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ORIGINAL ARTICLE

Barriers and solutions in integrating technology in disaster management: insights from Saudi Arabia's emergency operations centers

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ABSTRACT

Background: Integrating technology into disaster response, particularly in health crisis management, enhances communication, resource management, and patient care. However, critical barriers such as system interoperability, network reliability, and insufficient specialized training hinder its effective adoption.

Aim and Objective: This study explores the challenges faced by emergency operations center (EOC) leaders in Saudi Arabia in adopting technology for disaster medicine and identifies practical solutions to improve disaster preparedness and response.

Methods: A structured survey was administered to 110 EOC leaders, achieving a response rate of 78.2%. The survey incorporated validated tools to assess technology usage, training adequacy, and implementation challenges. Quantitative data were analyzed using descriptive statistics, while qualitative responses were explored through thematic analysis.

Results: Among the 86 respondents, 91.9% reported using telemedicine and digital tools in disaster scenarios. However, 58% found training inadequate, 44% cited staff resistance to new technologies, and 42% highlighted connectivity issues as a significant challenge. Data security concerns were noted by 11%, particularly among older respondents. Correlation analysis revealed that leaders with greater experience perceived technology as more impactful, especially for communication and patient care. Thematic analysis also highlighted the importance of involving staff in decision-making to reduce resistance.

Conclusion: Addressing training gaps, building resilient communication networks, and fostering adaptability among staff are critical to advancing technology integration in disaster response. These findings provide actionable insights for Saudi EOCs and offer a roadmap for enhancing global disaster medicine frameworks.

Keywords: Technology, disaster management, emergency operation center.

Introduction

Rapid technological advancements may improve disaster response capabilities, particularly within health crises in which effective communication, resource management, and patient care are essential [1,2]. Technologies, such as telemedicine, data management systems, and advanced communication tools, are increasingly crucial in enhancing situational awareness and supporting rapid decision-making in emergency operations centers (EOCs) [3].

Despite these potential benefits, several obstacles limit the effective integration of technology in disaster medicine. Key challenges include issues with system interoperability, in which different platforms and devices may not communicate seamlessly, creating gaps in information flow [4]. Additionally, reliable and secure communication networks are essential,

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especially in disaster settings in which networks may be strained or disrupted. This is particularly critical in Saudi Arabia, since disaster response can be impacted by factors, such as extreme temperatures and the need for robust infrastructure capable of supporting high-volume data transmission [5]. The demand for specialized training to ensure EOC leaders and personnel can effectively use these technologies under pressure remains challenging [6]. Previous studies on best practices in public health EOCs underscore the need for tailored approaches for training and support that address the demands of EOC personnel [7]. Addressing these challenges is essential for Saudi Arabia's EOCs, in which leaders are pivotal in adopting and implementing technology to enhance disaster response effectiveness [8].

Provided the well-recognized benefits of technology in disaster medicine, it is essential to understand and address the specific obstacles faced by EOCs in Saudi Arabia. This study examines the key challenges as perceived by EOC leaders, focusing on issues, such as training inadequacies, infrastructure limitations, and cultural resistance to change. By identifying these barriers and providing targeted recommendations, this study aims to contribute to the development of more resilient and efficient disaster response frameworks. These findings hold broader implications for disaster response policy and practice, offering valuable insights for countries facing similar challenges and underscoring the importance of cohesive, well-supported technological integration in EOCs worldwide.

Methods

This study employed a descriptive survey design to assess the perspectives of EOC leaders regarding the challenges and solutions in implementing technology within disaster medicine. The target population included 110 leaders from the Ministry of Health's EOCs in Saudi Arabia. Participants were selected by purposive, non-probability sampling to ensure that the sample represented individuals with substantial experience and responsibility in emergency management. This approach was chosen to capture a comprehensive view of leadership roles within disaster response.

Survey development and validation

The survey instrument was carefully designed with items adapted from established tools, including the technology acceptance model (TAM) [9], Telemedicine Satisfaction and Usefulness Questionnaire (TSUQ) [10], and Disaster Preparedness and Response Questionnaire [11]. The TAM provides a framework for understanding key factors, such as perceived usefulness and ease of use, which are essential for gauging technology adoption within EOCs. Widely validated in healthcare and emergency settings, the TAM assesses EOC leaders' acceptance of disaster management technologies. The TSUQ, while initially focused on telemedicine, offers relevant insights into technology satisfaction and perceived usefulness more broadly. The survey included multiple-choice questions, Likert scale items, and open-ended responses to capture quantitative and qualitative insights. Experts in disaster medicine reviewed the questionnaire for content validity, focusing on technological aspects relevant to the Saudi context.

