VOLUME 03 ISSUE 02 (2024)

AMERICAN JOURNAL OF MEDICAL SCIENCE AND INNOVATION (AJMSI)

ISSN: 2836-8509 (ONLINE)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Medical Science and Innovation (AJMSI)

Volume 3 Issue 2, Year 2024
ISSN: 2836-8509 (Online)
DOI: https://doi.org/10.54536/ajmsi.v3i2.3612
https://journals.e-palli.com/home/index.php/ajmsi

Enhancing Interoperability and Response Coordination in Disaster Settings: A Review of Methodological Frameworks and Technique

Alina Petrica[1], Mohammed Isa Lawan[2*], Amakama Nimisingha Jacob[2], Gilles Dusserre[2]

Article Information

Received: August 12, 2024
Accepted: September 09, 2024
Published: November 14, 2024

Keywords

Disaster Response, Electronic Medical Records, Emergency Medical Operating System, Interoperability, Mobile Field Hospital, Regional Hospital, Telemedicine

ABSTRACT

When mobile field hospitals are deployed for disaster response missions, they face several challenges. Notable among the challenges is the lack of interoperability with the regional hospitals which is essential for patient information sharing and transfer when the need arises. Several healthcare systems around the globe have interoperability platforms that are well in place. However, due to different standards and system design they cannot easily interoperate with one another. This is even more apparent when interoperability during disaster response is desired between a mobile field hospital and regional hospital. The several interoperability frameworks designed by vendors are mainly designed for usage in large stationary hospitals, hence there is need to consider frameworks that can enhance interoperability between a mobile field hospital and regional hospital to facilitate coordinated disaster response. In this article we argue that an effective disaster response interoperability framework should be adaptable, affordable, simple to use, and capable of being employed in isolated, harsh environments such as occurs during disaster response. An analysis of several healthcare interoperability frameworks is conducted in this article with the aim of proposing a suitable framework for possible adoption by mobile field hospital's interoperability with regionals hospitals during sudden onset disasters.

INTRODUCTION

Background and Significance

Disasters as defined by United State office for Disaster Risk Reduction (UNDRR) is a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts. The effect of the disaster can be immediate and localized but is often widespread and could last for a long period of time. The effect may test or exceed the capacity of a community or society to cope using its own resources, and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels necessitating request for mobile field hospital deployment (UNDRR, 2020).

A mobile field hospital is defined as mobile, self-contained, self-sufficient medical facility that is capable of rapid deployment, expansion or contraction to meet immediate emergency requirement for a specified period of time (Rossodivita, 2011).The conditions involved before a field hospital can be dispatched include: (a) a written request by health authorities of the affected country, (b) be Integrated into the local healthcare systems, and (c) a Clear definition of their roles, responsibilities, and operational attainment. The main purpose of a field hospital is to compliment or substitute local hospitals in advent of sudden impact events that produce a disaster. When mobile field hospitals are deployed for disaster response, they are faced with myriads of challenges, notable amongst is the lack of interoperability with other regional healthcare systems (Hamis *et al.*, 2023; Anyam Gift *et al.*, 2020; Olalekan & Gift, 2020; Raimi & Raimi., 2020)

Interoperability plays a role in emergency situation, especially in emergency departments, where it can be both essential and insufficient, at times, especially during large scale disasters (Migliorini, 2019). The concept of interoperability refers to the capacity of information systems, devices, and applications to access, exchange, integrate and collaborate through sharing data across organizational boundaries. This coordination aims to ensure access to information and optimize the well-being of individuals and populations (Li *et al.*, 2022). When health information systems lack interoperability, it compromises the quality of patient care, and leads to unnecessary resource wastage (Torab-Miandoab *et al.*, 2023).This brings about the importance to have a compatible healthcare interoperability frameworks.

In disaster situations the importance of interoperability frameworks has been growing. It is crucial for organizations involved in disaster response to communicate effectively and coordinate their efforts. Interoperability challenges can make information sharing and coordination, among organizations a daunting task, especially during a disaster (Migliorini, 2019; Matshaba *et al.*, 2023). Interoperability frameworks play a role in facilitating the exchange and sharing of data across diverse systems and services. These frameworks encompass a range of standards, guidelines and policies that outline the agreements for organizations to establish connections between their systems using

[1] University of Medicine, Timisoara, Timis, Romania
[2] IMT Mines Alès, France
[*] Corresponding author's e-mail: mohadamagum71@yahoo.com

interfaces and protocols. By implementing interoperability frameworks at levels, such as syntactic, semantic, organizational and legal aspects, seamless connectivity can be achieved (Ndlovu *et al.*, 2021). The European Interoperability Framework (EIF) serves as an illustration of an accepted method, for providing public services with seamless compatibility. Interoperability frameworks depend on public service governance that encompasses aspects like usability, security, privacy, and performance. When creating an interoperability framework, it is crucial to define four layers; legal, technical, semantic, and organizational. However, these layers are seldom defined in disaster settings, where inter-operability is required in the interaction between existing Regional Hospitals (RH) and Mobile Field Hospitals (MFH). The objectives of this study are to provide answers to two research questions;

(1) What are the healthcare interoperability challenges in disaster settings?

(2) Which of the current interoperability frameworks can improve the interoperability between a mobile field hospital and the regional hospitals during a disaster response?

