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2022

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### Original Publication Citation

He, W., Zhang, J. Z., Wu, H., Li, W., & Shetty, S. (2022). A unified health information system framework for connecting data, people, devices, and systems. *Journal of Global Information Management*, 30(11), 1-19, Article 39. <https://doi.org/10.4018/JGIM.305239>

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# A Unified Health Information System Framework for Connecting Data, People, Devices, and Systems

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## ABSTRACT

The COVID-19 pandemic has heightened the necessity for pervasive data and system interoperability to manage healthcare information and knowledge. There is an urgent need to better understand the role of interoperability in improving the societal responses to the pandemic. This paper explores data and system interoperability, a very specific area that could contribute to fighting COVID-19. Specifically, the authors propose a unified health information system framework to connect data, systems, and devices to increase interoperability and manage healthcare information and knowledge. A blockchain-based solution is also provided as a recommendation for improving the data and system interoperability in healthcare.

## KEYWORDS

COVID-19, Data, Health Information System, Interoperability, System Integration

## 1. INTRODUCTION

The COVID-19 pandemic has produced profound impacts on society. It has generated a rapid demand for the use of innovative information technology (IT) in mitigating the adverse effects of COVID-19 on public health, society, and the economy (O'Leary, 2020). State-of-the-art technologies and applications need to be actively used, deployed, or created to track and contain coronavirus outbreaks (De Moya, Pallud, & Wamba, 2021), including tracking those infected and their close contacts, to support quarantine and lockdown (WHO, 2020), and produce exemplary solutions for mitigation and elimination of COVID-19. To help curb the COVID-19 pandemic, public health agencies, healthcare providers, and epidemiologists need to know timely population information about coronavirus infected people, including those hospitalized, the demographic data from those confirmed patients, the length of the hospital stay, and how the health systems take care of those in needs (He, Zhang, & Li, 2021).

On the other hand, the COVID-19 outbreak has raised opportunities to advance technology-based solutions. The prominence of telehealth, telework, and online education in response to the coronavirus threat has demonstrated that technology is essential in managing and reducing the coronavirus risks during the pandemic and even after. It is well known that IT plays a vital role in healthcare, clinical

DOI: 10.4018/JGIM.305239

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decision support, group decision making, emergency/crisis response, and risk management (Chen et al., 2008; Angst & Agarwal, 2009; Ben-Assuli & Padman, 2020; Thompson et al., 2019). A growing number of technology companies and IT professionals are working in various ways to help fight the ongoing coronavirus pandemic (Mingis, 2020).

There is currently a shortage of research contributions in information systems (IS) to help fight the COVID-19. IS scholars should contribute to this global effort to fight against COVID-19 and future pandemics by leveraging their previous experience and knowledge on responding to crises, decision making, remote working, managing virtual teams, analyzing large data sets, etc. (Ågerfalk, Conboy, & Myers, 2020). What can IS researchers and practitioners do to help fight COVID-19 specifically? O'Leary (2020) has recently provided a list of areas that IS/IT scholars could contribute to. However, how to carry out the work in these areas remains an open question.

This paper focuses on data and system interoperability, a specific area that IS scholars could contribute knowledge and insights to fight against COVID-19. Interoperability is the ability to exchange and apply information from different systems and applications timely, accurately, effectively, and consistently (Dogac et al., 2007; Iroju et al., 2013; Costin and Eastman 2019). Data interoperability in healthcare is essentially an unreached goal and is needed stronger than ever (Freeman et al., 2020; Sreenivasan et al., 2020). Improved interoperability is the key to managing COVID-19 spread and future pandemics (McClellan et al., 2020). Interoperability in healthcare during a pandemic will make it easier to gather related data from various data sources, understand how it spreads, help different stakeholders (such as the governments, healthcare providers, and other organizations) for evidence-based decisions making, and improve their response to COVID-19 and future pandemics.

Currently, the US public health agencies and healthcare providers have not used the same information systems, data formats, or data standards. Each hospital purchases devices, equipment, and tools from manufacturers with specific interfaces. They are hampering the ability to share data. Hospitals must spend a lot of time and effort to develop middleware or other auxiliary systems to ensure that all devices, equipment, tools, and systems can talk to one another. Similarly, when a patient moves from one hospital to another, it is challenging to automatically transfer patient records due to different systems and data formats. The current US healthcare continues to operate in cultures defined by silos, fragmented processes, and disparate stakeholders. Most healthcare systems treat patient data as commodities and their competitive advantage (Reisman, 2017). Healthcare data silos make it nearly impossible for providers, pharmacies, and other stakeholders to work together for coordinated care (Clough, 2016).

The public health authorities' immediate goal is to coordinate efficiently and respond effectively. To ensure public health agencies and healthcare providers get the correct information at the right time, obtaining and using data across multiple technologies or systems is essential. It requires a reliable reporting system to quickly report accurate data about the outbreak from communities to states and then to the federal government so officials can rapidly identify and implement the most effective interventions. However, the standard-based interoperable system has not been implemented in many places across the US, primarily due to a lack of federal funding and the slow adoption of existing standards (Keller, 2020). There are no incentives for medical device manufacturers and electronic health record (EHR) vendors to drive fully interoperable solutions across various systems and technologies. Many stakeholders see open communication between devices and systems as a threat to their market share (NITRD, 2020).