To enhance linguistic and cultural relevance, the survey was initially developed in English and translated into Arabic, followed by a back-translation. This process ensured that the items maintained their intended meaning across languages, aligning with the regional context in which the study was conducted.

Data collection and analysis

The survey was distributed electronically through WhatsApp, and responses were collected via Google Forms. This digital distribution facilitated high engagement among busy EOC leaders, achieving a strong response rate of 78.2% (86 out of 110 leaders).

Data were analyzed using descriptive statistics to summarize demographic information and key survey findings. To examine relationships between variables, such as technology's role in communication, patient care, and training adequacy, Pearson's correlation analysis was conducted. Means and standard deviations were calculated for continuous variables, whereas frequencies and percentages were used to describe categorical data. For qualitative responses from open-ended questions, thematic analysis was conducted, identifying key themes that were categorized for inclusion in the results.

Ethical considerations

This study adhered to ethical guidelines, ensuring confidentiality and informed consent from all participants. Approval was obtained from the Institutional Review Board before commencing the study, ensuring compliance with ethical standards for research involving human participants.

Results

Participant demographics

The study achieved a response rate of 78.2% (86 out of 110 Saudi EOC leaders). The demographic breakdown of respondents showed that most were men (88.4%) aged 35-54 years (51.2%). Experience levels varied, with most respondents reporting between 0 and 5 years in emergency management (50%), whereas a significant portion had 6-20 years of experience.

Initial observations revealed that more experienced leaders rated the impact of technology on communication and patient care more favorably. This trend aligns with the detailed correlation analysis, which illustrates a moderate positive correlation between years of experience and perceived technology benefits. Additionally, older respondents expressed more concerns regarding privacy and data security (11% noted these as primary concerns), hinting at an age-related dimension in technology perception among EOC leaders.

Use of technology in disaster response

Among the participants, 91.9% reported using telemedicine or other technological tools in disaster response scenarios (Table 1). Key applications included maintaining communication during emergencies, resource management, patient monitoring, diagnostics, and surveillance activities. The primary uses of technology as reported by the EOC leaders are shown in Figure 1, emphasizing the prominent role of technology in supporting core disaster response functions.

Perceived impact of technology

Participants rated technology's impact on communication, patient care, and ease of use in disaster settings on a Likert scale. The mean rating for the improvement of communication during disasters was 4.8 out of 5. Technology's role in enhancing patient care was rated 4.7, whereas the ease of use in emergency settings averaged 4.5. These high ratings underscore the perceived effectiveness of technology across multiple aspects of disaster response.

Challenges and barriers

Respondents identified several challenges associated with technological implementation. The most frequently mentioned issues included technological limitations (53%), such as citing software and hardware issues, insufficient current training programs (58%), highlighting a need for enhanced training efforts, resistance to change (44%), noting reluctance among staff to adopt new technologies, connectivity issues (42%) such as challenges related to internet and network stability during emergencies, and privacy and security concerns (11%), which were primarily raised by older respondents concerning data security.

Figure 2 categorizes these challenges and provides further details on the frequency of each issue. The high frequency of inadequate training and resistance to change

Table 1. *Key findings summary of major findings, including technology usage, training needs, challenges, and impact ratings.*

Finding	Details
High use of technology for disaster response	91.9% of respondents reported using telemedicine or other tech tools in disasters
Perceived inadequacy of current training programs	50% rated training as inadequate, 96% emphasize ongoing education
Major challenges in technology integration	Technological limitations (53%), inadequate training (58%), resistance to change (44%)
High perceived impact of technology on communication	Communication improvement rated at 4.8 out of 5, patient care at 4.7
Significant correlation between experience and technology effectiveness	Positive correlation between years of experience and perceived tech effectiveness

