creation of a single and stable identity. Besides the hash, time stamping is also implemented in the block. This practice consists of a specific sequence of characters, which allows the block and consequently the transactions it contains to be identified clearly. This timeline allows the development of a timeline chart to understand the sequence of the transactions. It is essential to know the hash and the temporal brand in a distributed system applied to a blockchain to reconstruct the chain of blocks spatially and chronologically. Instead, the transaction contains 1) the sender's and receiver's IP address; 2) the cryptographic signature required to guarantee the transaction's security; and 3) the content and the transactions' characteristics. The number of transactions varies continually over time. It is possible due to primary cryptographic devices, which ensure the system's proper functioning on all network nodes. Besides, the transactions are invariable; any alteration needs the approval of all nodes in the network. The complete openness and unchangeability in the ledger are registered for all transactions. The booklet can be taken as a combination of a few blocks interconnected with primitive cryptography and hash. The blockchain is the achievement of the distributed ledger, the development of central and decentralized logic. In centralized logic, each transaction (centralized leader) is governed by a central node with centralized authority, acts as an intermediary, and verifies information accuracy and security. There is no single centralized authority in blockchain decentralised logic, but more central subjects are generated by local centralization. There is no crucial point of weakness in blockchain platforms that can disturb the system. These features differentiate the blockchain significantly from centralized databases. By altering a transaction within a block, the value of that particular transaction must be changed. Thus, the block in which that particular transaction is located is changed. This transition should also be replicated simultaneously with current technologies. These factors ensure the protection of the network details. The process to communicate with the system relates to the mechanism that leads to the formation of blocks starting from transactions: 1) creating the transaction and the public encryption key; 2) establishing the block containing the transaction mentioned above; 3) checking and consent from health network partners for the block; 4) verifying the healthcare network of the truthfulness of information; 5) analysing previous network block tests and supplements; 6) validating the transaction; and 7) publishing in the record of the transaction.

6. Design of the blockchain platform

A great deal of time and money is spent on coordination and communication in healthcare. Since most systems are not designed to communicate effectively with other systems, it becomes impossible to coordinate and manage benefits across many parties. The current coordination of care model calls for considerable manual effort on all parties, including patients and doctors, managers, and employees. Blockchain technology can significantly improve healthcare outcomes by reducing administrative costs and duplication, waste, abuse, and fraud. This network can drastically reduce the unacceptable administrative burden on healthcare professionals and strengthen personal care experiences. Rather than allowing anyone with an internet connection to be part of the transaction verification or allowing only one organization to complete control, we propose a private blockchain that benefits efficiencies and confidentiality of transactions. The proposed blockchain network is convenient for more actors in the healthcare field. It makes it easy and convenient to control their health care for people. They can share documents, manage prescriptions, view information on personalized care, and manage benefits. It allows physicians and carers to reduce administrative burdens, improve care results, and allow more time for actual care delivery. They can accurately and adequately handle the medical records, manage the consent, evaluate the prescription, and coordinate with specialists, laboratories, and therapists. The blockchain network addresses the core need to coordinate all parties and communicate all relevant events and circumstances using a distributed ledger approach that provides the right party with relevant information and conditions. This section includes information about developing and applying an EMR and ePHR blockchain system. The three principal design phases are as follows:

1. Problem identification
2. PoC design and deployment
3. Network modelling

The following paragraphs contain a detailed description of each phase.