Interoperability Challenges in Healthcare

For a time, the healthcare industry has recognized the issue of interoperability. Interoperability challenges in healthcare arise from the obstacles faced when trying to exchange and share data seamlessly among systems and services. These challenges encompass issues such, as.

• Lack of coordination among different facilities/health systems participating in or facilitating health information exchange (HIE) (Mitigating Barriers to Interoperability in Health Care | HIMSS, 2019).

• Resistance to data sharing and lack of skill (Top Healthcare Interoperability Challenges - Excellarate, 2023).

• Constraints in budget ('Interoperability in Healthcare Tech, 2022; Top Healthcare Interoperability Challenges - Excellarate, 2023).

• Lack of standardization of terminology and normalization of data(Healthcare Interoperability: Barriers and Solutions, 2020).

• Inconsistent information across multiple sources (Ali, 2022; Top 5 Challenges with Interoperability in Healthcare, 2021).

• Poorly enforced standards that can obstruct seamless health data exchange by complicating transactions and posing additional barriers to the flow of information (EHRIntelligence, 2017).

• Inability to identify patients consistently (EHRIntelligence, 2017).

• Legal system issues: Systems implemented before the establishment of common national standards are known as legacy systems, which typically have restricted interoperability capabilities (Barbarito *et al.*, 2012).

• Lack of interoperability standards or poorly enforced standards(EHRIntelligence, 2017).

• Complexity of healthcare domain (Barbarito *et al.*, 2012).

These difficulties can lead to negative health outcomes, increased expenses and a decrease in the quality of patient care (Iroju *et al.*, 2013; sadeghi *et al.*, 2023; Top Healthcare Interoperability Challenges - Excellarate, 2023). To address these issues, stakeholders are adopting healthcare technologies and approaches that promote interoperability. This includes utilizing intelligence empowering patients to engage with their health data and strengthening health information exchanges (3 Ways to Enhance Healthcare Interoperability with Health IT, 2020). Additionally, enhancing interoperability requires a combination of strategies like realigning incentives and overcoming barriers that hinder the exchange of electronic health information (Mitigating Barriers to Interoperability in Health Care, HIMSS, 2019) (Sadeghi *et al.,* 2023)

LITERATURE REVIEW

In this part, we'll look at several interoperability frameworks and extensively study each framework to evaluate its strengths, flaws, and applicability to diverse scenarios. The main aim is to find a suitable framework for mobile field hospital's interoperability with regional hospitals for patient information sharing and transfer during disaster response.

Electronic Medical Record (EMR)

An EMR has the potential to significantly enhance the quality, usability, security, and interoperability of documentation with other systems and teams (Schreiber *et al.*, 2022). According to Gaynor *et al.* (2014), EMRs that adhere to the US Office of National Coordinator's (ONC) meaningful use criteria will:

• Enhance clinical decision-making,

• Minimize redundancy,

• Improve compliance with documentation and treatment standards,

• Enable context-specific information presentation,

• Integrate clinical documentation and billing functions,

• Support clinical research and quality improvement.

The interoperability of health care applications becomes complex due to the components of an EMR. A typical hospital EMR consists of systems, clinical documentation, laboratory, radiology, pharmacy and physician order entry modules. When clinical data is recorded using data elements (HL7v3 CDA) encoded in a manner (XML) with accepted terminology (SNOMED) and stored in a manner that enables the use of standardized retrieval methods these benefits are more likely to be realized (Gaynor *et al.*, 2014).Hence sharing of electronic medical records will go a long way in improving interoperability across various healthcare systems.

Use of iPhone Application iChat

Electronic medical records are extensively utilized in both developed and some developing countries, playing a role in addressing challenges within the healthcare industry. Interestingly their significance becomes more pronounced during short medical service trips to areas

despite their limited implementation in such regions (Dainton & Chu, 2017). The research underscores the value of two technologies; the iPhone application called iChart and traditional satellite communication. The study highlights how EMR greatly benefits low resource settings and challenging environments. Specifically, it improves care coordination and information retrieval by enabling devices to access data thereby replacing the old paper chart system with longitudinal patient records and a centralized repository for essential patient information. However, it is worth mentioning that some limitations exist; for instance, the current version of iChart has been criticized for its time-consuming nature as it takes around two to five minutes to input patient data. Additionally, one of the authors noted that their EMR system becomes less usable on days when there could be up to 500 encounters (Dainton & Chu, 2017). According to the study, EMR has gained popularity while other EMRs-like systems are still in the pilot phase and mainly used internally by non-governmental organizations (NGOs). Based on this finding smaller rival EMR systems should consider enhancing their technology to facilitate communication and data manipulation, between physicians, patients, other clinicians and larger EMR platforms. This suggestion aims to enhance interoperability among these systems.

Intelligent Agent Technology (AIDA)

Researchers, from the University of Minho collaborated with one of Portugals leading hospitals Centro Hospitalar do Porto (CHP) to develop the Agency for Integration, Diffusion and Archive of Medical Information (AIDA). AIDA is a platform that facilitates the integration and sharing of data generated in healthcare settings. By utilizing tools like Service Oriented Architectures (SOA) and Multi Agent Simulation (MAS) which ensure interoperability in diverse contexts, AIDA offers ways to integrate information. What sets AIDA apart from systems are its programs functioning as proactive software agents and intelligent workers. These agents handle tasks such as managing information, sending, and receiving medical reports, photos, data collection, prescriptions, communicating with systems and providing accurate and timely responses to requests. As the volume and complexity of data generated in healthcare facilities continues to grow so does the need for a system to manage these agents effectively.