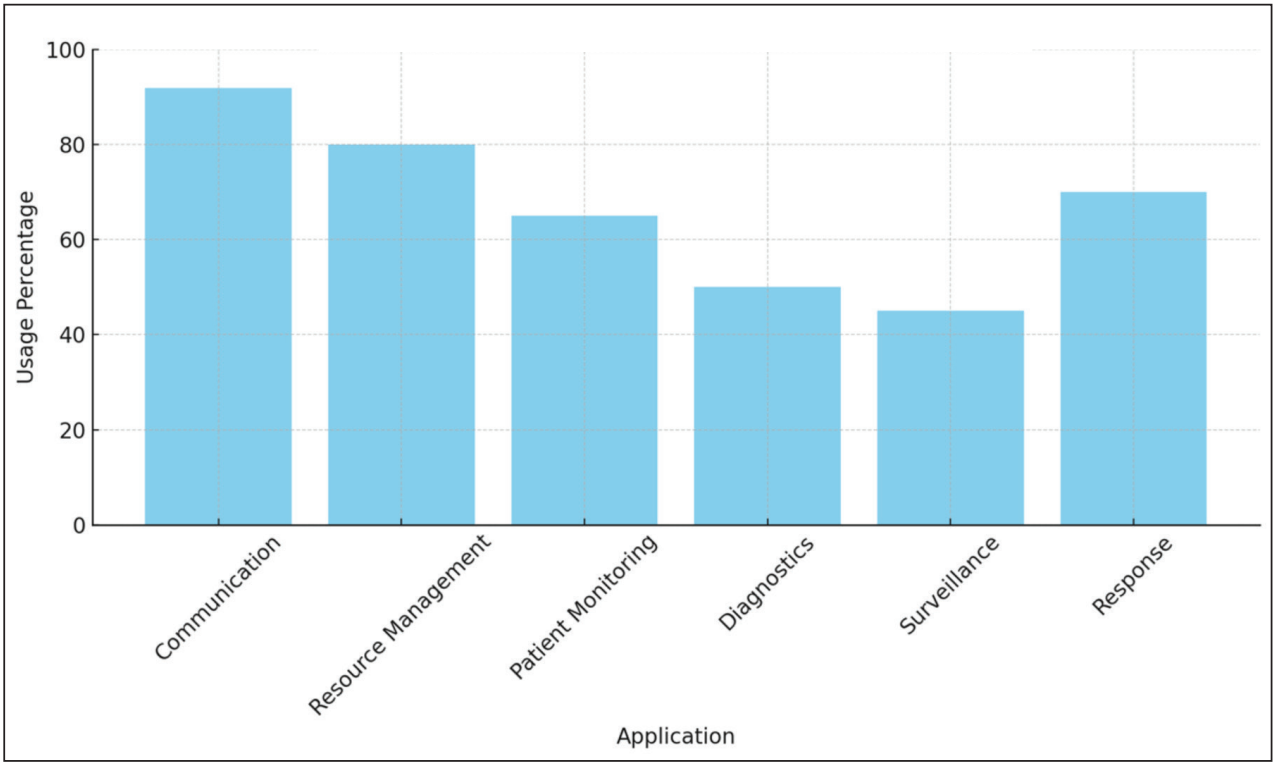

Figure 1. *Enhanced technology usage breakdown.*

underscores the need for targeted interventions to support technological integration in EOCs.

Training and technological integration

Adequate current training on technology use in disaster response was rated poorly by 50% of participants, with an additional 22% remaining neutral. However, 96% emphasized the importance of ongoing training, expressing a strong need for continuous education on emerging technologies. Furthermore, 95% of respondents agreed that technology should be more extensively integrated into disaster response plans. Figure 3 shows the frequency with which participants currently receive training, highlighting quarterly and annual sessions as the most common intervals. This alignment suggests a clear consensus on the need for regular training and