6.1 Phase 1 - Problem identification

The first activity consists in defining and justifying the value of a solution to the specific research problem. Since problem definition is used to develop an artefact that can provide a solution effectively, it also is helpful to conceptually convert the problem to capture the complexity of the solution (Peffers et al., 2007). Patients have their health information spread over multiple systems, hospitals, networks, and potentially countries in the current healthcare system. There are multiple fragmented records from the same patient, held at different institutions, all with their snapshot of the patient's health at the point of their interaction with them, such as blood tests, imaging, and clinic letters. A potential solution to significant challenges, such as smooth communications, inefficient reporting, and fragmented health records, can be represented by blockchain (Zhang et al., 2017). Knowledge discovery and methods for machine learning may be used to discover, classify, and predict novel patterns in data, such as results or risk assessment. This methodology can extend current decision-making support systems that integrate the patient data available with clinical guidelines to support the doctor at the point of care (Jensen et al., 2012). The development of infrastructure for national health information is ongoing, and it is based on research and development projects in various countries around the world. Those projects share several elements in the joint framework, which include (1) the involvement of patients in using their health records; (2) the necessity to establish core information of such records; (3) the choice and implementation of standards, nomenclatures, codes, and vocabulary. The most appropriate way to establish interoperability is by creating a patient summary. For instance, it can be included in the patient summary, an allergy, functional problems, test results, and medications. However, additional information may be provided, depending on the aims of the summary and the anticipated use context. Furthermore, it is necessary to investigate the amount of the patient summary's structured data (Häyrinen et al., 2008). There is a growing need for EHR systems throughout the world. Structured EHR data, such as encoded diagnosis and drug information, are the most easily processed data sources. However, advances in text mining methods have also allowed the analysis of narrative parts in the patient records. Statistical distribution and coincident clinical characteristics studies in large data groups can identify the correlations between diseases and drugs and adverse drug reactions (Jensen et al., 2012). Improving the interaction of the components of a system is essential to the attainment of system goals. It means that effort to understand how the use of EHR is associated with practice communication patterns can provide helpful insights into the design, implementation, and management of EHR systems to support the complex work of healthcare professionals (Lanham et al., 2012). The quantity and quality of the information available to healthcare professionals impact patient care outcomes and the continuity of treatment. The information contained in EHRs has various functions and supports decision-making in health policy and management. EHRs consist of unstructured, coded, and structured narrative texts. More systematic terminologies and codes will be needed in the future to use better the data contained in these documents in clinical research, health care management, health services planning, and the government's report (Van Ginneken, 2002). In contrast, the increasing emphasis on adopting EHR systems must be accompanied by financing and strategic data research, interoperability, and security standards. The right balance between public autonomy and privacy requirements and procedures for accessing data should be stipulated between legal issues such as data ownership, privacy, and consent. Collaboration between stakeholders and research groups will be necessary to realize the real potential of electronic health data for scientific discovery and improved public health (Jensen et al., 2012). Many types of research connect EHR to safer, higher quality, and more efficient care (Buntin et al., 2017). However, there are still challenges in achieving more comprehensive benefits through EHR use (DesRoches et al., 2010). One of the hurdles preventing EHR use by medical systems is the wide variety of methods used by medical professionals. For instance, doctors' preferences on clinical documentation can differ widely in the same practice, creating conditions where doctors decide to interact directly with EHR. In contrast, others rely on nurses or health workers to document clinical meetings in EHR. This example shows how the health system faces challenges regarding how much variation should be encouraged or allowed using EHR (Lanham et al., 2012).

6.2 Phase 2 - PoC design and deployment

The Proof of Concept (PoC) in computer science offers a realistic demonstration of a software app's basic operations or a whole digital system. The PoC incorporates it into an already existing environment. The PoC development demonstrates a flaw in a program or computer system that can allow unauthorized access or compromise the data's functionality. Modularity that allows defining the consensus process and membership management is a distinctive feature of the blockchain platform. It also provides the opportunity to create private channels that enable a group of participants, namely a fundamental requirement for creating an offering blockchain, to create a ledger, where transactions are registered personally and only by the nodes participating in it. Blockchain technology is currently set up on-site. Installing on-site software means installing it on a local computer, for instance, a machine that lives inside or is owned by an organization (an organization server).

6.3 Phase 3 - Network modelling

The network model in Figure 2 defined the players involved as nodes in creating the blockchain platform.