To address this need, Cardoso *et al.* (2014), proposed a module for AIDA that allows administrators to create agents to schedule their actions and monitor their activities closely. The primary goal of AIDA is to distribute and store datasets from various sources, like services, departments, units, computers, and medical devices. Additionally, it provides tools to make human connections easier. Ensuring that AIDA functions optimally and satisfies its stakeholders (such as administrators, physicians, nurses, patients) is crucial because the AIDA platform has become indispensable for operations in healthcare institutions where it's implemented. Given that the agents form the foundation of the AIDA platform (even a small anomaly during their execution) can lead to issues for a healthcare facility. These issues can directly or indirectly impact treatment. Thus, AIDA administrators need to be aware of an agent's tasks and their duration along with details. Consequently, it became necessary to develop a module for managing AIDA agents to identify agent failures.

Social and Healthcare Information Sharing System (SISS)

Barbarito *et al.* (2012) present the application of interoperability standards in the Lombardy Regional Healthcare Information System in Italy. The method included implementing the Health Level 7 (HL7) standard within individual institutions as well as establishing a technology infrastructure for data sharing based on regionally recognized interoperability protocols. This enables the integration of various healthcare organizations in the region, resulting in large-scale integration among healthcare providers while also serving patients. Also, it facilitates communication and message exchange across many actors in the healthcare system, including hospitals, general practitioners, specialists, nurses, and pharmacists, by utilizing standardized web services and integration profiles.

Telemedicine

Telemedicine refers to the use of information and communication technologies to deliver healthcare services and support when physical distance separates the people involved (Jamal *et al.*, 2007). In the study, telemedicine was utilized to enhance interoperability, between healthcare providers and tertiary healthcare facilities during an earthquake that occurred in Pakistan on October 8, 2005. Furthermore, telemedicine has the potential to address the issue of staff shortages, which was an observed challenge at COVID 19 field hospitals (Alpert *et al.*, 2018). An example of this success can be seen during the FMT type 3 Nepal mission in 2015, where a consultant pediatric cardiologist was not physically present to treat a child with difficulty breathing and an abnormal ECG. By utilizing telemedicine, images and videos were transmitted to the specialist who provided lifesaving advice. This intervention has not only resolved staffing shortages but also improved collaboration between healthcare systems when expertise from limited specialists is required.

Emergency Medical Operating System (EOS)

Emergency medical teams (EMTs) are dispatched immediately in response to sudden onset disasters to provide care for the injured. However, coordinating and communicating with regional hospitals can be challenging for EMTs due to the lack of information systems and standards (Schreiber *et al.*, 2022). To tackle these challenges the Emergency Medical Team Operating System (EOS) was specifically developed for EMTs. The European Modular Field Hospital (EUMFH) which is a Project

of the European Directorate General for European Civil Protection and Humanitarian Aid Operations (DG ECHO) supported by the General Directorate, for Civil Protection and Humanitarian Aid Operations of the European Commission aimed to conceptualize a European EMT3 and ultimately led to the creation of the Emergency Medical Team Operating System (EOS).

Sharing data with systems is crucial in situations where an EMT may collaborate with responders and nearby hospitals. To facilitate integration into an information processing chain an interface called HL7 FHIR was developed. Additionally, each information card can be linked to scanned or downloaded documents allowing for the inclusion of data and complementing EOS data forms while ensuring continuity of care. This feature would enable the use of preprinted EOS forms during prolonged power outages and enable the addition of completed forms scanned to their cards once power is restored. EOS can be accessed through a web browser that is compatible with any device ranging from smartphones to PCs making it user friendly and intuitive. The patient care user interface has been specifically designed for tablet PCs providing flexibility for staff members to move around the field hospital as needed (Schreiber *et al.*, 2022).

To effectively communicate with teams, the EMR language can be easily switched at any time. The system is designed to strike a balance between openness and necessary restrictions. Its aim is to minimize the number of clicks required for users to quickly respond in emergency situations. To ensure traceability, quality and safety standards are met, EOS maintains a comprehensive audit log that tracks all user added or modified data. Moreover, it allows flexible role allocation for healthcare professionals such as doctors, nurses, and technicians with system permissions for each role. EOS offers an EMR solution tailored specifically to meet the needs of EMTs. It addresses the standing need in the market for a portable digital tool that facilitates organized and transparent documentation—an essential aspect of managing, coordinating, and evaluating disaster relief operations. Initial assessments conducted during a field exercise demonstrated implementation of the system while receiving positive feedback from users (Schreiber *et al.*, 2022).

The Hermes Semantic Model

Vergeti *et al.* (2018) developed the HERMES model which is an ontological representation of the conceptual model of the Health Emergency Management domain that makes up the HERMES Semantic Model, which aims to: (a) provide an integral conceptual model of Health Emergency Management covering all relevant knowledge domains; and (b) address the previously mentioned interoperability and integration issues. HERMES reuses existing ontologies to produce a new upper model, a set of vertical models, and a data facet. A specific method imports data from the various resources using the model to give an integrated and consistent view of the data. The final standardized data may be used by different event management platforms to assist in making decisions during an emergency. Lastly, open data from open data sources is used to assess the model and the data harmonization process. The evaluation's findings confirm that the strategy is appropriate. Even though there are many ontologies accessible, the HERMES approach is unique since it establishes a general higher model for emergency response that can be used for any incident, including mass emergencies and everyday occurrences. Additionally, HERMES adheres to interoperability requirements that the Emergency Management Ontology does not anticipate.