In response to the need and challenges about interoperability, we reviewed the emerging interoperability challenges during a pandemic. This paper will first give an overview of healthcare interoperability, including the deficiencies in interoperability with the advanced data-people-system framework (Section 2) and the interoperability challenges and benefits in health IT (Section 3). Then we will propose a unified health IT framework to increase interoperability and facilitate data exchange and system integration in health IT in Section 4, along with its implications and concrete recommendations in Section 5, including a blockchain-based solution and implementation guidance. Overall, this paper describes our thoughts and vision for achieving healthcare interoperability.

## 2. CHALLENGES OF INTEROPERABILITY IN HEALTH INFORMATION SYSTEMS

In this research, we have conducted a search using academic databases and web search engines with a variety of queries related to technology, coronavirus, and COVID-19. The query results include discussions in newspapers, news websites, blogs, white papers, online forums, practitioner websites, grey literature, or academic literature. Synthesizing the information helps us better understand what roles of IS/IT could play in this challenging time. The discussions of technology's roles are currently disparate, fragmented, and distributed in different outlets. As health IS and IT are such evolving and fast-moving areas, many relevant discussions were posted by academics, technology practitioners, enthusiasts, consultants, and experts on news websites and social media before appearing in academic journals. Thus, those online information sources are valuable for learning what IS/IT could offer to address our targeted interoperability issue.

Healthcare researchers and practitioners believe that establishing interoperability across systems and technologies will result in many benefits (e.g., King et al., 2016; Ide, 2020), including but not limited to:

- help governments and healthcare providers identify trends in symptoms, recovery times, mortality rates, experimental treatment efficacy, etc. across different hospitals and geographic locations,
- reduce the time and resources required to analyze data and standardize our understanding of the pandemic and the most effective interventions,
- reducing adverse events, transcription errors, and redundant testing,
- reducing doctors' fatigue and time spent manually entering information,
- decreasing patient's length of hospital stays due to improved speed of information transfers,
- lowering costs related to integrating and maintaining technologies, and
- leveraging patients' data critical to information that drives clinical decision support and results in lower cost and better outcomes.

However, there are still many barriers to achieving interoperability in health information systems in practice (McClellan et al., 2020; Clough, 2016; Reisman, 2017; Holmgren, Apathy, & Adler-Milstein, 2020). Stakeholders with diverse interests have not reached a consensus on how to get there (Klecun et al., 2019). The primary concerns include physician dissatisfaction with EHR systems, overregulation, cost, system implementations, and patient information ownership. Other consequential concerns relate to patient privacy and confidentiality, security breaches, data inaccuracies, and access control to patient data. There are also issues associated with the commercialization of de-identified patient information. Many hospitals are worried that connecting all medical devices, data, and systems may threaten their market share. They may end up losing patients and revenue. The fundamental problem is the lack of sustainable business models for successful data and system interoperability. Many health stakeholders are not strongly motivated to change the status quo to establish a national health IT infrastructure that connects all medical devices, data, and systems.

A Chicago-based healthcare information publisher interviewed 15 healthcare leaders from leading organizations on interoperability in healthcare IT (Becker, 2020). The advice from each of the leaders was posted on a web page. After examining the advice from these 15 experts, two experienced researchers worked together to summarize some key issues affecting interoperability in healthcare IT (see Table 1).

## 3. PRIOR ENDEAVORS ON IS INTEROPERABILITY

During this unprecedented age of the COVID-19 pandemic, we are witnessing an accelerated adoption rate for advanced technologies, including various telehealth, mobile applications, online training, robots, and big data analytics platforms to serve the healthcare and other needs of millions of homebound individuals. The pandemic promotes an opportunity to reshape future information