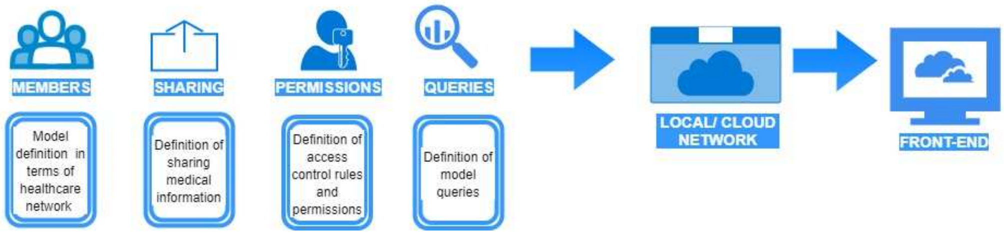

Figure 2: PoC system and implementation of the blockchain network

Patient data may come from various primary sources such as technological devices, laboratories, radiology and can subsequently be analysed and evaluated by the pharmacy, hospital medical team, and medical professionals. Later, with the private and permissioned blockchain network, creating the EMR and sharing it with cloud technology to the patient, caregiver, or other healthcare providers is possible. This system allows patients to add records. The modified transactions would then be distributed across the network, ensuring that each network transaction is distributed to all system participants and that no unauthorized users can alter or delete each transaction. Records in the blockchain network are updated and are available to all users. Providers can query necessary data over their network, including clinicians and laboratory personnel. When the patient offers access to the EHR ledger network to access and update his documents, the participant will visualize and update the patient's certification record. The electronic health record is a vital tool to promote the individual patient's treatment. It is a collection of personal health data on an individual's life stored at the treatment stage. The critical technical difficulty in applying these distributed electro-medical record systems consists of accessing this information by the approved professional and the stored data in a structured way (Iakovidis, 1998). Our healthcare network includes eight nodes (Figure 3):

1. *Technological devices (TD):* This node comprises home medical devices, health apps, and medical wearable devices. Medical devices (home or private facility) are a category of devices used for patients whose care is managed by a nonprofessional caregiver or family member. Health apps are applications to improve and monitor wellness. Safe wearable devices include different types, including wearable activity trackers, smart health watches, wearable ECG monitoring devices, wearable blood pressure monitoring devices, and biosensors.

2. *Laboratories (L):* the medical record can be combined with various specialities such as laboratory tests and diagnostics stories based on user profile's needs.

3. *Radiology (R):* radiography is the simplest, cheapest, and most readily available way to visualize and evaluate bones and some anatomical components.

4. *Healthcare provider (HP):* this node comprises three hospital figures as doctors, nurses, and pathologists.

5. *Health professionals (HP):* this node comprises medical professionals to whom patients can analyse health data.

6. *Pharmacy (P):* this node comprises the pharmacist specializing in drugs and all products for health and well-being, which deals with the correct dispensing, the proper dosage, adherence to therapy, and side effects of the drugs.

7. *Cloud database (CD):* this node represents the database containing all health information accumulated through hospitals or wearable devices.

8. *Patient/Caregiver (PC):* this node is represented by the patient and the caregiver. The caregiver is that person who takes care of a child, parent, or another family member who is disabled or who is not self-sufficient.

