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Evaluating the Impact of Healthcare Interoperability on Patient Outcomes: A Global Multi-Stakeholder Analysis

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Abstract

This study evaluates the impact of healthcare interoperability on patient outcomes from a global, multi-stakeholder perspective. Interoperability (the seamless exchange, integration, and utilization of health information across diverse healthcare systems) is vital for effective patient care coordination, error reduction, and treatment efficacy. However, while interoperability is well-established in high-income countries, low- and middle-income countries (LMICs) still face significant barriers, including infrastructure limitations, inconsistent policies, and resource constraints. Using a mixed-methods approach, the study conducted surveys and qualitative interviews involving healthcare providers, administrators, digital health vendors, and patients across 24 countries. Survey data revealed that over 90% of respondents recognize interoperability's positive impact on patient outcomes, notably through improved care coordination, reduced medical errors, and enhanced data accuracy. Qualitative insights further highlighted real-world benefits, such as reduced hospital readmissions, improved chronic disease management, and greater patient safety due to comprehensive medication records. Nevertheless, the research identified considerable variability in stakeholders' understanding of interoperability, particularly in LMICs, where data submission to national health management systems is often mistaken for interoperability. Key challenges identified include limited digital infrastructure and significant skill gaps among health workers. In conclusion, healthcare interoperability significantly enhances patient outcomes globally but requires tailored strategies to overcome implementation challenges in resource-limited settings. The study recommends further development of scalable, affordable interoperability frameworks, sustained longitudinal assessments, and patient-centered interoperability solutions to maximize healthcare quality, safety, and continuity worldwide.

Keywords: *EHR, EMR, Digital Health, HIE, Healthcare Interoperability, Patient Outcome.*

Background

The healthcare sector has experienced substantial changes, fueled by rapid technological advancements and the growing need for high-quality patient care. As individuals navigate various healthcare services, they encounter multiple providers and institutions, often resulting in their medical records being dispersed across different systems. The lack of seamless data exchange poses risks such as medical errors, inefficient care coordination, and administrative burdens, underscoring the need for robust healthcare interoperability frameworks.

Healthcare Interoperability

Healthcare interoperability is the capability of diverse health information systems, medical devices, and applications to seamlessly exchange, integrate, and utilize data for coordinated healthcare delivery [1]. Beyond being a mere technological advancement,

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interoperability serves as a fundamental pillar of contemporary healthcare, fostering seamless communication and data accessibility across multiple stakeholders. Effective implementation of interoperability ensures that crucial patient information, including medical histories, diagnostic results, and treatment plans, is readily available at the point of care, thereby reducing medical errors, enhancing care continuity, and ultimately improving patient safety [2].

As healthcare delivery systems grow increasingly complex and patient mobility rises, the need for interoperability has become more pressing than ever. Global initiatives such as the World Health Organization's (WHO) Digital Health Strategy and the Global Digital Health Partnership (GDHP) recognize interoperability as a fundamental component of achieving universal health coverage [3,4]. In developed nations, enhanced interoperability among electronic health records (EHRs) has been projected to save up to $30 billion annually by eliminating redundant diagnostic tests and reducing administrative inefficiencies [5]. However, in low- and middle-income countries (LMICs), progress remains hindered by fragmented healthcare infrastructures, insufficient resources, and inconsistent digital health policies, making the realization of full-scale interoperability significantly more challenging.

Research Objectives

This study evaluates interoperability's influence on patient care coordination, error reduction, and treatment efficacy across multiple regions and healthcare settings. This study aims to generate emperical evidence of impact or not of healthcare interoperability from multi-stakeholder perspectives.

Literature Review

Overview on Healthcare Interoperability

It is established that healthcare interoperability capability will ensures timely and seamless portability of information, which is essential for delivering efficient and effective patient care [6]. What is not clear is if this happens in practice, especially in low- and middle-income countries.

Interoperability can be understood across four distinct levels: foundational, structural (or syntactic), semantic, and organizational. Foundational interoperability involves basic data transfer from one IT system to another without the necessity for the recipient system to interpret the transferred data. Structural interoperability specifies the data exchange format, ensuring that exchanged data elements are consistently interpretable across different systems at a structural or field level. Semantic interoperability, considered more advanced, ensures not only the exchange of information but also its meaningful and accurate interpretation by participating systems. Organizational interoperability, the most comprehensive level, integrates governance structures, policies, legal frameworks, and social considerations to facilitate consent, trust, and effective workflows among multiple organizations [7].