Table 1. Key issues affecting interoperability in health information systems

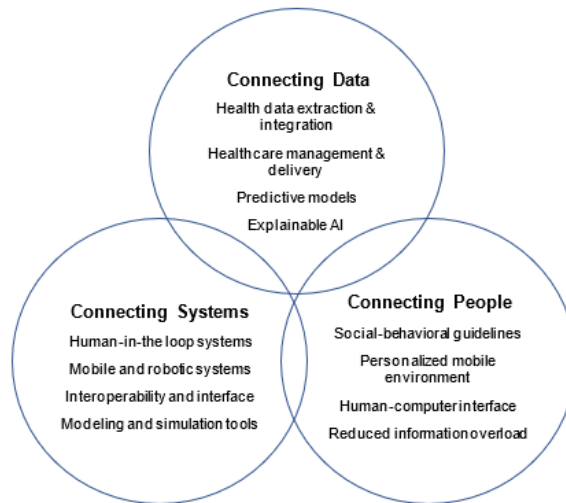
Attributes	Excerpts
Loss of control of their data	<ul style="list-style-type: none"> <li>• “many big players are protective of their data. While there are great solutions out there, sometimes the solutions can’t get to the data because people keep their systems closed” (quote from Jan De Witte)</li> <li>• “The problem is that exchange data with competitors is fundamentally against the self-interest of the party which created the data” (quote from John R. Graham)</li> </ul>
Lack of incentives	<ul style="list-style-type: none"> <li>• “vendors lack incentives to make their technologies work in a plug-and-play manner” (Michael Johns)</li> </ul>
Lack of data standards	<ul style="list-style-type: none"> <li>• “The biggest challenge is the lack of interoperability caused by an industry that does not have data standards” (Joy Grosser).</li> </ul>
Concern about the government’s role	<ul style="list-style-type: none"> <li>• “I think it’s important that policymakers avoid the temptation to micromanage the effort through steps and an overly bureaucratic system. The government needs to pay attention to the ‘what’ of interoperability and the ‘by when’ rather than the ‘how’ and ‘who’ (quote from Joe Ganley)</li> </ul>
Lack of a sustainable business model	<ul style="list-style-type: none"> <li>• “We still do not have the financial models in place. Hospitals are paying for services where the benefits accrue to others, especially to insurance companies. Of course, this also gives better patient care, which is why we are enthusiastic participants, but this is not a good long-term model” (quote from Bobbie Byrne)</li> <li>• Several state-designated and local HIEs have failed over the last few years, and I suspect more will fail as they find it difficult to sustain a viable financial model (quote from Dave Garret)</li> </ul>
Legislative issue	<ul style="list-style-type: none"> <li>• “the regulatory challenge is always there — legislation that leads to unintended challenges for a provider. I anticipate more legislative action at the federal and state level forcing aspects of interoperability” (quote from Dave Garret)</li> </ul>
Price/cost	<ul style="list-style-type: none"> <li>• “Stop the electronic medical record vendors from gauging physician offices with cost to connect to other repositories” (quote from Michael McTigue)</li> </ul>

systems for better health, science, education, and national security services. It particularly boosts the need to leverage technology to support and take care of vulnerable populations in home and community settings for future pandemics. Some efforts are underway to address different aspects of the device, data, and system interoperability challenge. King et al. (2016) propose a community health record framework that presents a multitiered, multisector model illustrating an iterative, flexible, and participatory process for achieving collaboration and information exchange among health care, public health, and community groups and organizations to aid the population health decision making.

Some specific technology applications, such as mobile tracking apps and chatbots, have been recently developed to fight against COVID-19. Applying these technologies can help reduce the impact of the coronavirus pandemic on people, organizations, and society. Innovative use of emerging technologies can help identify community spread of the coronavirus, monitor the condition of the infected patients, improve the treatment of COVID-19 infected patients, and help develop medical treatments and vaccines (Johnstone, 2020). However, public health authorities and healthcare providers face challenges in scaling up and getting these innovative technologies widely adopted by existing health systems. Because of the issues we mentioned earlier, it will take a lot of resources, effort, and time to deploy and integrate these new devices and technologies into existing health systems.

The data-people-system framework by Bardhan, Chen, and Karahanna (2020) proposes a multidisciplinary roadmap for controlling and managing chronic diseases by connecting data, people, and systems (see Figure 1). Specifically, connecting data needs advanced explainable artificial intelligence (AI) solutions, including accurate predictive models and other elements shown in Figure 1. Connecting people requires new social-behavioral theories and mobile health applications. Connecting systems entails human computing interaction, system interoperability, and simulation

Figure 1. A framework of connecting data, people, and systems (adapted from Bardhan, Chen, & Karahanna, 2020)



modeling. Fully connecting data, people, and systems should adopt a multidisciplinary approach to collaborate the social-cultural, behavioral, organizational, economic, ethical, legal, design science, and data analytics fields.

However, the above framework does not satisfy the IS requirements for combating the COVID-19 pandemic, especially with the current destructive pandemic situation and its consequence, which requires a higher level of connectedness of data, people, and systems than dealing with the typical non-pandemic situation or normal conditions (Kotlarsky et al., 2020). The pandemic occurs on a scale crossing the globe for an extended period, which is different from emergencies like hurricanes and earthquakes in a specific region for a short time. The pandemic's increased scale, severity, and duration pose a challenge yet provide an opportunity to accelerate the data and system interoperability in healthcare IT.

Regardless of these challenges, society has an ethical obligation to do what is best for patients and take rapid actions to develop and implement standard-based devices, technologies, and systems that can talk to one another easily. We must act now and make it easier for healthcare professionals and researchers to do their job. Sittig and Singh (2020) say:

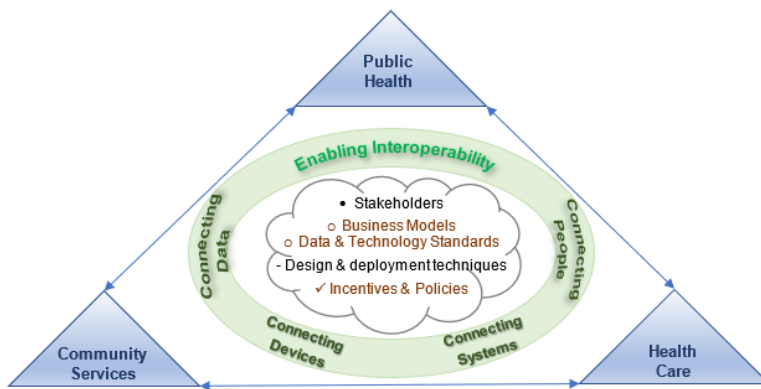
*“It is time to make some difficult decisions and exploit and enhance the existing technical capability to build and deploy these solutions. Given the severity and immediacy of the COVID-19 pandemic, the US should no longer rely on outdated laws, social norms, or potentially inaccurate modalities to obtain timely, accurate, and reliable health information essential to save lives.”*