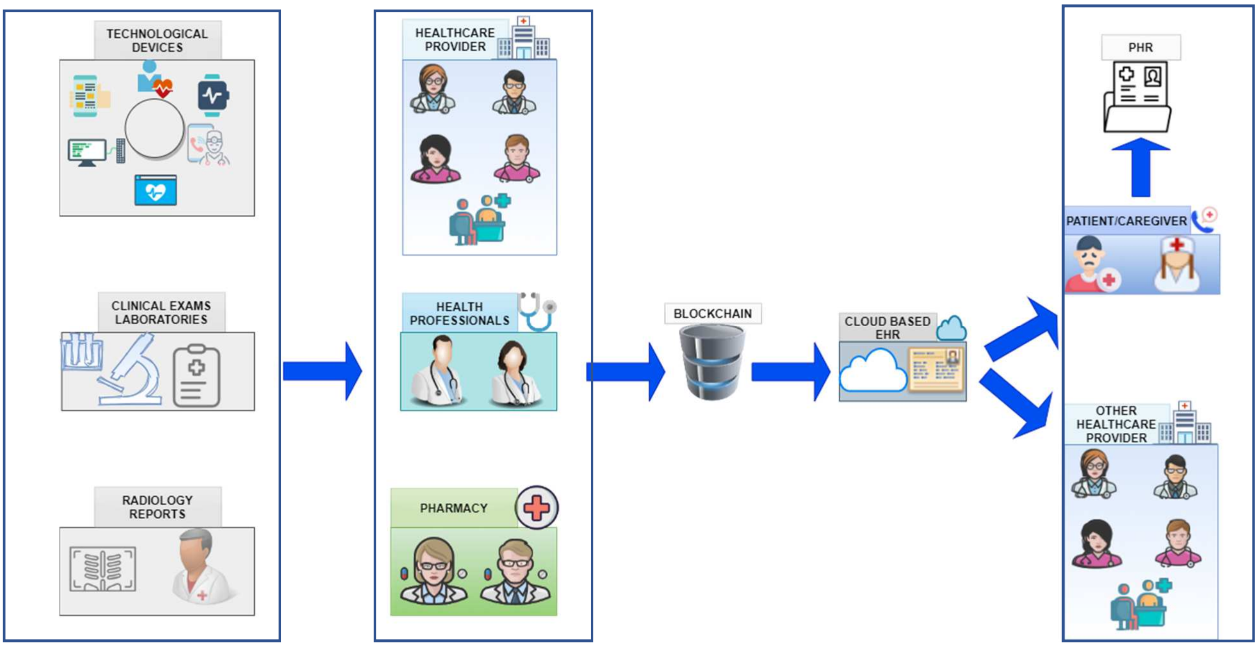

Figure 3: Private and permissioned blockchain network

The key features required to define blockchain partners are illustrated in Figure 4. These features have defined the critical functional criteria for implementing the blockchain network. Functional specifications allow transactions to be displayed and accepted. The healthcare providers, healthcare professionals, radiologists, and pharmacies have full permission to view and authorize transactions based on a private and approved blockchain model. In contrast, the patient and caregiver can only visualize and accept their transactions.

PATIENT

```
participant Patient
identified by Patient_ID {
 o String Patient_ID
 o String Patient_name
 o String Patient_medicalhistory
 o String E_mail
 o String Telephone
}
```

HOSPITAL PHYSICIAN

```
participant Hospital Physician
identified by HP_ID {
o String HP_ID
o String HP_name
o String HP_localisation
o String HP_manager
o String E_mail
o String Telephone
}
```

PHYSICIAN

```
participant Physician
identified by Physician_ID {
 o String Physician_ID
 o String Physician_name
 o String Physician_localisation
 o String Physician_specialization
 o String E_mail
 o String Telephone
}
```

PHARMACIST

```
participant Pharmacist
identified by Pharmacist_ID {
 o String Pharmacist_ID
 o String Pharmacist_name
 o String Pharmacist_localisation
 o String E_mail
 o String Telephone
}
```

RADIOLOGIST

```
participant Radiologist
identified by Radiologist_ID {
 o String Radiologist_ID
 o String Radiologist_name
 o String Physician_localisation
 o String E_mail
 o String Telephone
}
```

CAREGIVER

```
participant Caregiver
identified by Caregiver_ID {
 o String Caregiver_ID
 o String Caregiver_name
 o String Caregiver_history
 o String E_mail
 o String Telephone
}
```

Figure 4: Identification of blockchain partners

7. Discussion of results

In line with the IPT, organizations are complex systems whose primary problem is acquiring and using information concerning their environment. An organization's primary objective or function is to develop the best configuration to enable information gathering, processing, and diffusion. Different structures have various capacities at the organizational level of analysis to effectively process and reduce uncertainty (Tushman et al., 1978). An organization is more efficient when information processing requirements have matched. As the environment changes over time, organizations adapt their services to satisfy information processing requirements. The information processing perspective is widely applied to health services institutions, given the wide variety of healthcare organizations and the uncertain environments in which they operate (Bolon, 1998). The designed blockchain platform is not just a PoC. It is also a pilot platform to analyse the new ways health information is shared and discussed. Consequently, three factors are processed by checking for pre-and post-implementation: 1) information sharing, 2) processing capability, and 3) organizational flexibility, including trust, traceability, and transparency.