Interoperability has gained traction worldwide, driven by regulatory mandates, incentives, and technological advancements. According to OECD insights, Countries like the UK (NHS Spine), Estonia (blockchain-enabled e-health records), and Denmark (National Health Data Exchange) have successfully implemented nationwide interoperability frameworks. However, in many low- and middle-income countries (LMICs), interoperability remains fragmented due to infrastructure limitations, lack of standardization, and funding constraints.

Numerous studies have highlighted the positive impact of healthcare interoperability on patient outcomes. For instance, research conducted by Vest and Gamm in 2010, a decade and a half earlier, indicates that interoperability facilitates better coordination of care, reducing the likelihood of medical errors and improving

the overall quality of care [8]. Ever since several interoperability initiatives have been documented. Edmond et al. systematically documented the impact of Electronic Health Records (EHR) in high-income countries [9]. They categorized the impact of interoperability on patient outcomes into patient safety events, medication safety, data accuracy & errors, and Care effectiveness.

Patient Safety Events

The ability to share health information seamlessly across different healthcare settings and among various healthcare providers is critical in reducing medical errors and enhancing patient safety, a vital component of healthcare outcomes. Interoperability improves patient safety by ensuring that all healthcare providers have access to complete and accurate patient information at the point of care. According to a study by Menachemi et al., healthcare facilities that implemented advanced interoperable health information technologies reported a significant reduction in serious medication errors and noted improvements in overall patient safety metrics [10].

Medication Safety

Interoperable systems facilitate a cohesive flow of patient information, which includes detailed medication lists, histories of allergies, and past adverse drug reactions. This information can be beneficial to either the individual patient's care or the collective Patient health through better insights from medication characteristics. As noted by Koppel and Lehmann, interoperability between prescribing systems, pharmacies, and point of care ensures that all stakeholders have consistent and accurate drug information, which is critical for safe medication practices [11]. Moreover, interoperability supports the implementation of clinical decision support systems (CDSS) which provide alerts and guidance to healthcare providers at critical decision-making junctures. For example, a CDSS can alert a provider if a prescribed medication could potentially interact with another drug the patient is taking, or if the patient has a recorded allergy to an ingredient in the medication. This is especially so, if the patient is moving across specialties or health institutions; without interoperability, such insights will be near impossible. Beeler et al. provide evidence that such systems, supported by interoperable electronic health records, significantly reduce the risk of adverse drug events by facilitating real-time, informed clinical decisions [12]. This continuity is crucial for avoiding medication discrepancies and ensuring ongoing patient safety. Laugaland et al. highlight how interoperable health information exchange systems can decrease hospital readmissions by ensuring that outpatient care providers have immediate access to hospital treatment records, including changes to medication regimens [13].

Data Accuracy and Errors

Interoperability across various healthcare information systems ensures that accurate and current patient data is available wherever care is provided. This comprehensive data integration helps maintain data integrity by minimizing discrepancies that often arise from manual data entry or from handling the same patient information across multiple, non-integrated systems. It has been demonstrated that real-time data exchange and Analysis could reduce errors in patient records, thereby improving the reliability of the data used for clinical decision-making [14].

Case Studies from Multiple Settings

Several case studies illustrate the practical benefits and challenges of healthcare interoperability in different regions. In Denmark, the implementation of a national health information exchange (HIE) has significantly improved the quality of care and patient safety. According to a study by Johansen et al., the Danish HIE reduced clinical errors by

70% and enhanced information sharing among healthcare providers [15].

In the United States, the Health Information Exchange Services (HealthEConnections) in New York connects hospitals, practices, laboratories, and imaging centers. A report by HealthEConnections indicated that the HIE delivered 7.5 million alerts from 600,000 unique patient records in 2018 alone, involving 2,700 physicians from 860 organizations [16]. This level of data integration has facilitated better care coordination and improved patient outcomes.

In Africa, initiatives such as OpenHIE and OpenEHR have shown promise in enhancing healthcare interoperability [17, 18]. However, these initiatives face significant challenges related to infrastructure, funding, and capacity building. Despite these challenges, the communities involved in these projects are working towards establishing frameworks to measure and improve the impact of interoperability on health outcomes.

Methodology

The research used a mixed-method approach leveraging surveys and qualitative interviews. This study did not require ethics approval as it did not use human or animal subjects in the research.

Survey of Digital Health Stakeholders

The study population includes digital health and interoperability solutions designers, electronic medical record (EMR) vendors, healthcare providers, healthcare administrators, and patients across various settings. The target population was drawn from the following groups: The Global Digital Health Network (GDHN) listserv, The Digital Health Interoperability Network (DHIN) community of practice members, the DHIN LinkedIn followers, Nigeria EMR vendors directory, comprising 50 EMR vendors, and An Interoperability WhatsApp group of digital implementers in Nigeria. In all, 48 persons from 24 countries responded to the survey between 9th May 2024 and 5th June 2024. The characteristics of respondents have been represented in Table 1.