Complete And Resilient Documentation (Card) For Operational Medical Environments

Clemson University United States sponsored the research by Woo *et al.* (2019) on interoperability framework known as the complete and resilient documentation for operational medical environment (CARD). This system-oriented approach aimed at enabling resilient handsfree data collection, preserve complete documentation and provide timely information for medical operations. It is a highly flexible and evolvable framework which addresses challenges of handsfree electronic health record data entry in noisy operational environments, preventing disruption of care for documentation and avoiding loss of documentation.

Systems, Methods, and Techniques for Interoperable Emergency Communication

Ma *et al.* (2020) proposes the use of systems methods and techniques for interoperable emergency communication. This proposes a framework for triggering and releasing emergency communication escalation events which enhances emergency communication systems. The framework suggests the use of notifications to inform specific individuals or groups involved in escalation, ensuring timely communication during emergency situations. Even though the framework was aimed for military emergency response, the concept of emergency communication escalation can be applied within organizations or across multiple organizations, facilitating coordinated responses to emergency. Hence such approach can be applied to filed hospitals and enable interoperability with other regional hospital during disaster response.

Interoperability Framework for Integrated E-Health Services

This framework, which is built using Web Service technology and the service-oriented architecture (SOA) paradigm, is proposed (Amin *et al.*, 2020). During the analysis and design phases of system development, a technique called service-oriented analysis and design (SOAD) is employed to create a service portfolio that is divided into three levels: conceptual, logical, and physical views.

The Service Oriented Architecture (SOA) paradigm in system development is demonstrated by the service portfolio, which was created because of the architecture of the interoperability framework for the e-health service utilized in this study.

An array of computer-based information systems, including emergency department, inpatient, laboratory, financial, and other services, are integrated into the e-health service to satisfy stakeholder information needs and patient demands. The goal of the project was to develop an interoperability mechanism model for sharing information and data between multiple databases, including the National Population Database, the Health Insurance Database, and e-health services run by hospitals or other health data providers.

Automatic Ambulance System Using Internet of Things

Saha *et al.* (2020) suggested this model in which The Raspberry Pi serves as the foundation for the architecture, with sensor units connected to it. Sensors are used to measure the patient's physiological characteristics. Parameters include heart rate, temperature, blood pressure, glucose, cholesterol levels, and more. The machine also has a camera module for capturing patient images at regular intervals.

After completing the ambulance module, upload the data to the cloud. The Cloud module includes two cloud services. They're ThinkSpeak and Dropbox. The ThinkSpeak cloud platform allows numerical data to be submitted. ThinkSpeak cloud provides graphical representation of uploaded data. The images are uploaded to DropboxCloud.In the hospital module, the doctor monitors the data that has been uploaded to the cloud. The red detected image aids clinicians in determining the severity of wounds. The hospital module includes a basic application that downloads data from the cloud. With the data collected, the doctors plan for an immediate medical response. This, however, is best suited for interoperability between emergency medical ambulance and regional hospitals within a given metropolitan.

Table 1: Comparative analysis of selected interoperability frameworks

Author (s)	Methodology	Advantages	Disadvantages	Applicability
Cardoso *et al.*, 2014.	Service Oriented Architecture (SOA) and MAS. Uses intelligent agent-based technology AIDA	Enhance communication with various systems and provide accurate and prompt responses to requests. Flexible and can be applied to different healthcare environments.	Expensive and complex	More useful in larger healthcare systems.
Barbarito *et al.*, 2012.	Social and healthcare information sharing system (SISS): Adoption of HL7, using a conceptual framework with technological infrastructure for data sharing	Provides interoperable social healthcare system that, by putting international health standards into practice, connects patients, healthcare providers, healthcare organizations, and healthcare professionals in a vast and diverse territory	Expensive and complex, may not be easily used in areas with low connectivity and power supply.	Suitable for stationary healthcare facilities. Some aspects, such as EHR, appointment scheduling and reporting tools could be useful with mobile field hospital
Dainton *et al.*, 2012.	Highlighted two most popular EMR systems technology (proprietary iPhone application called iChat to create a patient log and custom-built clinical database constructed for the Palm operating system (OS) using the Smart List to Go program, and 5 personal digital assistants (PDAs)	Used by mobile field hospitals during Haiti earthquake. Shows importance of the creation of longitudinal patient records and a centralized repository of basic patient information resulted in improved provider handoffs and continuity of care. Data could be accessed from multiple devices, rather than one fixed central location in the case of paper charts, resulting in improved interoperability	The current version of iChart was reported to be too cumbersome, as it took 2-5 and a half minutes to input a single patient encounter. Researchers reported their EMR system to be impractical during busier days when there could be upwards of 500 patient encounters.	Suitable for use in a low resource setting and mobile medical facility such as the mobile field hospital