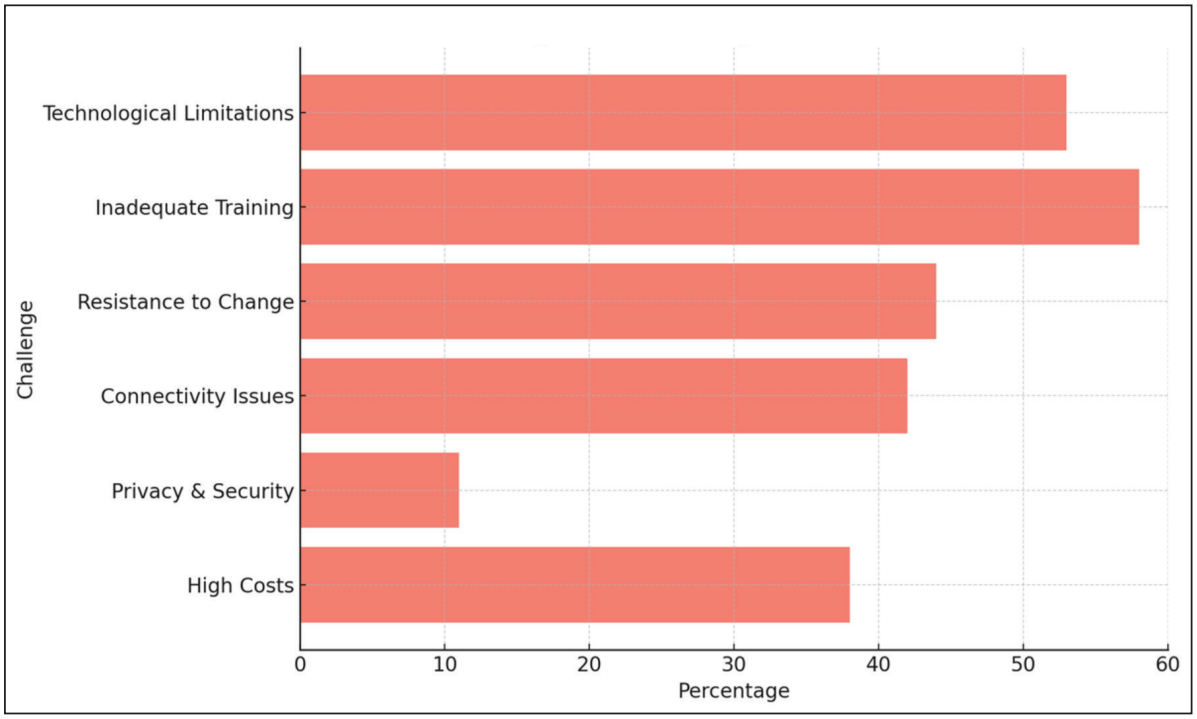

Figure 2. *Challenges and barriers.*

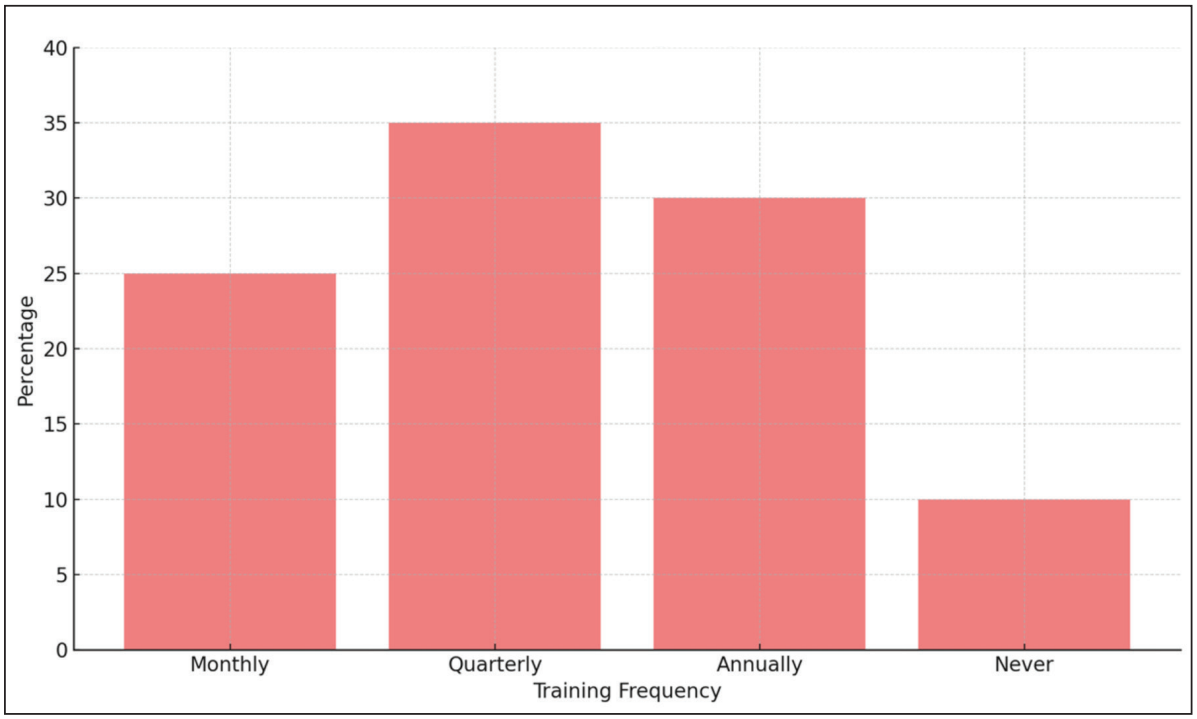

Figure 3. *Training frequency.*

improvements in content and integration of advanced technology in EOCs.