Table 1. Characteristics of Survey Respondents

Country	Yrs of Expirience	HIE Experience	No. of Respondents
Australia	5-10	Yes (very familiar)	1
Barbados	21-Over	A little (a little familiar)	1
Chad	1-5	Yes (very familiar)	1
DRC	6-10	Yes (very familiar)	1
Ecuador	11-15	Yes (very familiar)	1
Ethiopia	1-5	Yes (very familiar)	1
	11-15	Yes (very familiar)	1
France	1-5	Yes (very familiar)	1
Georgia	1-5	A little (a little familiar)	1
Ghana	6-10	Yes (very familiar)	1
Honduras	1-5	Yes (very familiar)	1
India	11-15	Yes (very familiar)	1
	16-20	Yes (very familiar)	1
Indonesia	6-10	Yes (very familiar)	1

Jordan	21-Over	Yes (very familiar)	1
Kenya	1-5	A little (a little familiar)	1
	11-15	Yes (very familiar)	1
	6-10	Yes (very familiar)	1
Lesotho	11-15	Yes (very familiar)	1
Nepal	6-10	Yes (very familiar)	1
Nigeria	1-5	Yes (very familiar)	3
		A little (a little familiar)	1
	11-15	Yes (very familiar)	5
	16-20	Yes (very familiar)	1
	21-Over	A little (a little familiar)	1
		Yes (very familiar)	1
	6-10	Yes (very familiar)	2
Rwanda	16-20	Yes (very familiar)	1
Sierra Leone	11-15	Yes (very familiar)	1
Sri Lanka	6-10	Yes (very familiar)	1
Tanzania	1-5	Yes (very familiar)	1
UK	1-5	Yes (very familiar)	1
	6-10	Yes (very familiar)	2
US	1-5	A little (a little familiar)	1
	11-15	Yes (very familiar)	2
	21-Over	Yes (very familiar)	1
Uganda	1-5	Yes (very familiar)	1
	11-15	Yes (very familiar)	1
	6-10	A little (a little familiar)	1

The summary of their characteristics is represented in the bar chart of experiences as in Figure 1.

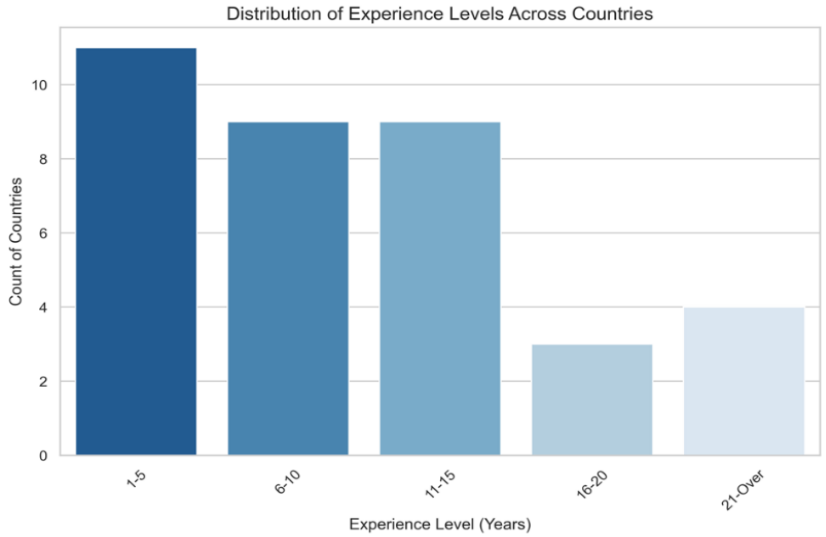

Figure 1. Summary of Participant's Digital Health Experience

Qualitative Key Informant Interviews

Additionally, purposive sampling was used for the qualitative interviews to select key informants from the list of survey respondents. This targeted two persons per geographic region of the world to gain additional global insights into the practice of healthcare interoperability. The interviews also targeted two representatives each from digital health and EMR vendors, healthcare professionals, administrators, and patients. In all only 10 respondents were eventually interviewed. See the distribution and characteristics of eventual interview respondents by age, gender, role, and geographic location shown in Table 2.

