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How Interoperability Challenges Are Addressed in Healthcare IoT Projects

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Abstract. The rapid development and implementation of Internet of Medical Things has made interoperability a serious challenge. In this scoping review, we provide an overview of the interoperability challenge, as reported in the health literature, and highlight the proposed solutions. After searching between January 2018 and June 2023 in Compendex via Engineering Village and PubMed, we found 18 publications. The interoperability challenges identified were device heterogeneity, system heterogeneity, data standardization, security and safety, system and architecture standard, system and workflow integration and regulatory and compliance requirements. Solutions included ontology approaches, conceptual semantic frameworks, improved standards, design of middleware, and using blockchain technology.

Keywords. Interoperability, Internet of Medical Things, Healthcare

1. Introduction

With rapid development and implementation of various types of Tele-Health and wide use of Internet of Medical Things (IoMT) for telemonitoring, there is a serious need to address interoperability with a more robust approach. In this context, interoperability refers to the ability of different medical devices, systems, and software applications to communicate, exchange data, and work together effectively [1]. Interoperability allows the huge amount of data generated and collected by medical devices and systems such as wearable sensors, remote monitoring devices, electronic health records, and healthcare management systems to be shared, integrated, and utilized across different devices and platforms, enabling healthcare providers to make informed decisions, improve care coordination, and ultimately achieve a more efficient and patient-centred care [2].

Being essential to holistic and integrated healthcare, researchers face various challenges in achieving interoperability. These challenges have been observed and reported both in theoretical approaches and empirical studies. We intend to provide an

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overview of these challenges, as reported in the health literature, and highlight the proposed solutions.

2. Method

For this scoping review, we searched for studies in the English language only, between 1st Jan 2018 and 1st June 2023 in Compendex via Engineering Village and in PubMed. We also searched the reference lists of included articles, with no limitations to document type, study completion status and publication status. The keywords included were Interoperability, Internet of things, Health care, IoT, IoMT, delivery of health care, interoperable, interoperate, and other similar constructs, terms, and concepts.

We imported the search results into EndNote 20 and de-duplicated them. Two reviewers (OP and TM) screened the results independently against the eligibility criteria. Titles and abstracts were reviewed and screened by the independent reviewers. Following the initial screening, the full text of the remaining articles was evaluated. Discrepancies were resolved through discussions or by asking a third reviewer (TA).

We included documents if they discussed the Internet of Things in healthcare and interoperability, with or without proposing a solution. The articles were excluded if they did not address healthcare, or if they only discuss challenges of interoperability. All peer-reviewed research articles and non-research reports from national or international organisations, dissertations/theses, books/book chapters, conference abstracts and research in progress from grey literature were accepted.

Data from selected documents were extracted in MS Excel and later checked against the full text for corrections or amendments if deemed necessary. Study name, year of publication, country(ies) of origin, number of collaborating centres and challenges mentioned were recorded. Solutions were also listed if the authors had proposed any. We summarised the collected data in tables and described them narratively.

3. Results

After duplicates' removal, we screened 75 articles, from which 18 publications were included in the final analysis. We included 5 articles, 12 conference papers and proceedings and one report. Three documents resulted from international collaborations. India had the highest number of publications with 4 studies, followed by Indonesia, Korea, Pakistan, Spain and the USA each with 2 publications. The Czech Republic, Egypt, Germany, Tunisia, the UK and Sweden were also present in the list. Most of the publications were single centre based studies. The list of included studies is presented in Table 1, below.