Jamal *et al.*, 2007	Telemedicine mobile device connected to a base unit via a customized software which enables seamless exchange of data between the two units	Speeds up diagnosis and therapeutic interventions by allowing primary healthcare providers to receive continuous assistance from specialized centers. It is has the advantage of being cost effective	Require technology and communication infrastructure. Data privacy and security are not guaranteed.	This can be applied to areas where specialized care is absent or lacking and can address the issue of staff shortage. Suitable for mobile field hospital
Schreiber *et al.*, 2022.	Emergency medical team operating system. Uses EMR, FHIRHL7.	Data sharing with other systems is essential since an EMT might work alongside first responders and nearby hospitals. HL7-FHIR interface promote standard information transmission and make it easier to be incorporated into a larger information processing chain	Staff may require training regarding its usage.	Specifically designed for use by deployable emergency medical teams such as the mobile field hospital
Amin *et al.*, 2019.	Utilized system-oriented architecture (SOA) and implemented using web service technology. This is developed using service-oriented analysis and design (SOAD).	Materialize data interoperability and information exchange among several e-health systems.	Cannot be used on multiple platforms e.g., laptop, desktop, and mobile phones.	Designed for data exchange between multiple databases.
Vergeti et al, 2018	Developed a semantic model called HERME which reuses an existing ontological model to provide an upper model which imports data from various sources hence providing an integrated and harmonized view of the data.	The model can be applied to any incident (every day or mass emergency). Also aligned with interoperability standard not foreseen in emergency management ontology	Maily focusses on semantic interoperability	Flexible and can be applied to any incident
Woo *et al.*, 2021	Complete and Resilient Documentation (CARD) for Operational Medical Environments is a system-oriented approach aimed at enabling resilient handsfree data collection, preserve complete documentation and provide timely information for medical operations	Addresses challenges of handsfree electronic health record data entry in noisy operational environments, preventing disruption of care for documentation and avoiding loss of documentation	Limited or unreliable network coverage in disaster-stricken areas may hinder effectiveness of CARD	Highly flexible and evolvable system which is applicable in variety of scenarios including harsh austere disaster settings
Ma *et al.*, 2020	Proposes a framework for triggering and releasing emergency communication escalation events	Improves response times and enhance emergency communication systems	May require personnel training and internet connections	Flexible and can be applied to healthcare emergency response such as deployed mobile field hospitals

Amin *et al.*,2020	This framework uses web service technology and service-oriented architecture to build an interoperability model for information sharing between several data bases	Serve as a guide for creation of e-health systems across a range of medical applications	Further research is needed for developing e-health systems using multi platforms environments	Flexible and can be used for variety of healthcare system interoperability

MATERIALS AND METHODS

We conducted searches in credible databases including Web of Science, PubMed, and Google Scholar. Google search of websites was also included. The keywords used include "disaster response", "mobile field hospital", "regional hospital", "emergency medical operating system", "telemedicine", and "electronic medical records".

For inclusion, we targeted articles published in English within the previous 20 years and focussing on the state-of-the-art on several healthcare related interoperability standards, frameworks, and applications. While for exclusion, we removed opinion pieces and studies with insufficient data.

By using the search, 400 articles were found at first. Upon examining abstracts and titles, we narrowed the field down to 86. After carrying out a full-text examination, we included 46 articles that satisfied the predetermined standards and chosen for in-depth analysis. Finally, 28 articles were selected with additional 16 website obtained Via google search containing relevant information as per the criteria. Thus, assisting in gaining valuable understanding about several interoperability frameworks, their limitations, strengths and opportunities for improvement and application in disaster settings. These reviews were critical in the proposal of an appropriate methodological framework with features and capabilities that is anticipated to address the challenges that are usually associated with interoperability, vis-à-vis the improvement of healthcare delivery and subsequent patient outcomes in disaster settings.

RESULTS AND DISCUSSION

Result

Table 1 is a summary of the analysis done on selected healthcare interoperability frameworks. As the main aim of this research is to device a suitable framework that can be adopted during disaster response to enhance interoperability between mobile field hospital and regional hospital, we hold that the framework should meet some criteria: it should be cost effective, has ease of usage, is feasible in low connectivity or resource area, its practicality during emergency and it has data and security privacy. Categorizing these frameworks based on these requirements we obtain the following results:

Cost Effectiveness

This must be considered when deciding which frameworks to use for mobile field hospital as a cheaper framework will be easy to implement in disaster and low resource settings. Some of the frameworks that fits into this criterion include:

1. Use of iphone applications e.g ichart
2. Telemedicine
3. Emergency medical team operating system

Ease of Understanding

For it to be adopted in emergency response, the framework should be easy to understand by the healthcare personnel. Among the reviewed frameworks, it is obvious that the ones having easy mode of operation or requiring less training include:

1. Use of iphone applications e.g ichart
2. Telemedicine
3. Emergency medical team operating system

Feasibility In Low Connectivity Areas (REMOTE LOCATIONS)

Based on the analysis, the frameworks that are feasible in remote and low resource settings include:

1. Use of iphone applications e.g ichart
2. Telemedicine
3. Emergency medical team operating system

Practicality During Emergency Situations

Among the reviewed frameworks, those that are best designed and suited in emergency situations include:

1. Use of iphone applications e.g ichart
2. Telemedicine
3. Emergency medical team operating system
4. framework for triggering and releasing emergency communication escalation events by ma *et al.* (2020).
5. Complete and Resilient Documentation (CARD) for Operational Medical Environments

Privacy And Security Concerns

Privacy is an important challenge in interoperability and any framework must have data privacy and security protection even in emergency response situations. Some of the frameworks that have more data privacy based on the information provided include the following:

1. Uses intelligent agent-based technology AIDA.
2. Social and healthcare information sharing system (SISS)
3. Complete and Resilient Documentation (CARD) for Operational Medical
4. Framework for triggering and releasing emergency communication escalation events by ma *et al.* (2020).

