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Advancements in Digital Technologies for Infection Control in Healthcare Settings: A Scoping Review

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Abstract: The emergence of infectious diseases, exemplified by the 2014–2015 Ebola outbreak and the COVID-19 pandemic, highlights the ongoing global challenge posed by infections and the necessity for effective surveillance, prevention, and control strategies. Digital technologies are revolutionizing public health by improving the efficiency, accuracy, and scalability of infection monitoring and control efforts. This scoping review explores recent advancements in digital technologies for managing healthcare-associated infections (HAIs) in hospital and long-term care settings between 2018 and 2023. The review underscores the significance of cognitive technologies, the complexities of integrating digital solutions, and the importance of interdisciplinary collaboration to ensure successful implementation and equitable access to these innovations.

Keywords*: Digital Technologies, Infection Control, Healthcare-Associated Infections (HAIs), Surveillance, Cognitive Technologies, Interdisciplinary Collaboration, Equitable Access, Long-Term Care Facilities (LTCFs).*

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I. INTRODUCTION

Outbreaks of infectious diseases are unpredictable and can have significant consequences for individuals and society [1][2][3]. The Ebola outbreak of 2014–2015 in West Africa put immense pressure on healthcare systems, while the COVID-19 pandemic led to global economic disruption and placed heavy demands on both healthcare and social care services [4][5][6]. While predicting future outbreaks remains difficult, experts agree that infectious diseases will continue to present challenges at local, national, and international levels [7][8]. Factors such as rapid urbanization, increased global travel, population growth, and agricultural practices contribute to the emergence and severity of infectious disease outbreaks [9]. The latest advancements in information and communication technologies (ICT), particularly digital innovations, have the potential to enhance infectious disease surveillance, prevention, and management. These technologies enable real-time mapping, data collection, and pathogen identification, all while reducing costs [10]. Additionally, they play a crucial role in combating misinformation that can hinder disease control efforts [11]. However, despite their potential, the adoption of digital technologies in public health is inconsistent due to differences in infrastructure, training, and standardization across healthcare systems [12].

II. METHODOLOGY

This scoping review adheres to the PRISMA-ScR framework to examine the role of digital technologies in infectious disease monitoring, prevention, and control [13]. Research was sourced from databases such as PubMed, Scopus, Web of Science, and the Cochrane Database of Systematic Reviews. Additionally, EU-funded projects and systematic reviews were analyzed [14].

- *Search Strategy*

The review incorporated key terms related to infection prevention and control (IPC), including "infection prevention," "infection control," "artificial intelligence," "robotics," and "smart technology." Boolean operators were applied to refine search results across databases. The study focused on research published between January 1, 2018, and November 4, 2023, specifically analyzing digital innovations in the surveillance of

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healthcare-associated infections (HAIs) in hospitals and long-term care facilities (LTCFs). The reference lists of relevant systematic and scoping reviews were also examined [15].

➢ *Study Selection*

The study selection process was conducted in three stages:

- Initial screening of titles and abstracts by seven reviewers.
- Full-text review conducted by five reviewers.
- Final screening during data extraction to eliminate redundant or non-extractable data.

Eligible studies included randomized controlled trials, non-randomized comparative studies, observational research, and cross-sectional studies. However, meta-analyses, case reports, and narrative reviews were excluded. Research from all geographical regions was considered, with a primary focus on hospitalized patients and those in LTCFs [16].

➢ *Data Extraction and Analysis*

A standardized form was used for data extraction, collecting details such as study location, duration, setting, technology type, and study population. Quality assessment was conducted using tools like the Cochrane Risk of Bias Tool (RoB2) and the Newcastle-Ottawa Scale [17]. Quantitative data were processed using Microsoft Excel, while qualitative data underwent thematic analysis to identify key trends and implementation barriers [18].

III. KEY FINDINGS

➢ *Emerging Digital Technologies in Infection Control*

The review identified the use of cognitive technologies, including artificial intelligence (AI), machine learning, and mobile health (m-health) tools [15]. These innovations offer various advantages, such as:

- Real-time monitoring and predictive analytics.
- Enhanced communication between healthcare providers and patients.
- Improved tracking of healthcare-associated infections (HAIs).

Despite their potential, most studies remain at the conceptual or pilot stage, with limited large-scale implementation.

➢ *Underutilization of IoT and Robotic Automation*

Although the Internet of Things (IoT) and robotic automation have the potential to transform infection prevention and control (IPC), their adoption remains limited [16]. Research on automation and robotics in hospitals is either outdated or lacks significant impact. Current hospital IPC strategies primarily focus on hand hygiene (HH) and ultraviolet (UV) disinfection, rather than leveraging AI, big data, and IoT solutions[16].

➢ *Implementation Challenges*

- Lack of Standardization: The absence of uniform standards in digital health tools makes integration into healthcare systems challenging.
- Limited Healthcare Worker Involvement: Many studies indicate that healthcare workers (HCWs) are not adequately included in the design and training of digital technologies. Their active participation in co-designing and training is essential for successful adoption [17].
- Digital Divide: Limited access to digital health tools, particularly in low-income settings and among vulnerable populations such as the elderly, remains a major concern [18].

IV. DISCUSSION

Challenges in Integration and the Need for Collaboration Incorporating Health 4.0 technologies into healthcare requires collaboration among experts from various fields, including biomedical engineering, computer science, clinical practice, and public health. Policymakers must work toward standardizing digital health tools and ensuring that healthcare professionals receive adequate training to use these technologies effectively [17][18][19].

V. FUTURE DIRECTIONS

➢ *Assessing Long-Term Impact*

Further research is needed to examine the long-term effects of digital technologies on:

- Patient health outcomes.
- Healthcare expenditures.
- The effectiveness of infection prevention and control strategies.

➢ *Enhancing Digital Innovation in IPC*

Conducting mapping exercises across the EU/EEA and globally can help connect key stakeholders in digital public health, identifying areas for growth and improvement. Structured evaluations of digital interventions will be crucial in optimizing their implementation in healthcare environments.

VI. CONCLUSION

This scoping review highlights critical areas for future research on the role of digital technologies in infectious disease surveillance and forecasting. Innovations such as cognitive technologies, big data analytics, and simulation tools show great promise in improving infection prevention and control. However, challenges—including inconsistencies in methodology, limited real-world application, and digital inequities—must be addressed. Strengthening interdisciplinary collaboration and adopting strategies to bridge the digital divide will be essential in unlocking the full potential of digital healthcare innovations. Engaging healthcare workers in

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technology development and ensuring equitable access to digital health tools will be crucial for improving infection control and patient safety worldwide.

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