7.1 Blockchain effect on information sharing

The use of EMRs in hospitals can simplify the activities of all health professionals. Implementing our blockchain system for using the EMR allows storing more structured information, facilitating the information retrieval that all health teams can share. The shared EMR allows members of a care team to take advantage of all information, which can be easily found. Thanks to this information, it is possible to trace the patient's entire clinical history. Through our network, there is continuous sharing of patient health information. The information shared comes from wearable technology devices, laboratories, radiology, and doctors. The information is thus easily accessible by physicians in other health facilities, the patient or caregiver, radiology, and pharmacies who can directly procure the necessary drugs. The patient can access the platform to have a clear picture of the situation, and the results of his analyses are tracked during a specific time. The implemented framework is advantageous even during hospitalization. The patient's clinical picture can be available to provide care and resignation instructions. In this way, care can be managed more appropriately, especially when the patients are unconscious and cannot provide further details on their health. Thanks to the implementation of this network, it is possible not to lose sight of essential information for the patient's health. An EMR allows collecting data, creating orders, sharing information with other operators, recording clinical results, and carrying out actions accordingly. Besides, it is possible to have an accurate and complete archiving of the patient's treatments, allowing doctors, nurses, and other operators and collaborators to proceed with a complete information set. Furthermore, these integrated systems check the status of workflow activities before proceeding to the next step and allow easy understanding of information through an easy-access platform for doctors, hospital operators, and patients or caregivers. Each communication step is satisfied by respecting the policies and procedures to respect and protect sensitive data. Only those who have permission can access clinical information, and the patient cannot make any changes. Furthermore, this digitization system eliminates a series of supplementary costs, sometimes not valid for the system's efficiency. Thanks to the digital medical record, it is possible to acquire, update, and consult the patient's information at any time. Our model's implementation makes it effortless to share information among team members and analyse research and statistics of the data available to organise the hospital system's procedures.

7.2 Blockchain effect on the processing capability

Information processing capability is an organisation's capacity to collect, analyse, and synthesize information efficiently that facilitates decision-making (Tushman et al., 1978). EMRs make it possible to have all the patient's health data available. Therefore, it is possible to use the data to carry out statistical surveys. Digitization can improve clinical data collection, sharing, and decision-making accuracy and speed. With the evolution of digital healthcare, the information is also manageable through apps (downloaded directly by the patients on their smartphone, tablet) or through wearable devices equipped with sensors that detect, for example, heart rate, body temperature, brain activity, sleep patterns or muscle movements. The patient can monitor own health independently and share it with the doctor. The use of digital solutions in healthcare can innovate healthcare processes ultimately and increase their quality, making them more efficient and less expensive. In this way, a single patient generates thousands of data relating to diagnoses, treatment paths, drugs, medical devices, digital images, and laboratory analysis results. The massive volume of new data generated overwhelms institutions' ability to manage it and researchers to use it effectively. In fact, for the analysis of this mass of data to be meaningful, the latter must necessarily be validated, processed, and integrated within a system: the combination of the processing systems of this information aimed at creating new value in the organization of health services also expresses the potential of big data. Our model with the sharing of medical records can support clinical decisions to obtain better healthcare results. Specific algorithms' development potentialities become evident to move more easily among all this information, especially replacing and automating the most standardized and repetitive operations. The goal is to support clinicians on several fronts, from facilitating diagnosis to patient management and treatment choice. Interpreting patient data can reduce treatment costs, predict epidemics, avoid preventable diseases, and improve the overall quality of life.