Discussion

Table 1 summarizes the weaknesses, strengths, and opportunities of the selected frameworks. Some frameworks are better suited for a larger stationary healthcare system while others can be suitable for use in austere settings such as during disaster response. We hold that the suitable framework should have specific features applicable to a low resource disaster setting, they include adaptability, flexibility, cost effectiveness and privacy. The emergency medical team operating system was one that fits well because it has almost all the attributes. It was designed specifically for mobile field hospitals and was tested during a full-scale European union module exercise and proven to be effective by 21 team members from 9 different countries. Its resource management feature enhances interoperability and coordination. The second one in line is the Telemedicine. Even though it lacked some qualities such as data privacy, it has excellent features which can easily be adopted for interoperability during disaster. The most prominent feature is the ability to allow medical consultations remotely. This is extremely important in situations of staff shortage or when a specialist intervention from a different location is required. The third is the iChat which is also very similar to the first two as it is suitable for use in low resource settings. Another similarity is it also can be used on several platforms e.g. phones, laptops, and tablets. Other frameworks that are very specific for emergency response include: the Hermes semantic model, complete and resilient documentation (card) for operational medical environments, and interoperability framework for integrated e-health services. These frameworks can also be considered due to their specificity for emergency response, data security and flexibility to several conditions. However, they maybe be costly and may also require some operator skills. Furthermore, they have not been tested for usage in a mobile field hospitals or emergency medical teams as in the case of the Emergency medical team operating system. Other frameworks have better data security and privacy and are better suited for larger stationary hospital e.g. Uses intelligent agent-based technology AIDA and The Social and healthcare information sharing system (SISS).In view of this, it can be seen that the best suitable framework is not the one with the greatest quality in one aspect but the one that is more flexible to accommodate a whole different attributes. This is to make disaster response easier in an environment where the resources are lacking, and more technical and sophisticated expertise is not available. We therefore suggest that choosing a framework that satisfy the conditions proposed by the authors will greatly enhance interoperability between mobile field hospitals and regional hospitals in disaster response.

LIMITATION

The disadvantage of this study is that various alternative frameworks may have been overlooked due to a lack of access to non-open-source literature focusing on interoperability. Furthermore, most of the information presented about each framework was based on the information provided in the article, and thus it may contain some characteristics that were not recorded in this article.

Future Directions

The several frameworks and systems shows potential for exploration and advancement. Here are a few aspects that can be explored further.

Resource Allocation Algorithms

Create algorithms that enhance the distribution of resources by utilizing up-to-date patient information and facility capacities. Research could delve into AI powered models to forecast patient requirements and adjust resource allocation strategies accordingly, in line with the frameworks highlighted.

Scalability and Adaptability

Discover the potential of each framework to effectively respond to types of disasters whether they are small scale incidents or major emergencies. The research could concentrate on developing a structure that can adjust to patient volumes and resource requirements.

Remote Training and Education

Explore the possibilities of the frameworks in facilitating training and education for healthcare professionals during disaster response situations. This may involve utilizing simulations training modules and platforms for sharing knowledge.

Regulatory and Legal Frameworks

It is important to study the regulatory aspects related to using the frameworks. This includes exploring licensing, liability and cross-border healthcare regulations. Creating a framework that complies with requirements is vital for ensuring its widespread adoption.

Ethical Guidelines

Create a set of guidelines to govern the use of the frameworks. These guidelines should cover aspects like ensuring consent for remote consultations, maintaining patient confidentiality, and promoting equal access to healthcare services.

Implementation and Adoption Strategies

Explore approaches for implementing the frameworks within established healthcare systems. This involves addressing change management, designing training programs, and devising strategies to overcome any resistance to the adopting technologies.

Human Factors and Psychology

Investigate the effects of consultations on healthcare professionals and patients in times of disasters. Gaining insights into the emotional aspects can aid in enhancing the design and implementation of the framework.

CONCLUSION

As the world is experiencing increasing incidents of disasters, mobile field hospitals serve as the beacon of hope among chaos especially when the local capacity is at stake. However, to achieve a better patient outcome, these deployed mobile field hospitals will need to interoperate with the regional hospital to facilitate patients transfer and information sharing whenever required. Most of the healthcare interoperability frameworks focus on creating frameworks that are more suitable for stationary healthcare facilities. To solve this problem, this article investigated various healthcare interoperability frameworks with the aim of finding a suitable framework between mobile field hospitals and regional hospitals during disaster response scenarios. The frameworks were selected based on their focus on interoperability of healthcare systems. Their strengths, weaknesses, and applicability to mobile field hospital were analyzed. To find the best framework for adoption, we hold that the framework should be cost-effective, easy to use, feasible, and practical in disaster and austere settings. Patient data and security must also be considered. The result of the comparative analysis shows that some frameworks are less cost effective than others, have more feasibility in low resource settings, and have better ease of understanding. They include Use of iPhone applications iChat, Telemedicine, and Emergency medical team operating system. Other frameworks have better practicality during disaster situations. They include framework for triggering and releasing emergency communication escalation events, Complete and Resilient Documentation (CARD) for Operational Medical Environments, Use of iPhone applications iChat, Telemedicine, and Emergency medical team operating system. While others have more privacy and data security. They include Intelligent agent-based technology AIDA, Social and healthcare information sharing system (SISS), Complete and Resilient Documentation (CARD) for Operational Medical, framework for triggering and releasing emergency communication escalation events by ma *et al.* (2020).