Correlation analysis

Correlation analysis (Figure 4) revealed significant relationships between several variables related to technology's impact in emergency management settings. There was a moderate positive correlation between years of experience in emergency management and the perception that technology improves communication and enhances patient care. This suggests that individuals with more experience tend to have a higher appreciation of technology's role in effective communication and patient outcomes. Additionally, strong positive correlations were observed between the belief that technology improves communication and its perceived ability to enhance patient care and ease of use. This indicates that as respondents recognize the communication benefits of technology, they are more likely to view it as user-friendly and beneficial for patient care, highlighting an interdependent perception of these factors.

Discussion

The study findings underscore the significant role of technology in bolstering disaster response within EOCs in Saudi Arabia. EOC leaders consider technology as integral to enhancing communication, patient care, and operational efficiency, a sentiment that aligns with existing research on technology's transformative role in emergency and healthcare settings [12]. However, while technology's potential is widely acknowledged, substantial barriers limit its full integration in disaster response efforts.

Addressing technological challenges through comprehensive training programs

Inadequate training emerged as a primary obstacle, with >50% of the participants indicating that current training programs are insufficient for effective technology use. The emphasis by 96% of respondents on the need for ongoing education highlights a significant gap in preparedness. These results resonate with findings from disaster and healthcare literature that stress the importance of continuous training to keep pace with technological advancements [13]. Without regular and updated training, EOC leaders and teams may struggle to harness the full potential of technological tools during crises.

Therefore, disaster response agencies should implement structured, comprehensive training programs that cover technical skills and introduce strategies for adapting to evolving technologies (Table 2). Training could be delivered by combining simulations, hands-on workshops, and e-learning modules tailored to specific