We learned from various news reports that improved healthcare interoperability is the key to managing the COVID-19 spread (McClellan et al., 2020). There is a stronger need than ever to have interoperability in healthcare. The spread of COVID-19 demonstrates the need for a national health information technology infrastructure (Sittig & Singh, 2020), which should be considered as a national priority better prepared for future pandemics. Governments, hospitals, health systems, device manufacturers, vendors, and all related communities must unite to make changes and solve interoperability challenges before the next pandemic comes. Some transformations of society caused by this pandemic will be far-reaching and require careful observation, discussion, and reflection to understand the short-term and long-term implications and consequences of this pandemic.

## 4. A PROPOSED UNIFIED HIS FRAMEWORK TO INCREASE INTEROPERABILITY

Based on an integration of the community health record framework (King et al., 2016), the data-people-system framework (Bardhan et al., 2020), and the requirements of a pandemic, we propose a united health information system (HIS) framework of connecting devices, data, and systems as shown in Figure 2.

Figure 2. A unified health information system framework of connecting devices, data, and systems



### 4.1 The Three-layered Architecture of the Framework

The proposed framework will adopt a three-layered architecture, as illustrated in Figure 2. **The inner layer** contains the following four major components.

- 1) *The stakeholders in healthcare*, who use the framework, which include humans (such as patients, providers, pharmacists, legislators, researchers, and health information technology professionals, etc.), health care facilities (such as hospitals, pharmacies, testing labs, etc.), government agencies (such as county and state departments of health), insurance companies, community groups (especially various non-profit healthcare associations and the World Health Organization, WHO), and various academic institutes in public health, and health technology companies (such as device vendors, EHR Vendors, and others).
- 2) *The standards* for data (such as the OMOP Common Data Model), technologies (including devices), and business models, which will be used in implementing the connected middle layer for system interoperability (Overhage et al., 2012; Hripcsak et al., 2015).
- 3) *The design techniques and deployment guidance* to enable interoperability, including software tools (such as Fast Healthcare Interoperability Resources, *i.e.*, FHIR (HL7, 2020)), hardware (such as devices and sensors), and software-hardware interfaces. The best interoperability practice is to use established standards, such as SNOMED, ICD-10, LOINC, RxNORM, USCDI, FHIR, etc.
- 4) *The government incentives and policies*, such as a mandated disease and healthcare report form with well-defined fields or a reduced timeframe for premarket approval and clearance of drugs and medical devices, will add value to various stakeholders of healthcare. Federal agencies, such as the Office of the National Coordinator for Health Information Technology (ONC), are coordinating stakeholders to develop consistent policies and regulations to promote interoperability.

The **middle layer** of the unified framework will be responsible for implementing the framework, which will fully connect data, people, devices, and systems, based on the standards, business models, and technologies in the inner layer, supported by government incentives and enforcement policies, and guided by the best practices in interpolation design and deployment. The major components in the middle layers have the following characteristics to ensure interoperability.

- **Data:** The connected data will expedite data extraction, integration, and reporting, especially in a timely fashion during a pandemic, such as COVID-19. It enables patients to have control of their health data (e.g., medical history) so that they can easily access or share their health information across health providers (dentists, eye doctors, family doctors, pharmacists, etc.) for better clinical care or decision support (Silva, Sloane, & Cooper, 2020). The standardized well-formatted data can be easily shared across multiple EHR or HIS platforms.
- **People:** People are whom the framework serves and those stakeholders who make decisions. The ultimate purpose of the framework is to better serve people through leveraging the knowledge creation and sharing of all stakeholders through collaboration and coordination (Sundaresan & Zhang, 2012), including all the professionals and supporting staff in health care, public health, and communities.
- **Devices:** Medical device interoperability refers to the ability to safely, securely, and effectively exchange and use information among one or more devices, products, technologies, or systems. This exchanged information can be used in various ways, including displaying, storing, interpreting, analyzing, and automatically acting on or controlling another product.
- **System:** Health-related information systems from state and local public health departments, private health care providers, pharmacies, health-related laboratories, and manufacturers should be connected to work together to provide real-time data on diseases and available resources to treat patients and advance the effective delivery of healthcare for individuals and communities.

The **outer layer** is the application of the framework to clinical medical care, community services, and public health. Existing applications used in clinical medical care, community services, public health, and other related stakeholders, including insurance companies, pharmacies, laboratories, and manufacturers, need to be upgraded and tested to ensure they are connected to provide a complete picture of available healthcare information and resources for offering better healthcare. New applications can be developed to implement big data analysis for various data collected from connected systems for more comprehensive decision support than ever (Gharajeh, 2017 & 2018).

## 4.2 The Four Levels of Interoperability

The proposed unified framework supports the following 4 levels of interoperability.