7.3 Blockchain effect on organizational flexibility

A health record protects a patient's health privacy, including saving a person's data regarding their health status and treatment method. Every citizen who accesses a health facility for visits, examinations, or hospitalizations must be guaranteed absolute confidentiality, respecting his fundamental rights and dignity. Health documents contain personal data relating to the category of sensitive data, as they are suitable for detecting personal and health data. Personal data must be processed lawfully and fairly for well-defined, explicit, and legitimate purposes. In our blockchain network for sharing health information, the data subject's rights are recognized. The patient is aware of the presence, updating, correction, or integration of his data, the indication of the origin, the purposes and methods of treatment, and the subjects to whom the data may be communicated. Traceability keeps track of data relating to wearable devices, doctors' decisions, and drugs used. Furthermore, traceability allows one to know what happened, even after some time, by reconstructing the activities and going back to the perpetrators. It will be possible to trace the authors' date, time, and identity for all patient healthcare activities. Without using our platform, patients have problems sharing their health data. Information from different sources such as laboratories, pharmacies, or radiology is not easy to share between nurses, doctors belonging to the same health organization and not belonging to the same health organization. With the platform's implementation, real-time monitoring of the patient's health status allows for better assistance and disease prediction. Healthcare transparency is defined as making available to the public reliably and understandably information on the health care system's quality, efficiency, and consumer experience with care, including quality data, to influence patients, providers, nurses, and others to achieve better outcomes. Transparency is a fundamental element of the processing of personal data. It is necessary to offer concise, transparent, and intelligible information to make the patients aware. In our platform, the patient has easy access to the vision and information about his state of health to understand better a simple language of doctors' prescriptions. Moreover, transparency can help patients and caregivers make informed choices when selecting a health plan, hospital, clinical practice, or choosing among alternative treatments. Besides, increased healthcare transparency can allow for increased trust in the patient-physician relationship and health care systems.

8. Conclusions

In the modern healthcare sector, the use of blockchain plays a vital role in designing healthcare systems. It may result in automated data collection processes and authentication, accurate and aggregated data from multiple static sources, immune to tampering and protected data, and lower cyber risk. The sensor network technology captures patients' physiological data from various diseases by patient tracking systems or EHRs. Health is a human right that is universal and integral to everyone's life. Advances in medical technology have made life longer, healthier, and better. Included in medical care and equipment are many of these impressive advances. The medical data administration also showed progress in the EHRs, a digital record of patient health information. An EHR contains medical history, treatment schemes, allergies, and other data relevant to the health history. It is essential to facilitate the easily shared and used information about paperless health. Users expect a smooth and instantaneous data flow in today's world. ePHRs allows EMR to preserve patient records and support patients by exchanging the data with other departments or hospitals and providing better care. Many healthcare organizations have been motivated to use technological advancements for EMRs, clinical software, and health management information systems. Physicians have trouble using EMR since most doctors have paper-based medical records practice. Furthermore, EMR provides them with help for all patients' medical needs, and EMR can help them effectively. Our network enables sharing any information material that leads to continuation or collaboration between departments in healthcare management; besides, it allows the end-user to search for any scientific documentation in operation, treatment protocols, and the health care system's protection. We present a system architecture based on the blockchain network to implement an EHR sharing system. This illustrates the capacity and value of blockchain in different fields and demonstrates that it may be the next ground-breaking technology to replace existing healthcare systems. Although medical records' digitalization is constantly changing across the most advanced countries, current EHR systems do not fully support advanced privacy systems and security in several cases. The challenge remains to create a robust, scalable, patient-centred environment. Many industries have adopted, or are in the process of adopting, required technologies to satisfy their users' demand for instant information. Regrettably, the healthcare sector has lagged. We propose a system architecture and access control policy algorithm to achieve privacy and safety for patient data within the EHR system. Besides, the implementation of a blockchain-based EHR sharing system is provided. The work presented eliminates the central power and a single failure point in the system. The system's security is achieved by immutable ledger technology, as no user can change the ledger. Legacy programs are inconvenient, sluggish, and sometimes vulnerable, and they play a minor role in the patient's care. Due to varying formats and standards, health data in the legacy systems are siloed and challenging to share with others. In short, the current landscape of healthcare data is fragmented and unsuitable for modern users' immediate needs. EMR is the source where each patient gives details such as drug allergies, drug reactions, previous patient care in one hospital, and essential personal details such as abortions, psychiatric issues, and physical violence are also part of EMR. Our model aims to ensure the authenticity of the chain of health records and the privacy of data. Although the model shows the potential to protect patients' privacy, more protection and privacy testing are needed. Many healthcare providers follow their systems to use health records and typically do not share them with other organizations. Thus, a patient can have health records dispersed in many health institutions. With this model, since the first communication with the health organization, healthcare professionals will have access to the complete EHR of patients supported. This model's advantage for healthcare professionals is that their patient's health information, which is already maintained in the institution, is always up to date, beyond the ability to extract medical statistics to increase treatment quality. This model suggests scalability, elasticity, and interoperability architecture for patients to gain a single view of patient health information. The model has a fundamental challenge in ensuring the informant's identity and authenticity, whether the patient, doctor or patient-related sensor are not working. This study's scientific contribution introduces a viable proposal for a distributed and interoperable EHR architecture. The model requires further assessments as future work, specifically security, privacy, and integration with other systems. With cybercrime increasing worldwide, healthcare systems are no exception. More data breaches occur in the healthcare industry than in any other sector, and medical records are stolen and transferred. Besides, many challenges need to be discussed and addressed, ranging from choices to the versatile model of access rules and replicating data to subjective questions of how patients can manage and share their information in practice. Therefore, the proposed framework allows an existing organization to use the capabilities of a private and permissioned blockchain technology to secure the current data management system's transaction modifications with reduced complexity and improved efficiency and reliability. The scientific contribution of this work is a viable proposal for a distributed and interoperable EMR architecture. The model assessment shows that our model can promote EHR into data blocks and proportional distribution. Hence, we suggest a model in which health information exchange benefits everyone concerned. Clinics rely on research and testing for informed diagnosis and possible treatment decisions. Traditionally, an investigation or test should only be requested and arranged to lead to a different probable diagnosis or alternative treatment. Unfortunately, even when research results or tests are returned, they are rarely widely shared with patient care professionals. Usually, they are isolated in the institution that was initially requested. Other institutions do not know the complete history of a patient, and in turn, this could lead to improper decision-making, delays, and unnecessary patient or health institution costs.