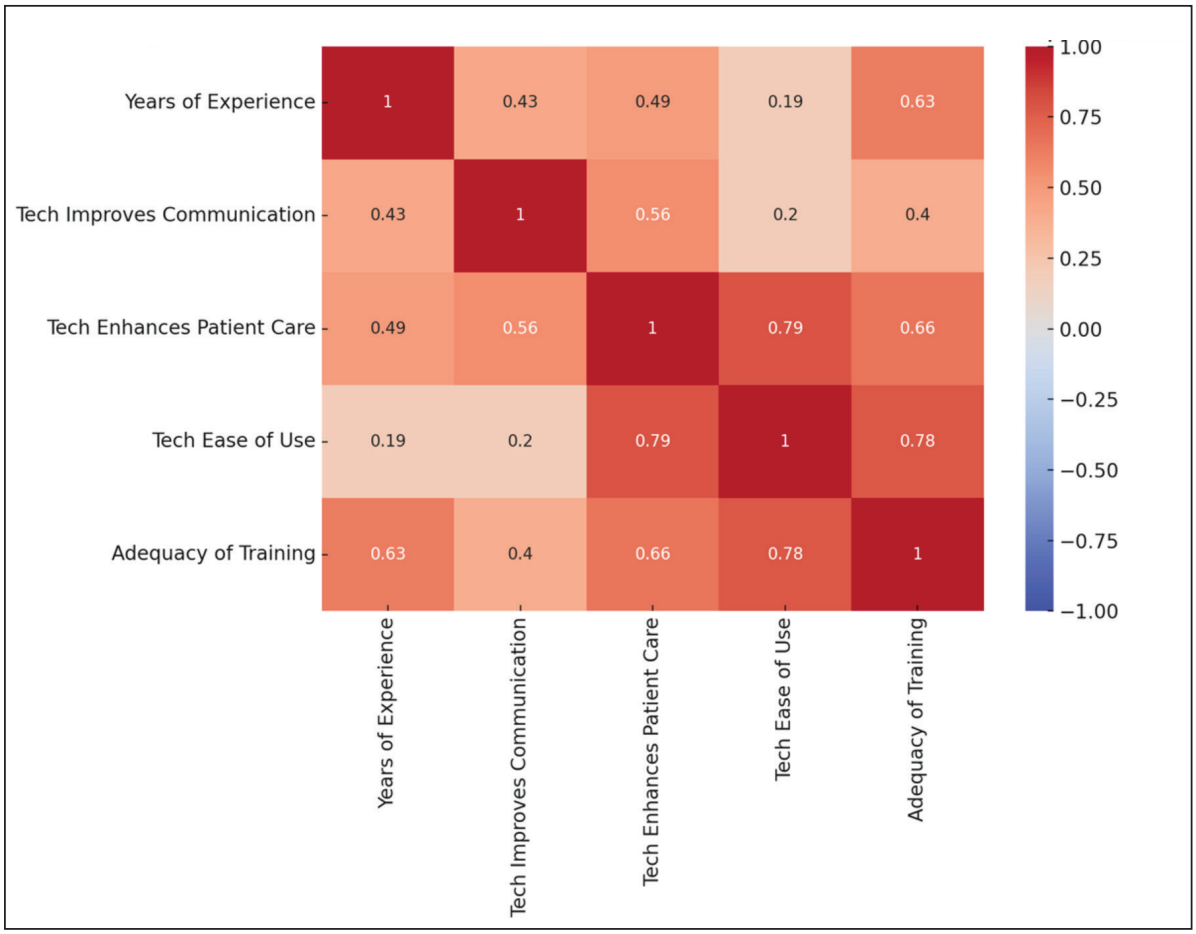

Figure 4. *Correlation matrix of key variables in technology disaster preparedness.*

Table 2. *Recommendations for improving the implementation of technology in disaster medicine.*

Theme	Recommendations
Continuous training and education	• Emphasize continuous training for health practitioners and emergency personnel on the latest technological tools and software. • Develop and implement regular training programs and workshops to keep staff updated on new advancements. • Integrate disaster management training into health colleges' curricula.
Infrastructure development	• Strengthen the technological infrastructure, including reliable and effective communication networks. • Ensure the availability of necessary technological tools and resources across all healthcare facilities. • Establish robust and flexible technology systems to handle disaster response efficiently.
Integration and automation	• Implement automation at all stages of disaster management to improve efficiency. • Integrate technology into emergency and disaster response plans, ensuring seamless data flow and communication. • Use artificial intelligence (AI) to enhance data analysis, decision-making, and overall disaster management capabilities.
Enhancing communication	• Develop strong, reliable communication networks that link all stakeholders involved in disaster response. • Utilize modern communication technologies to facilitate faster and more accurate information dissemination.
Backup and redundancy plans	• Avoid over-reliance on a single technology; instead, have backup plans (Plan A and B) to ensure continuity during technical failures. • Regularly assess and update these plans to maintain preparedness.
Improving response and coordination	• Increase awareness among leadership and operational teams about the role of technology in disaster preparedness and response. • Develop effective coordination mechanisms that link all relevant entities, including real-time messaging systems for field users.
Research and development	• Promote ongoing research and development to innovate and improve existing disaster management technologies. • Encourage collaboration with local and international companies to enhance technological solutions.
Specialization and expertise	• Employ specialists in technology and disaster management to oversee and guide the implementation of new systems. • Ensure that trainers and personnel are knowledgeable in both disaster medicine and technological applications.
Enhancing technological flexibility	• Build flexible and adaptive technology systems that can handle various challenges and scenarios during disasters. • Focus on developing technologies like drones and robots for search, rescue, and supply chain management in disaster areas.
Data management and analysis	• Establish comprehensive databases linking all official entities and departments to streamline information flow. • Use advanced data analysis tools, including AI, to provide accurate and timely insights for decision-makers.

disaster response scenarios [3,7,8]. By fostering technical resilience, such programs would equip EOC leaders to effectively navigate the challenges posed by rapidly changing technological landscapes, ensuring readiness and adaptability in crisis situations.

Overcoming resistance to change through targeted change management

Resistance to technological change was a prominent challenge, with 44% of the respondents indicating reluctance among staff to adopt new tools. This resistance may stem from a lack of familiarity or confidence with emerging technologies, underscoring the need for strategic change management within disaster response settings [14,15]. In disaster medicine, in which rapid adaptation to innovative solutions is often required, reluctance to change can impair operational readiness and responsiveness [6].