- **Foundational (Level 1):** Establishes the interconnectivity requirements needed for *one system or application* to securely communicate data to and receive data from another, which is achieved by following the same communication protocols. Stakeholders should be working together to define or adopt the same communication protocols or requirements for intra-connectivity within one system or application.
- **Structural (Level 2):** Defines the standard, format, syntax, and organization of *health data and information exchange*, including at the data field level for interpretation. It is achieved by the data and technology standards in the inner layer of the framework.
- **Semantic (Level 3):** Establishes the inter-connectivity requirements needed for *two or more systems and applications*, which is achieved in the middle layer of the framework. Heterogeneity and inconsistency in data, devices, and systems require generic solutions to share and reuse data while ensuring data integrity across heterogeneous systems. Novel distributed and standards-based technology architecture and platforms, including blockchains and middleware, can be used to tackle the interoperability issue and provide an interoperable solution.



- Organizational (Level 4): Includes governance, policy, social, legal, and organizational considerations to facilitate the secure, seamless and timely communication and use of data both within and between organizations, entities, and individuals. These components enable shared consent, trust, and integrated end-user processes and workflows (Benamati, Ozdemir, & Smith, 2021).

### 4.3 The Advantages of the Proposed Framework

First, the tiered framework will *enable interoperability* between devices, data, and systems among all stakeholders, valuable for health care, public health, and community services.

Second, the unified framework will *facilitate strong coordination and collaboration* through a national health IT infrastructure to provide extensive big data for health decision-making and patient care. It is necessary to coordinate applications and implementations of existing standards such as Fast Healthcare Interoperability Resources for data sharing across healthcare stakeholders (Silva, Sloane, & Cooper, 2020).

Third, the framework will *leverage government incentives and policies*, promoting **rapid adoption and implementation of standards**. It helps pilot a national health IT infrastructure in the near term. Rapid pilot projects provide the opportunities to assess the current conditions, adopt devices, create data standards, and establish interoperability between devices, data, and systems among all healthcare stakeholders at a small scale (King et al., 2016). Rapid pilot projects also offer opportunities to learn by doing and to identify unforeseen issues, needs, and opportunities before scaling.

Finally, the unified framework will *foster viable business models* to sustain a national health IT infrastructure in the long term. There is a need to support innovative business models, such as tying the adoption of interoperability standards to reimbursement or linking interoperable equipment to value-based care.

In summary, the proposed united health IT framework will help achieve interoperability in healthcare by facilitating the close coordination and collaboration of various stakeholders, especially patients, providers, insurance companies, pharmacies, vendors, legislators, and health information technology (IT) professionals.

### 4.4 Benefits

During the COVID-19 pandemic, there were no national public health information systems in the USA. The governments and healthcare authorities have limited capabilities to direct vital resources from surplus areas to undersupply areas (Blumenthal et al., 2020). There is an increased need for improved interoperability in such a global public health emergency. All health care stakeholders will need to be a part of the interoperability effort to break down health data silos and allow patient health information to be available across all settings of care. Public health agencies, hospitals, and vendors must enable their systems to openly communicate with different systems. The government will need to provide more substantial incentives to engage all healthcare stakeholders to promote interoperability.

The unified health IT framework will ultimately lead to a nationwide health IT infrastructure and a national public health information system that provides the following benefits (King et al., 2016; Jason, 2020) for tackling future pandemics:

- giving real-time information on a need for hospital resources, such as personal protective equipment and ventilators, and optimizing the allocation of resources;
- potentially identifying new or enhanced therapies based on facility-specific factors,
- identifying hotspots and showing where social distancing should occur based on local, state, or regional data sets;
- linking clinical data to cellphone-based location data, which would identify infected individuals and see where they were on a map;
- proposing national surveillance system capabilities to identify regional variation and curb the spread of the virus.

## 5. RECOMMENDATION: USING BLOCKCHAIN FOR IMPROVING HEALTHCARE INTEROPERABILITY

As healthcare interoperability is complicated and involves many issues such as legacy systems, laws, regulations, standards, and cost, there are undoubtedly many technical and non-technical challenges (e.g., data governance, incentives, regulation, funding) in implementing the proposed framework in practice. Strong government support, including policy, regulation, funding support, and close collaboration and coordination among various stakeholders in healthcare, are needed to create a cooperative environment for achieving healthcare interoperability. From the technology perspective, we examined a variety of emerging technologies, including multiple middleware and standards, for implementing the unified health IT framework. Given the current convergence movement in health care toward adopting blockchain technology for interoperable health care (Stagnaro, 2017; Zhang et al., 2018; Zhou et al., 2019; Durneva, Cousins, & Chen, 2020), we recommend using blockchains for improving interoperability in healthcare, particularly for implementing the **middle layer** of the unified framework (see Figure 2). An increasing number of proof-of-concept user cases or pilot projects are being implemented in the healthcare industries, and some promising results have been reported (Gordon & Catalini, 2018; McGhin et al., 2019; Al Mamun, Azam, & Gritti, 2022). Considerations of what should be stored on and off chains are important for compliance with laws and regulations such as the Health Insurance Portability and Accountability Act of 1996 (HIPAA) and the EU's General Data Protection Regulation (GDPR) (Durneva, Cousins, & Chen, 2020). It is unlikely that blockchains can address all interoperability issues in healthcare (Houlding, 2018). However, blockchains could play an important role in significantly improving healthcare interoperability and facilitating the shift to patient-centered interoperability (Gordon & Catalini, 2018).