Table 2. Characteristics of Key Informant Interview Participants

ID	Age	Gender	Role	Location
001	54	m	Vendor	Nigeria
002	31	f	MD	Nigeria
003	35	m	MD	Rwanda
004	46	m	Hosp. Admin	Kenya
005	49	m	Hosp. Admin	Nigeria
006	41	f	Hosp. Admin	Nigeria
007	50	f	Patient	USA
008	27	f	Patient	Nigeria
009	47	m	Vendor	USA
010	52	m	Hosp. Admin	Australia

Analysis

The collected data was analysed using Python Jupiter notebook.

Results

Awareness of what constitutes interoperability varied widely amongst stakeholders. More than half of respondents consider data submission to public health portal interoperability; another half consider information sharing with a healthcare organization interoperability. Respondents from low- and middle-income countries (e.g. from Africa, like Nigeria and from Southeast Asia, like Indonesia) mostly identify submissions into the National HMIS from health facilities as a form of interoperability. Figure 2 shows this distribution.

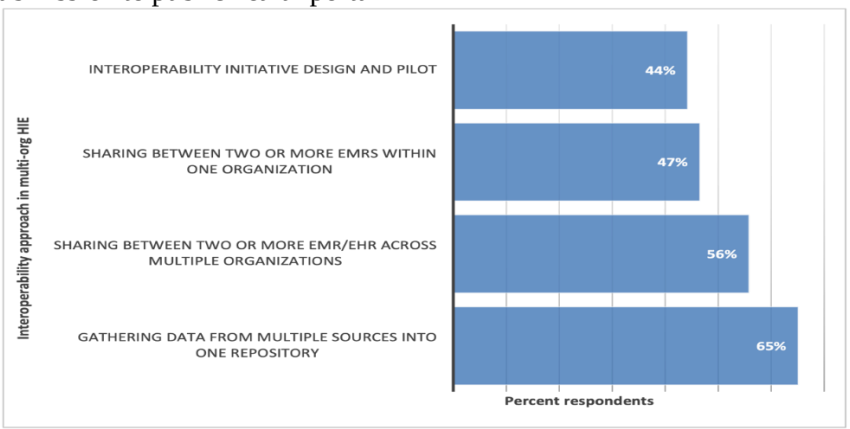

Figure 2. Respondents Who are Aware of Interoperability Between Multiple Organizations

Quantitative Survey Analysis

The survey data revealed significant insights into the impact of healthcare interoperability on patient outcomes. The majority of respondents (over 90%) were very familiar with the concept of healthcare interoperability and indicated their organizations were involved in digital health interoperability initiatives. The analysis showed that healthcare interoperability positively influenced patient outcomes by enhancing care coordination and reducing medical errors through improved quality of care.

Respondents associate care quality improvement, reduced delays and waiting time, and enhanced patient data security to positive patient outcomes of healthcare interoperability initiatives as in Figure 3. Though 13% of survey respondents think interoperability generally worsen wait time due to the added use of technology. On the other 4% of respondents think healthcare interoperability had no impact on patient outcomes in the initiatives they were involved.

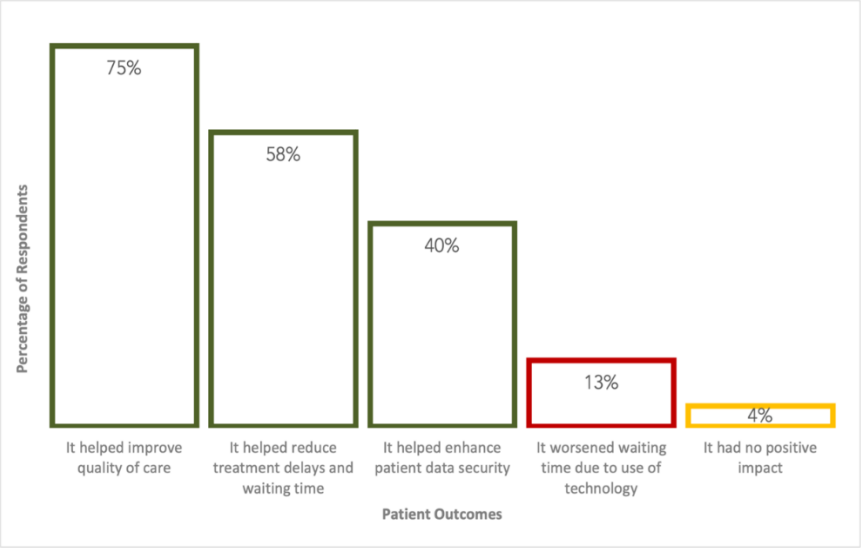

Figure 3. Respondents' Recollection of Patient Health Outcome Attributable to Interoperability

In addition, to those views as expressed in the options, others, less than 1% each included comments such as:

"work in progress", "economic benefits", "improved data quality and reporting", "sometimes the impact is not known and measured", "yet to go live", ".provides longitudinal health data to patients mobile phone", "reduce data entry work for health workers", ".helps with data analytics.", "...not yet mature enough to define impact"

Similarly, respondents believe the expected health outcome of HIE should be improved quality of care (90%), reduced treatment delays and waiting time (83%), and enhanced patient data security (30%). Others, Less Than One Percent Each Included Other Comments:

"support for decision making", "patient can also review their clinical information", "reduced cost of accessing healthcare", "allows continued care", "economics".