Table 1. List of documents included in the review

Title	Author	Publication Year
An Intelligent Edge Computing Based Semantic Gateway for Healthcare Systems Interoperability and Collaboration [3]	Sigwele et al.	2018
A semantic interoperability approach to heterogeneous internet of medical things (IoMT) platforms [4]	Villanueva-Miranda et al.	2018
Pre-Standards Workstream Report: Clinical IoT Data Validation and Interoperability with Blockchain [5]	IEEE-Standards Association Pre-Standards Workstream	2019
A web of thing middleware for enabling standard web access over BLE based healthcare wearable device [6]	Bhawiyuga et al.	2019
Meaningful Integration of Data from Heterogeneous Health Services and Home Environment Based on Ontology [7]	Peng et al.	2019
An ontology-based healthcare monitoring system in the internet of things [8]	Titi et al.	2019
An Analysis of IoT Interoperability Standards in the Healthcare Sector [9]	Chituc	2019
Mobility management for healthcare services in coap-based iot networks [10]	Jung et al.	2019
Allowing iot devices collaboration to help elderly in their daily lives [11]	Flores-Martin et al.	2019
Towards Medical Data Interoperability through Collaboration of Healthcare Devices [12]	Jaleel et al.	2020
Issues and Challenges in Incorporating the Internet of Things with the Healthcare Sector [13]	Bhattacharya et al.	2021
Schema Ontology Model to Support Semantic Interoperability in Healthcare Applications: Use Case of Depressive Disorder [14]	Chong et al.	2021
Healthcare domain in IoT with blockchain based security- A researcher's perspectives [15]	Yogeshwar et al.	2021
A Patient-Centric Healthcare Framework Reference Architecture for Better Semantic Interoperability Based on Blockchain, Cloud, and IoT [16]	Gohar et al.	2022
A Proof-of-Concept IoT System for Remote Healthcare Based on Interoperability Standards [17]	Lemus-Zúñiga et al.	2022
Building Dynamic permutation based Privacy Preservation Model with Block Chain Technology for IoT Healthcare Sector [18]	Yogeshwar et al.	2022
Canny aspiration paraphernalia framework based healthcare monitoring system and secure medical interoperability [19]	Narahari et al.	2023

Most of the articles mentioned and discussed at least three different challenges of interoperability on IoMT. The mentioned challenges can be categorized into seven categories. Interoperability issues because of device heterogeneity and system heterogeneity were each addressed by 13 publications and are the main concern of many researchers. Data standardization and security and safety concerns were highlighted in 10 and 8 documents respectively. System and architecture standards (4 publications), System and workflow integration (3 publications) and Regulatory and compliance requirements (1 publication) were also mentioned by the researchers.

Most of these documents proposed solutions for the mentioned challenges. These solutions include proposing a series of ontology approaches, conceptual semantic

frameworks, improved standards, design of middleware and using blockchain technology.

4. Discussion

The reviewed literature highlights the focus of researchers on better understanding the barriers to implementing successful interoperability. Yet, most of the documents addressing this issue are conference papers, which might indicate that although researchers consider challenges of interoperability a serious topic of concern, few studies have been designed and implemented to target this topic directly or indirectly.

Although many of the challenges have been addressed by researchers in the IoMT field, topics like lifecycle management and connectivity and network issues have rarely been discussed. Authors have also tried to propose solutions to the mentioned challenges. In most cases, these solutions are of theoretical nature, but some real-life systems and platforms have been introduced. Further reports on the performance of such systems can shed light on different aspects of interoperability.

The use of blockchain technology was frequently recommended by different researchers. Despite the increased focus on it, as the most viable standards solution, the pre-standards workstream for Clinical IoT has concluded that it is neither necessary for device interoperability nor necessarily meets the connected healthcare TIPPSS (Trust Identity Privacy Protection Safety And Security) needs [20]. These recommendations emphasize even more the importance of research and discourse to achieve successful solutions for the existing challenges.

The interoperability challenges identified by researchers in the field of IoMT can be categorized into seven categories of device heterogeneity, system heterogeneity, data standardization, security and safety, system and architecture standard, system and workflow integration and regulatory and compliance requirements. Addressing these challenges requires collaboration among stakeholders, including healthcare providers, device manufacturers, regulatory bodies, and standardization organizations. Efforts to establish common data standards, communication protocols, and security frameworks can significantly improve the interoperability of IoMT systems and enhance patient care.

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