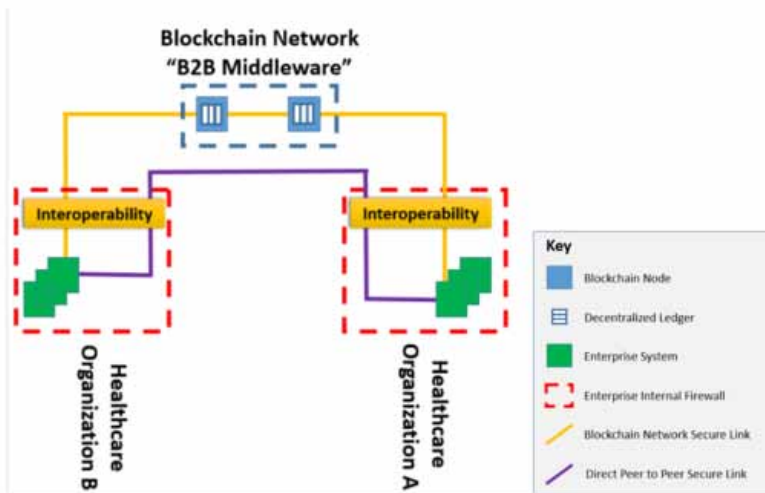
### 5.1 Blockchain-Based HIS Framework

Blockchain is defined as “a comprehensive information technology with tiered technical levels and multiple classes of applications” (Swan, 2015). Blockchain can reduce the possibility of fake or false records and secure the digital records on all the computers in the blockchain network (Zheng et al., 2021). As a novel technology, blockchains can offer significant advantages for promoting direct communication among multiple parties involved in the healthcare business without governmental interventions and customized services provided by third parties (Swan, 2015; Lacity, 2018; Hughes et al., 2019).

#### 5.1.1 Data

Blockchain technology provides private keys and public keys to encrypt the enterprise records, such as transaction records, patient/customer records, devices management, network management, etc. According to Figure 3, most person-related healthcare data such as patients' personal information will remain in healthcare enterprise systems due to privacy, security, regulation compliance reasons (Xiao, Mou, & Huang, 2021). In cases where blockchains reference healthcare records stored off the chain, metadata stored on the chain can include pointers to the source systems containing off-chain data and necessary metadata such as source data format, semantics, code sets, and version information. To ensure the healthcare information stored on the blockchain can be read and used by the rest of the blockchain network, it is necessary to enforce interoperability when the new information is appended to the blockchain. Data or information that will be stored on the chain should be formatted in a way that is compliant with the interoperability requirements of the blockchain. For example, Healthcare Organization A can write information to a blockchain through an interoperability module that formats the information to comply with the interoperability requirements of the blockchain. On the receiving end, Healthcare Organization B can read healthcare information from the blockchain through its own Interoperability module serving the purpose of translating blockchain formatted information into formats digestible by the target enterprise systems of Healthcare Organization B.

Figure 3. Using Blockchain for Improving Healthcare Interoperability (Houilding, 2018)



### 5.1.2 System

Blockchains provide a distributed ledger that catalogs transactions in an immutable, time-ordered manner. Specifically, blockchain applications can eliminate the need for reconciliation, provide data provenance, accomplish transactions quickly, accurately, and cheaply and offer fault tolerance for a security model. It allows any party in the blockchain network to confirm the transactions in no time rather than after the fact (Lewis, 2017; Lacity, 2018; Hughes et al., 2019). Houilding (2018) suggests that blockchains can be viewed as a new type of middleware for promoting communication among different healthcare organizations in a Business-to-Business network. As more healthcare organizations explore blockchains, new software and solutions that leverage blockchain technology are being developed. Diverse ecosystems include different organizations, their associated partners, and blockchain solution providers. Many healthcare blockchain ecosystems in different regions or states will likely appear as more healthcare stakeholders adopt blockchains.

### 5.1.3 Devices

Blockchains remove the “distrust” between healthcare professionals and third-party health tracking devices, apps, and services, and offer the ability to allow devices to access, exchange, integrate, and cooperatively use data in a coordinated manner (Durneva, Cousins, & Chen, 2020). For instance, IoMT (Internet of Medical Things)—healthcare IoT—the collection of medical devices supporting applications that connect to healthcare blockchain systems through online computer networking. In a broad sense, the devices include sophisticated medical devices equipped with sensors and personal IoT devices such as eHealth wearable devices (Rehman et al., 2021). Machines can share their operating data with those responsible for maintaining it through blockchain applications without violating compliance and privacy. Sensitive information, such as patients who have been treated with the device, types of procedures, and the images or other information can be shared with the maintainers but can be used for auditing, reporting, and compliance. Blockchain can also keep service records that may be required depending on the device and its purpose. Blockchain can be leveraged to keep permanent records of the development, design, production, and distribution of medical devices as well as all of the parts from suppliers.