Future directions

Medical records should not only be considered as medical records but also as legal documents. It is a criminal offence to pass on a revised record as contemporary, and any retrospective changes should be indicated, dated, and signed, and the reason for such changes documented. The difference in existing medical records, the deletion, or the addition of falsified documents, puts a physician at risk of medical consequences. Authentic and original clinical notes are required for the reclamation, and failure may render the reclamation untenable. Patients have their health information spread through several systems, hospitals, networks, and countries within the healthcare system. When the patient interacts with them, several fragmented reports from the same patient are held at various institutions with their health snapshots, such as blood tests, imaging, and clinical letters. The time to search for a consultation is massively reduced from the patient's viewpoint by eliminating the need to attend the doctor's practice. Many simple problems can be handled on the phone; however, blockchain makes it possible to improve patients' experience by providing a telemedicine component by facilitating a more thorough visual consultation that is profitable for doctors and patients. A patient can cancel his job in advance of a doctor's appointment. The clinic's waiting time is often for a simple request to see the doctor. Telemedicine allows the patient to select a particular time for consultation and encourages choice and freedom at its leisure. Besides, patients can choose which doctor they wish to consult with, whereas, perhaps logistically, it would not have been possible beforehand if they had been based in diverse cities. The doctor can also take advantage of telemedicine. It can offer clinicians a flexible working pattern to conduct consultations from anywhere with adequate internet connectivity. The physician can access the patient's health record (with patient permission). During the consultation, the doctor will also be given access to all information required to propose relevant research and develop a treatment plan. Healthcare providers have plenty of benefits from this blockchain network. They will first benefit from a more thorough picture of a patient's health status and reduce the time spent collecting records. Besides, they would benefit from not continually investing in upgrading or maintaining their health records. This paper presented the design, implementation, and validation of a blockchain-based EHR system that enhances the private and permissioned blockchain network to store medical records and data exchange among healthcare providers. Thus, this blockchain network eliminates the health system's barriers since a patient's medical data is shared across various medical organizations. Our study confirms the effectiveness of the approach to electronic record management in a tamperproof manner. Therefore, the proposed mechanism permits an existing organization to use private blockchain technology capabilities to protect against modification transactions with reduced complexity and greater efficiency and reliability of the current information management system. The contribution proposed leads to many ways of working for the future. Future directions concern the possibility of using artificial intelligence to generate dynamic, intelligent contracts to tackle cross-domain diversities. It is evident that the integration of blockchain technology into health research, from data sharing and monitoring to the required transparency and privacy concerns for patients, can have many beneficial benefits. Additional future research directions include expanding the network size to a vast extent and implementing the solution offered into the cloud architecture to address this issue. This paper outlines a new method for designing and implementing a decentralized platform for managing EMRs with blockchain technology. The aim is to provide patients and healthcare providers with safe, transparent, and meaningful medical assistance through services in the hospital. The proposed study can be extended to many other application scenarios based on the designed application. Finally, a research direction concerns the opportunity to adopt blockchain to bridge trust, traceability, transparency factors affecting knowledge flows during pandemics. To achieve this aim, future contributions could design novel blockchain models to assure the immediate need for personal protective equipment (PPI) like medical gowns, surgical masks, gloves, and the acquisition and deployment lifecycle of equipment like ventilators, respirators, and medical tests. More in detail, future contributions could provide fertile ground for experimentation and proof-of-concept testing of private and permissioned blockchain platforms to manage material and information flow of PPI supply processes, including different actors, namely medical device suppliers, pharmacies, hospital procurement departments, and local governments.