Acknowledgments

We would like to express our gratitude to IMT Mines Alès for providing us with a conducive research environment. Additionally, we extend our thanks to the Petroleum Technology Development Funds for their support, in the form of scholarship, for authors 1.

REFERENCES

Alpert, E. A., Weiser, G., Kobliner, D., Mashiach, E., Bader, T., Tal-Or, E., & Merin, O. (2018). Challenges in implementing international standards for the field hospital emergency department in a disaster zone: The Israeli experience. *The Journal of Emergency Medicine, 55*(5), 682–687. https://doi.org/10.1016/j.jemermed.2018.07.019

Ali, D. N. (2022, December, 6). *EHR interoperability challenges and solutions*. EHR in Practice. https://www.ehrinpractice.com/ehr-interoperability-challenges-solutions.html

Amin, M. M., Sutrisman, A., Stiawan, D., Ermatita, E., Alzahrani, M. Y., & Budiarto, R. (2020). Interoperability framework for integrated e-health services. *Bulletin of Electrical Engineering and Informatics, 9*(1), 354–361. https://doi.org/10.11591/eei.v9i1.1825

Anyam Gift, R. A., & Olalekan, R. M. (2020). Access to electricity and water in Nigeria: A panacea to slow the spread of COVID-19. *Open Access Journal of Science, 4*(2), 34. https://doi.org/10.15406/oajs.2020.04.00148

Barbarito, F., Pinciroli, F., Mason, J., Marceglia, S., Mazzola, L., & Bonacina, S. (2012). Implementing standards for interoperability among healthcare providers in the public regionalized healthcare information system of the Lombardy Region. *Journal of Biomedical Informatics, 45*(4), 736–745. https://doi.org/10.1016/j.jbi.2012.01.006

Bokolo Anthony Jnr. (2020). Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic. *Journal of Medical Systems, 44*(7). https://doi.org/10.1007/s10916-020-01596-5

Cardoso, L., Marins, F., Portela, F., Santos, M., Abelha, A., & Machado, J. (2014). The next generation of interoperability agents in healthcare. *International Journal of Environmental Research and Public Health, 11*(5), 5349–5371. https://doi.org/10.3390/ijerph110505349

Dainton, C., & Chu, C. H. (2017). A review of electronic medical record keeping on mobile medical service trips in austere settings. *International Journal of Medical Informatics, 98,* 33–40. https://doi.org/10.1016/j.ijmedinf.2016.11.008

Dinh, A., Yin, A. L., Estrin, D., Greenwald, P., & Fortenko, A. (2023). Augmented reality in real-time telemedicine and telementoring: Scoping review. *JMIR MHealth and UHealth, 11,* e45464. https://doi.org/10.2196/45464

EHRIntelligence. (2017, August 14). Top 5 challenges to achieving healthcare interoperability. *EHRIntelligence.* https://ehrintelligence.com/news/top-5-challenges-to-achieving-healthcare-interoperability

European Commission, Directorate General for Informatics. (2017). *New European interoperability framework: Promoting seamless services and data flows for European public administrations. Publications Office.* https://data.europa.eu/doi/10.2799/78681

FHIR®—Fast Healthcare Interoperability Resources® | eCQI Resource Center. (2023). https://ecqi.healthit.gov/fhir

FHIR | Cloud Healthcare API. (n.d.). *Google Cloud.* Retrieved August 2, 2023, from https://cloud.google.com/healthcare-api/docs/concepts/fhir

Gaynor, M., Yu, F., Andrus, C. H., Bradner, S., & Rawn, J. (2014). A general framework for interoperability with applications to healthcare. *Health Policy and Technology, 3*(1), 3–12. https://doi.org/10.1016/j.hlpt.2013.09.004

Hamis, A. A., Md Bukhori, A. B., Heng, P. P., Jane Ling, M.

Y., Shaharuddin, M. A.-A., A Fauzi, N. A. F., Masdor, N. A., Othman, R., & Ismail, A. (2023). Strategies, challenges and opportunities in the implementation of COVID-19 field hospitals: A scoping review. *BMJ Open, 13*(3), e067227. https://doi.org/10.1136/bmjopen-2022-067227

Healthcare interoperability: Barriers and solutions. (2020). https://www.healthcatalyst.com/insights/healthcare-interoperability-barriers-solutions

HealthITAnalytics. (2022, February 23). FHIR interoperability basics: 4 things to know. *HealthITAnalytics*. https://healthitanalytics.com/news/4-basics-to-know-about-the-role-of-fhir-in-interoperability

Interoperability frameworks | Identification for Development. (n.d.). Retrieved on August 12, 2023, from https://id4d.worldbank.org/guide/interoperability-frameworks

Iroju, O., Soriyan, A., & Gambo, I. (2012). Ontology matching: An ultimate solution for semantic interoperability in healthcare. *International Journal of Computer Applications, 51*(21), 7–14. https://doi.org/10.5120/8325-1707

Jamal, A., Hussain, S., Zafar, A., & Malik, A. Z. (2007). Role of telemedicine during disaster: A case study. *2007 9th International Conference on E-Health Networking, Application and Services, 97,* 261–263. https://doi.org/10.1109/health.2007.381645