#### *5.1.4 Improving Blockchain's Interoperability and Integration*

As additional ecosystems grow, there is a need to share data across several different healthcare blockchain ecosystems. For example, a hospital may participate in a blockchain network for hospitals and another blockchain network built by pharmaceutical companies to meet their varying needs. Each of these blockchains could have its own interoperability requirements. To allow data sharing across these blockchain networks or ecosystems, efforts need to be made to ensure interoperability across the range of blockchains they participate in. Perrons and Cosby (2020) found the absence of data standards and interoperability are key barriers for industries to reaping significant benefits from blockchains. Organizations need to explore the feasibility of integration approaches for different healthcare blockchains to connect compatible blockchains, non-compatible blockchains, or non-blockchain platforms and to address issues such as cross-authentication (for compatible blockchains), oracles (which transfer external data to the blockchain for on-chain use), or application programming interfaces (for incompatible blockchains) through ongoing practice (Durneva, Cousins, & Chen, 2020).

In the meantime, a need for governance around healthcare ecosystem interoperability is becoming increasingly crucial for the healthcare sector. A clear set of rules is needed to define the engagement between participants of an ecosystem. Additional rules will be needed to govern communication across and between different healthcare ecosystems (GS1, 2020).

Leveraging common standards for identification and data sharing is core to any full solution addressing the challenges of interoperability. More work on standards is needed to ensure interoperability between different blockchain networks or ecosystems. Data stored or referenced by blockchain networks can be structured for shared communications and interoperability through the use of standards. For example, the GS1 and ISO open standards of Electronic Product Code Information Services (EPCIS) and Core Business Vocabulary (CBV) enable standardized data exchange and item-level tracking. GS1 US is a standards organization supporting and educating businesses and industries in using and adopting GS1 Standards to improve business. GS1's global standards for identification and structured data enable blockchain network users to scale enterprise adoption and maintain a single, shared version of the truth about supply chain and logistics events—increasing data integrity and trust between parties and reducing data duplication and reconciliation (Al-Hasan, Khuntia, & Yim, 2021). Some organizations use EPCIS as the standardized event data and exchange format, which makes it possible for all parties to receive data from a common understanding of the information being exchanged. Defining requirements for ledger components is essential for blockchains. Establishing inter-ecosystem and ecosystem-to-ecosystem governance policy and rules is necessary for data-sharing at a large scale, which helps network participants behave in gathering, using, and sharing data. Some blockchain companies, such as SIMBA Chain, are implementing tools to help integrate various blockchains. Several blockchain projects have been developed to focus on interoperability through different approaches (O'Neal, 2019). For example, Polkadot, a multichain or cross-chain technology, allows different blockchains to connect into a larger-scale ecosystem. Technically, Polkadot includes parachains (i.e., parallel blockchains that process transactions and transfer them to the original blockchain), a relay chain (i.e., a central component that connects parachains and ensures their security), and bridges that connect Polkadot to external blockchains. Chainlink allows data to be retrieved from off-chain APIs and put on a blockchain. By offering a decentralized oracle service, the oracle nodes can receive real-world data, process it through the network, and then move it to the blockchain. Thus, Chainlink serves as a bridge between blockchains and all the off-chain infrastructure.

#### *5.1.5 People*

Some of the blockchain characteristics—decentralization, robustness, data traceability, audit simplicity, and security—are desirable for the healthcare sector to serve people better. Many patients also favor implementing blockchain-based mechanisms for privacy protection, coordination, and information exchange purposes (Esmailzadeh & Mirzaei, 2019). Using blockchains will allow patients to control

their medical data when they need it. If patients have ownership and access to their electronic health records, they can more easily move between different healthcare providers. This can help patients to have access to better quality healthcare. As some stakeholders do not understand blockchain technology, it is recommended to establish industry consortia of influential health care players who can collaborate to educate other stakeholders to spur adoption (Durneva, Cousins, & Chen, 2020). Further research is needed to investigate what incentivizes stakeholders to work together to adopt blockchain for healthcare.

## 5.2 Blockchain for Healthcare: A Use Case

One of the co-authors has been working on blockchain development with a healthcare company. Healthcare Company SME is a not-for-profit healthcare organization on the east coast of the US. It offers a whole spectrum of healthcare services in 12 acute care hospitals. SME operates its healthcare functions across two states with nearly half a million health-plan members, thousands of beds, and three assisted living facilities.

SME built their blockchain because they believe it will become a new business and technical protocol in the large ecosystem consisting of different types of healthcare organizations. They thought that blockchain technology could disrupt and disintermediate many points of friction and cost for inpatient services and revenue cycle management in the healthcare industry.

SME decided to invest in the blockchain applications to inform them of the technical capabilities and limitations of the available hyper-ledger platforms, create identity data that is 100% trustworthy, and facilitate the removal of all points of friction. Blockchain technology aims to help them build use cases to improve B2B and B2C capabilities through the adopted blockchain protocol, developing a large B2B and B2C ecosystem network.

SME has integrated its blockchain solution within its existing IT ecosystem. Specifically, their blockchain can uplift all of their Identity Management capabilities, including millions of patients/plan members, over 60,000 workforce members, and the hundreds of service partners they work with. SME has also developed a blockchain-empowered cybersecurity solution to monitor network activities of mobile devices and provide real-time alerts of unauthorized devices or communications. The blockchain can detect any unauthorized entity accessing data and rogue devices. The goal is to provide the ability to track and report any unauthorized access or modification to data (Cawley, 2018). A senior executive of SME said:

*“The platform will improve our overall cybersecurity posture and, being built on blockchain technology. We believe it will result in many yet-to-be-reaped opportunities in the future.”*

Over the next ten years, they are planning to gradually shift all of their technology platforms to leverage the capabilities that blockchain can improve upon. In terms of the values that blockchain has provided to their organization, SMEs believe that blockchain will help them reach new customers, strengthen relationships, increase sales, help better meet customer needs, offer more value, and enable the organization to compete more effectively.