Though about 17% of respondents believe waiting time is expected to increase with introduction of HIE in a health system.

Qualitative Interview Responses

A Healthcare Provider from Abuja, Nigeria, stated:

"*Healthcare interoperability has significantly improved patient outcomes at our tertiary hospital. For instance, the EMR system allows for real-time access to patient records, which has been crucial in managing chronic diseases. One notable example is a diabetic patient who frequently visited the emergency*

department due to complications. With the interoperable system, all healthcare providers involved in the patient's care could access their medical history, leading to a coordinated treatment plan that significantly reduced emergency visits."

A Similar Sentiment was Echoed by a Healthcare Provider in New York:

"In interoperable healthcare settings, patient care is more efficient and coordinated. Healthcare providers have access to comprehensive patient histories, leading to more accurate diagnoses and timely interventions. This has resulted in better health outcomes for me, including fewer hospital visits and improved management of my chronic conditions."

Discussion

Healthcare interoperability has demonstrated significant improvements in patient outcomes by fostering seamless data exchange, enhancing care coordination, and reducing medical errors. This study reaffirms existing literature, which highlights interoperability as a cornerstone of effective healthcare delivery. For instance, Menachemi et al. observed that hospitals with robust, interoperable systems report lower adverse medication events and higher patient satisfaction [19]. Similarly, insights from respondents in this study indicate that real-time access to patient data has significantly improved chronic disease management, such as diabetes and hypertension, by enabling coordinated and timely care.

Case studies further illustrate this impact. Denmark's national health information exchange reduced clinical errors by 70%, showcasing how structured and semantic interoperability ensures data accuracy and supports clinical decision-making [15]. These findings highlight the critical role of interoperability in enhancing patient safety, particularly in high-resource settings. However, in low-resource settings, such as parts of Sub-Saharan Africa, the benefits remain limited by infrastructural challenges and fragmented healthcare systems [20]. From the survey responses, 75% of all respondents still indicate that infrastructure availability to support healthare interoperability is either not available or averagely available in their countries (ranking 1, 2, or 3 out of 5). Similarly, 69% of survey respondents indicate that skills gap remains a major challenge in executing interoperability initiatives.

The positive impact of interoperability on patient outcomes underscores the need for healthcare organizations to prioritize the implementation of interoperable systems. Policymakers should consider incentivizing healthcare providers to adopt and utilize interoperable systems, as this can lead to improved quality of care and patient safety. At the same time, policymakers need to invest more in infrastructure and skills enablers that will aid interoperability of health information systems.

Conclusion

Healthcare interoperability is an indispensable component of modern healthcare systems, aligning closely with the public health principles of efficiency, equity, and evidence-based decision-making. This study highlights the profound impact of interoperability on patient outcomes, providing compelling evidence for its integration into healthcare delivery systems globally. The findings underscore that interoperable systems improve patient outcomes through enhanced care coordination, reduced medical errors, and more efficient resource utilization.

Future research should focus on the following areas to further advance healthcare interoperability and its integration into public health systems:

1. Development of Scalable Interoperability Models: Future studies should explore scalable and cost-effective interoperability frameworks tailored to low-resource

settings. These models should prioritize affordability, ease of deployment, and alignment with existing health system infrastructures.

2. Longitudinal Studies on Interoperability Impact: Conduct long-term studies to evaluate the sustained impact of interoperability on patient outcomes, cost-efficiency, and system resilience. These studies should assess the return on investment (ROI) and cost-effectiveness of interoperability initiatives across diverse healthcare contexts.
3. Patient-Centric Interoperability: Explore models that empower patients to have greater control over their health data. This could involve personal health records (PHRs) integrated with interoperable systems to improve continuity of care and patient engagement.
4. Regional and Global Comparison: Comparative studies across different regions and countries with larger respondents can provide insights into best practices and lessons learned from various interoperability initiatives. Understanding the factors contributing to successful implementations in different contexts can inform global strategies for enhancing interoperability.

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