Addressing this challenge requires a multifaceted approach, combining training with organizational support for change. Leadership training in best practices for change management could empower EOC leaders to foster adaptability and openness to technological innovations. Additionally, involving the staff in the decision-making process for new technology adoption may enhance acceptance by providing them with a sense of ownership [16]. This approach would help to build trust in new systems and reduce resistance, ultimately contributing to smoother integration of technology across disaster response teams.

Building reliable infrastructure for communication and data security

The study findings further emphasize the importance of reliable communication infrastructure and robust data security measures. Connectivity issues and privacy concerns, as reported by 42% and 11% of respondents, respectively, highlight the need for investments in secure and resilient communication systems [4]. Stable communication channels are vital in disaster scenarios in which rapid information exchange can directly impact operational effectiveness and outcomes. As telemedicine and data-intensive tools become more prevalent in disaster response, safeguarding communication availability, data integrity, and confidentiality is essential for public trust and regulatory compliance. Guidelines to address these challenges in disaster and crisis scenarios emphasize the need for robust infrastructure and effective privacy measures [8].

Emerging studies highlight the transformative potential of AI in enhancing disaster management frameworks. Recent research [17] has examined various AI applications, including early warnings and logistics, illustrating AI's critical role in crisis scenarios. Similarly, another study [18] discusses how AI can process disaster-related data to support informed, timely decision-making across preparedness and response phases. These findings reinforce the importance of integrating advanced AI solutions within Saudi Arabia's EOCs to bolster resilience and adaptability during crises.

Broader implications for policy and practice

These findings offer several actionable recommendations for improving disaster response frameworks in Saudi Arabia. First, the development of a standardized, nationwide training curriculum focused on technology use in disaster response could ensure that EOC leaders and staff across regions are equally prepared [19]. By implementing such a curriculum, agencies can build technological competencies uniformly and efficiently.

Second, policy efforts could emphasize investment in resilient infrastructure, particularly in enhancing communication systems and cybersecurity frameworks [2,5]. This infrastructure development is crucial for supporting reliable, secure technology integration in disaster response, enabling Saudi Arabia to maintain operational continuity during crises [1].

Finally, promoting adaptability through structured change management programs may further ease technology adoption. Change management strategies, such as transparent communication about new technology benefits and phased implementation, can alleviate apprehensions among the staff, fostering a more open and technologically adaptive environment within EOCs. Furthermore, it is essential to recognize the role of advanced technologies and their integration into disaster response protocols, which could significantly enhance operational efficiencies and overall effectiveness [7].

Limitations

This study has several limitations. The purposive sampling method may limit the generalizability of findings across all EOC leaders in Saudi Arabia, as experiences may differ regionally. Additionally, reliance on self-reported data could introduce bias, as participants may overestimate their familiarity and satisfaction with current technologies. By focusing primarily on leaders' perspectives, the study may not fully capture the experiences of frontline staff who engage more directly with these tools. Moreover, the rapid pace of technological change means that the relevance of findings on current tools may diminish gradually, suggesting a need for ongoing assessment.

Conclusion

Although technology holds significant promise for enhancing disaster response capabilities, this study reveals notable barriers to its full implementation within Saudi Arabia's EOCs. Key challenges include the need for robust training programs, overcoming resistance to change, and ensuring reliable communication infrastructure. Addressing these areas is crucial for developing a resilient disaster response framework. The findings underscore the importance of comprehensive, ongoing training programs that familiarize EOC staff with essential tools and foster adaptability to rapidly evolving technologies. Investing in resilient communication infrastructure will further support operational continuity during emergencies, ensuring that EOC leaders can effectively leverage technology in high-stakes scenarios. Implementing these strategies can significantly improve Saudi Arabia's readiness and coordination in disaster scenarios, positioning the nation to respond more effectively to future emergencies. Additionally, these insights may benefit other regions facing similar challenges in disaster management, highlighting the universal need for cohesive and well-supported technological integration in emergency operations.

Acknowledgment
None.

List of Abbreviations

EOC	Emergency operations centre
NHEOC	National Health Emergency Operations Centre
TAM	Technology acceptance model

Conflict of interests
The author declares that there is no conflict of interest regarding the publication of this article.

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Consent to participate
Participation in the survey was voluntary, and informed consent was obtained from all participants before their participation.

Ethical approval
Approval was obtained from the Institutional Review Board (IRB) before the commencement of the study via IRB log No: 24-55 M, Dated 29-5-2024.

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