SH believes that a robust ecosystem of businesses is crucial for blockchains. They will need dozens, if not hundreds, of healthcare providers and players involved to reap the most valuable outcomes of blockchains. SME recommends an early test of use cases and blockchain platforms by various healthcare stakeholders. The ultimate success of blockchains in healthcare is critically dependent on healthcare organizations participating in blockchain networks achieving interoperability (Houding, 2018).

## 6. CONCLUSION AND FUTURE WORK

The proposed unified health IT framework of connecting devices, data, and systems provides a way to build and sustain a national health IT infrastructure. Blockchain technology has been recommended as a promising technology to implement healthcare interoperability. Emerging technologies, including the IoT, big-data analytics, and AI, should be utilized and further integrated with blockchain to facilitate real-time data sharing and develop smart strategies for addressing immediate challenges caused by the pandemic (Wu & Trigo, 2021; Zhang et al., 2021). The emerging convergence of blockchain, the IoT, and AI promises to address issues such as trust and security in public health (Gurgu et al., 2019; Singh et al., 2020). For example, medical device data and non-personal sensor data collected by IoT can be stored and shared on blockchains. Patients' personal data can still be stored in the hospitals' enterprise systems due to privacy regulations such as the GDPR (Agbo et al., 2019; Onik et al., 2019). AI and big data technologies can be leveraged to analyze and visualize both on-chain and off-chain data and provide near real-time analytics and recommendations to relevant stakeholders through customized dashboards (Mangla et al., 2021).

Before a national health IT infrastructure becomes a reality, immediate actions are needed to help solve this pandemic. To help combat COVID-19 in terms of the proposed framework from a short-term perspective, technology researchers should leverage their previous experience and knowledge on responding to crises, group decision making, remote working, managing virtual teams to facilitate strong coordination, collaboration, and information sharing among all health stakeholders. Kotlarsky et al. (2020) suggest that coordination practices that support business-as-usual may not be suitable for addressing emergencies. Multi-stakeholder working groups need to be convened to provide recommendations on specific aspects of health IT interoperability, develop white papers for policymakers and decision-makers, develop standards, rules, and protocols for technology interoperability such as standards for integrating different blockchains.

The Computing Research Association (CRA) has been doing this to convene researchers in their fields to contribute expertise and write white papers and annual reports to help the government agencies, policymakers, and legislators understand what they should consider or do for solving problems facing society at the local, national and global level. The Brookings Institution also does similar activities, including writing reports and hosting weekly webinars to help policymakers from US cities and states to multinational organizations organize responses to COVID-19. Their roles are well received by the government and legislators and resulted in a series of new programs to support research and efforts on fighting COVID-19. Association for Information Systems (AIS) could play a role in organizing IT/IS faculty to do the same thing and engage the government policymakers and legislators to bring IT/IS faculty's expertise to the table for advocating a national public health information system for adding future pandemics. AIS recently created an online form for its members to discuss issues related to Covid-19 and incidents or activities relevant to research and teaching. That is a great start but is still insufficient. AIS could charge a group of IT/IS faculty to form specific task forces in various expertise areas to inform and help policymakers address the evolving COVID-19 pandemic in the United States and around the globe. The federal government has some meetings that are open for the public to attend. For example, the US Networking and Information Technology Research and Development (NITRD) Program, as the Nation's primary source of federally funded research and development (R&D) in advanced information technologies (IT) in computing, networking, and software, provide regular opportunities for the public to engage and participate in information sharing among Federal agencies and non-Federal participants. Information technology and systems researchers are encouraged to participate and contribute their expertise and ideas for building national health information systems.

The COVID-19 also provides an excellent opportunity for technology researchers to pursue federal research grants. The US National Science Foundation, National Institutes of Health, other federal/state agencies, and private foundations offer funding opportunities to encourage the research community

to contribute ideas and solutions to help address the challenges caused by COVID-19. There is an increasing call for the federal government to work with Congress to develop policies and legislation to establish a functional nation public health system for responding to the pandemics (Blumenthal et al., 2020; Chin & Chin, 2020). Technology researchers should lead or join an interdisciplinary team to write the grant proposals and get funding to directly work on health IT projects, including pilot or demonstration projects to improve interoperability and add value to health stakeholders.

In conclusion, as COVID-19 continues to impact the US, there is a stronger need than ever to develop the interoperability of health IT, which would enable collecting, sharing, analyzing, and utilizing data related to COVID-19, as well as help the governments, healthcare providers, and other organizations improve their response to COVID-19 and future pandemics. While it may take months to implement a national health IT infrastructure and a national public health information system, technology scholars must advocate the interoperability of health IT and help speed up this process by engaging in various initiatives to strengthen the collaboration and coordination among stakeholders.

## **CONFLICTS OF INTEREST STATEMENT**

The authors whose names are listed in this manuscript certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

## **FUNDING AGENCY**

The publisher has waived the Open Access Processing fee for this article.

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