Kalvesmaki, J. (n.d.). Three ways to enhance the interoperability of cross-references in TEI XML. *Proceedings of the Symposium on Cultural Heritage Markup, 16*. https://doi.org/10.4242/balisagevol16.kalvesmaki01

Li, E., Clarke, J., Ashrafian, H., Darzi, A., & Neves, A. L. (2022). The impact of electronic health record interoperability on safety and quality of care in high-income countries: Systematic review. *Journal of Medical Internet Research, 24*(9), e38144. https://doi.org/10.2196/38144

Madsen, C., Poropatich, R., & Koehlmoos, T. P. (2023). Telehealth in the military health system: Impact, obstacles, and opportunities. *Military Medicine, 188*(Supplement_1), 15–23. https://doi.org/10.1093/milmed/usac207

Ma, S., & Spicuzza, J. F. (2020). U.S. patent no. 10,869,179. Washington, DC: U.S. Patent and Trademark Office.

Matshaba, L., Nxozi, M., & Herselman, M. (2023). Guiding the development of interoperable health information systems: A conceptual IT governance framework. In *Design science research for a new society: Society 5.0* (pp. 143–156). https://doi.org/10.1007/978-3-031-32808-4_9

Migliorini, M., Hagen, J. S., Mihaljević, J., Mysiak, J., Rossi, J.-L., Siegmund, A., Meliksetian, K., & Guha Sapir, D. (2019). Data interoperability for disaster risk reduction in Europe. *Disaster Prevention and Management: An International Journal, 28*(6), 804–816. https://doi.org/10.1108/dpm-09-2019-0291

Mitigating barriers to interoperability in health care | HIMSS. (2019). https://www.himss.org/resources/mitigating-barriers-interoperability-health-care

Ndlovu, K., Mars, M., & Scott, R. E. (2021). Interoperability frameworks linking mHealth applications to electronic record systems. *BMC Health Services Research, 21*(1). https://doi.org/10.1186/s12913-021-06473-6

Olalekan, R. M., & Gift, R. A. (2020). The toughest triage in decision impacts: Rethinking scientific evidence for environmental and human health action in the times of concomitant global crises.

Pamplin, J. C., Davis, K. L., Mbuthia, J., Cain, S., Hipp, S. J., Yourk, D. J., Colombo, C. J., & Poropatich, R. (2019). Military telehealth: A model for delivering expertise to the point of need in austere and operational environments. *Health Affairs, 38*(8), 1386–1392. https://doi.org/10.1377/hlthaff.2019.00273

Rossodivita, A. (2011). The role of field hospitals in severe environments: Guidelines to prepare and build a field hospital during a disaster. *Prehospital and Disaster Medicine, 26*(S1), s95–s96. https://doi.org/10.1017/s1049023x11003244

Schreiber, E., Gaebel, J., de Hoop, T., & Neumuth, T. (2022). The emergency medical team operating system: Design, implementation, and evaluation of a field hospital information management system. *JAMIA Open, 5*(4). https://doi.org/10.1093/jamiaopen/ooac106

Sadeghi, M., Carenini, A., Corcho, O., Rossi, M., Santoro, R., & Vogelsang, A. (2023). Interoperability of heterogeneous systems of systems: From requirements to a reference architecture. *The Journal of Supercomputing, 80*(7), 8954–8987. https://doi.org/10.1007/s11227-023-05774-3

Telehealth: A post-COVID-19 reality? | McKinsey. (2021). *McKinsey*. https://www.mckinsey.com/industries/healthcare/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality

Top 5 challenges with interoperability in healthcare. (2021). *Datavant*. https://www.healthjump.com/blog/5-challenges-with-healthcare-interoperability

Top healthcare interoperability challenges—Excellarate. (2023). Encora. https://www.encora.com/insights/overcoming-healthcare-interoperability-challenges

Torab-Miandoab, A., Samad-Soltani, T., Jodati, A., & Rezaei-Hachesu, P. (2023). Interoperability of heterogeneous health information systems: A systematic literature review. *BMC Medical Informatics and Decision Making, 23*(1). https://doi.org/10.1186/s12911-023-02115-5

Vergeti, D., Ntalaperas, D., & Alexandrou, D. (2018). Semantically enhanced interoperability in health emergency management. In *On the Move to Meaningful Internet Systems. OTM 2018 Conferences* (pp. 368–385). https://doi.org/10.1007/978-3-030-02671-4_23

Weistra, W. (2022, September 29). FHIR is transforming interoperability in healthcare – but what exactly is it? *Firely*. https://fire.ly/blog/what-is-fhir/

Weymouth, W., Thaut, L., & Olson, N. (2018). Point of view telemedicine at point of care. *Cureus*. https://

doi.org/10.7759/cureus.3662

What are the real-life benefits of FHIR for healthcare? (2022, November 16). *Prolifics*. https://prolifics.com/us/resource-center/specialty-guides/fhir-guide/fhir-benefits

Woo, M., Mishra, P., Lin, J., Kar, S., Deas, N., Linduff, C., Niu, S., Yang, Y., McClendon, J., Smith, D. H., Shelton, S. L., Gainey, C. E., Gerard, W. C., Smith, M. C., Griffin, S. F., Gimbel, R. W., & Wang, K.-C. (2021). Complete and resilient documentation for operational medical environments leveraging mobile hands-free technology in a systems approach: Experimental study. *JMIR MHealth and UHealth, 9*(10), e32301. https://doi.org/10.2196/32301