Implications

Various institutions of health often use different EHR systems. In other words, although information can freely be shared within a particular institution or cluster, data is often truncated or unavailable for other institutions using different EHR systems. This leads to a silos effect in which patient medical data are restricted to a single institution and are then summarized or transcribed manually for access by another institution. It is increasingly indefensible the existence of such access barriers in a time when the transmission of information is immediate. Health practitioners need to have access to all medical services of the patient. When health practitioners see patients, it is essential to access all patients' medical information for all visits, including diagnoses, research, results, drugs, and allergies. The absence of a patient's complete longitudinal health history increases the risk of medical errors and costs. This study's results have practical managerial effects on blockchain network design, development, and execution. To design or redeploy the blockchain network is essential to make it simple and easy to use. Therefore, we suggest testing the platform's pilot application by potential users to improve its acceptance during its development stage. The interoperability between systems allows to overcome the concept of local health; furthermore, it opens the possibility of exchanging clinical data even at a considerable distance, providing better healthcare to citizens and facilitating analysis and interpretation of data down geographic barriers. Interoperability represents an opportunity to address significant health challenges, such as preventing, identifying, and treating chronic and degenerative diseases that are increasingly widespread. Digital technologies, such as blockchain, are increasingly the primary option for obtaining and processing information, exchanging data between operators and patients. It is possible to build databases to carry out analyses and subsequently identify the endless ways to improve performance from the data obtained. A digital language is a mental approach that requires people accustomed to using it, reliable infrastructures, and a propensity on the part of decision-makers to imagine processes that use digital technologies as strengths. The ability to add speed and accuracy to processes results in economies of scale. There is a need to improve and implement digital technologies and interoperability in healthcare as the foundation for further improvement for all these reasons. It is essential to follow four objectives: (1) standardization of digital language in healthcare; (2) to require all public and private providers to make health and clinical data of the patient available to all those who wish to have access in digital format and in real-time; (3) to move all performances that can be done with good quality to digital channels; (4) to lead decision-makers with digital skills to the leadership of healthcare institutions. Each of these goals has not been seriously pursued to date. These standards are not enough to be decided at the local level to pursue the first goal. The standards should follow the principles defined as "fair", namely findability, accessibility, interoperability, reusability. To pursue the second goal, there is a need to create interfaces and applications. The interfaces are created for improved and implemented effective data transmission between public and private health actors. The applications can be improved and implemented to allow data to be collected through wearable devices and analysed to provide health information. In this way, knowledge is also improved, and the work of doctors is made more accessible. Indeed, physicians could obtain automated analysis using software capable of producing clinical intelligence from the patient's health data. To pursue the third goal, the continuous participation of doctors who carry out video consultations, video visits, chats, sensors, and the exchange of intelligent devices is necessary. To pursue the fourth goal, professionals involved in the health sector have to improve their digital knowledge to enhance the entire health ecosystem.

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